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Advances in Production Management Systems

Sustainable Production and Service Supply Chains

IFIP WG 5.7 International Conference, APMS 2013
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IFIP – The International Federation for Information Processing

IFIP was founded in 1960 under the auspices of UNESCO, following the First World Computer Congress held in Paris the previous year. An umbrella organization for societies working in information processing, IFIP's aim is two-fold: to support information processing within its member countries and to encourage technology transfer to developing nations. As its mission statement clearly states,

> IFIP's mission is to be the leading, truly international, apolitical organization which encourages and assists in the development, exploitation and application of information technology for the benefit of all people.

IFIP is a non-profitmaking organization, run almost solely by 2500 volunteers. It operates through a number of technical committees, which organize events and publications. IFIP's events range from an international congress to local seminars, but the most important are:

- The IFIP World Computer Congress, held every second year;
- Open conferences;
- Working conferences.

The flagship event is the IFIP World Computer Congress, at which both invited and contributed papers are presented. Contributed papers are rigorously refereed and the rejection rate is high.

As with the Congress, participation in the open conferences is open to all and papers may be invited or submitted. Again, submitted papers are stringently refereed.

The working conferences are structured differently. They are usually run by a working group and attendance is small and by invitation only. Their purpose is to create an atmosphere conducive to innovation and development. Refereeing is also rigorous and papers are subjected to extensive group discussion.

Publications arising from IFIP events vary. The papers presented at the IFIP World Computer Congress and at open conferences are published as conference proceedings, while the results of the working conferences are often published as collections of selected and edited papers.

Any national society whose primary activity is about information processing may apply to become a full member of IFIP, although full membership is restricted to one society per country. Full members are entitled to vote at the annual General Assembly, National societies preferring a less committed involvement may apply for associate or corresponding membership. Associate members enjoy the same benefits as full members, but without voting rights. Corresponding members are not represented in IFIP bodies. Affiliated membership is open to non-national societies, and individual and honorary membership schemes are also offered.

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IFIP WG 5.7 International Conference, APMS 2013
State College, PA, USA, September 9-12, 2013
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Preface

For the last several years, APMS has been a major event and the official conference of the IFIP Working Group 5.7 on Advances in Production Management Systems, bringing together leading experts from academia, research, and industry. Starting with the first conference in Helsinki in 1990, the conference has become a successful annual event that has been hosted in various parts of the world including Washington (USA, 2005), Wroclaw (Poland, 2006), Linköping (Sweden, 2007), Espoo (Finland, 2008), Bordeaux (France, 2009), Cernobbio (Italy, 2010), Stavanger (Norway, 2011), and Rhodos (Greece, 2012). By returning to the Americas after eight years, we hope to widen the global reach of the Working Group and the APMS conference.

Through an open call for special sessions and papers, APMS 2013 sought contributions in cutting-edge research, as well as insightful advances in industrial practice in key areas of sustainable production and service supply chains, including green manufacturing, sustainability of additive manufacturing processes, advanced control systems, enterprise information systems and integration, sustainable logistics and transportation. The intent of special sessions is to raise visibility on topics of focused interest in a particular scientific or applications area. This year we have planned 15 special sessions which are focused around the theme of the conference. Over 135 papers have been accepted based on blind peer-review. The main review criteria were the paper's contributions to science and industrial practice. Accepted papers of registered participants are included in this volume. This is the first time for APMS conference that full papers have been submitted and reviewed from the outset thereby eliminating the extended abstract stage and allowing for the final proceedings to be available at the time of the conference.

Following the tradition of past APMS conferences, the 6th APMS Doctoral Workshop is planned offering Ph.D. students the opportunity to present, discuss, receive feedback and exchange comments and views on their doctoral research in an inspiring academic community of fellow Ph.D. students, experienced researchers, and professors of the IFIP WG 5.7 community. The Doctoral Workshop will be chaired by Sergio Cavalieri (University of Bergamo).

Two types of awards have been planned for APMS 2013 participants:

- Burbidge Awards for best paper and best presentation
- Doctoral Workshop Award

Approximately 150 participants from across academia, research labs, and industry from 23 countries are expected to attend the APMS 2013 conference. The Scientific Committee consisting of 77 researchers, many of whom are active members of the IFIP WG 5.7, have played key roles in reviewing the papers in a timely manner and providing constructive feedback to authors in revising their manuscripts for the final draft. Papers in this volume are grouped thematically as follows:

- **Part I Sustainable Production:** Enablers for Smart Manufacturing, Social Sustainability in Manufacturing, Intelligent Production Systems and Planning Solutions for Sustainability, Design, Planning and Operation of Manufacturing Networks for Mass Customization and Personalization, Energy Efficient Manufacturing
- **Part II Sustainable Supply Chains:** Sustainability Characterization for Product Assembly and Supply Chain, Interoperability in the Manufacturing and Supply Chain Services, Sustainable Manufacturing and Supply Chain Management for Renewable Energy, Closed Loop Design, Supply Chain Management
- **Part III Sustainable Services:** Service Manufacturing Systems, Art of Balancing Innovation and Efficiency in Service Systems, Simulation Based Training in Production and Operations Management, Modelling of Business and Operational Processes, Servicization,
- **Part IV ICT and Emerging Technologies:** ICT-Enabled Integrated Operations, Sustainable Initiatives in Developing Countries, LCA Methods and Tools, ICT for Manufacturing and Supply Chain Management, Product Design for Sustainable Supply Chains

We hope that the present volume will be of interest to a wide range of researchers and practitioners.

August 2013

Vittal Prabhu
Marco Taisch
Dimitris Kiritsis

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Optimum Allocation Method of Standby Taxi Vehicles at Taxi Stands

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Abstract. There are two ways for a taxi company to get customers. One is to deliver taxi for a telephone request, and the other is to get customers on street. In previous research we researched rearrangement method of the taxi drivers working hours so as to operate many taxis with many telephone requests for the former method. In this paper, we propose optimum allocation method of standby taxi vehicles at taxi stands for the latter method. In order to minimize the total mileage, fulfilling the taxi demand of all the allocation and maximum number restriction of taxi stands, we formulate this problem as Linear Programming problem. As a result of numerical calculation, there are some improving points to change the number of standby taxi vehicles at taxi stands, and it turned out that total mileage may be reducible by 30%.

Keywords: optimum allocation, taxi company, linear programming, service productivity.

1 Introduction

In Japan, the number of customers who use taxis has been decreasing for about fifteen years. But the number of taxi vehicles (we call taxis in this paper) has been increasing from 2002 by regal revision. As a result, income of a taxi per day decreases [1]. It became very severe to get customer between taxi companies. Then taxi companies introduce various methods to gain more customers, for example, customer membership. Some companies introduce new taxi operation system using GPS and smartphone to shorten taxi waiting time. For 90% of taxi companies, the number of possession taxis is less than 50. Moreover, for 70% of taxi companies, the capital is less than 10 million yen. Therefore it is difficult for many taxi companies to introduce above system because of financial deficit. From above reason, we research improvement method of service productivity to gain more customers by little investment for small taxi companies.

There are two customer acquisition methods for taxi companies in Japan. One is to deliver a taxi for a telephone request, and the other is to get customers on street. For the former method, it is required to deliver a taxi immediately by telephone requests. We researched improvement method of rearranging taxi drivers' working hours so as to work many taxis with many telephone requests [2]. For the latter method, it is

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required to allocate taxis for a place with many customers who need a taxi. We research the optimum allocation method of standby taxis at taxi stands to minimize total millage between taxi stands and the place where customer takes a taxi.

In this paper, we analyze present situation of the Taxi Company which we research (we call Company A in this paper), research the optimum allocation method, and apply our method to Company A.

2 Subjects of Company A

Company A is typical small taxi company whose business area is less than 30 minutes drive by taxi. Maximum numbers of taxis at each taxi stand, the number of taxis which can be worked in every hour, and the operation records for each place where customer took the taxi in 2011 are as follows.

2.1 Maximum Numbers of Taxis at Each Taxi Stand

Maximum numbers of taxis at each taxi stand are shown in Table1. They are determined by the size of taxi stand, distribution with other taxi companies, etc.

Table 1. Maximum numbers of taxis at each taxi stand

Taxi stand	a	b	c	d	e	f	g	h	i	j
Maximum numbers	3	3	4	1	2	1	4	5	5	2

2.2 Total Numbers of Taxis Which Can Be Worked in Each Hour

Total numbers of taxis which can be worked in each hour are shown in Table2. There are many taxis in time zone between 7:00 and 1:00 for large number of taxi demand, and few taxis in time zone between 3:00 and 6:00 for small number of taxi demand.

Table 2. Total numbers of taxis in each hour

Time zone	0	1	2	3	4	5	6	7	8	9	10	11
Total numbers	21	16	11	7	5	5	5	16	21	21	21	21

Time zone	12	13	14	15	16	17	18	19	20	21	22	23
Total numbers	26	26	25	26	26	26	26	21	21	21	21	21

2.3 The Operation Records

The operation records for each place where customer took the taxi in 2011 are shown in Table 3. These records are counted on the time when customer took the taxi. Area in Table 3 is a group of the near place of distance. “Deliver” in Table 3 is a call from a customer and picking up a customer at the call place. “Getting” in Table 3 is encountering and picking up a customer at taxi stand or on street.

There are 50 areas in the operation records of Company A. It is difficult to solve the problem with 50 areas because size of problem is large. Therefore we pick up 26 areas exceeding 1000 equivalent to 0.5% of about 200,000 annual sum totals in “Deliver” or “Getting”. The analyzing results of monthly operation record are as follows.

- Many areas of taxi use increase in December because of year-end party.
- Specific area of taxi use increase in March because of graduation ceremony and farewell party.

Table 3. The operation records

Area	A1	A2	A3	…	A48	A49	A50	Total
Deliver	2085	11476	4633	…	115	24	103	109036
Getting	47076	3935	10897	…	137	5	8	83220
Total	49161	15411	15530	…	252	29	111	192256

From this result, it is better to consider different taxi allocation in March and December from an all year. We analyze also about the operation record in each area according to time zone. The results are as follows.

- In many areas, there is much use of taxi in time zone between 8:00 and 20:00. In this time zone, many people go out and many supermarkets open.
- In A2 area, there is much use of taxi in time zone between 21:00 and 3:00. It seems that there are many bars in A2 area.
- In some areas, there is little use of taxi in time zone between 10:00 and 17:00. In these areas, there is much use of a morning, the evening, and night. Therefore, it seems that the taxi is used at the time of commuting and going home.

As mentioned above, the time zones with much use of taxi are different in areas. Therefore, it is necessary to decide optimum allocation of standby taxis at taxi stands in every hour.

3 Formulation

We research the optimum allocation method of standby taxis at taxi stands to minimize total millage between taxi stands and the place where customer takes a taxi (we call it demand place). In this company, it is possible to drive taxi to all demand places from any taxi stands. In order to minimize the total mileage, fulfilling the taxi demand of all the allocation, it is considered how many taxis should be driven to a demand place from a taxi stand (see Fig.1).

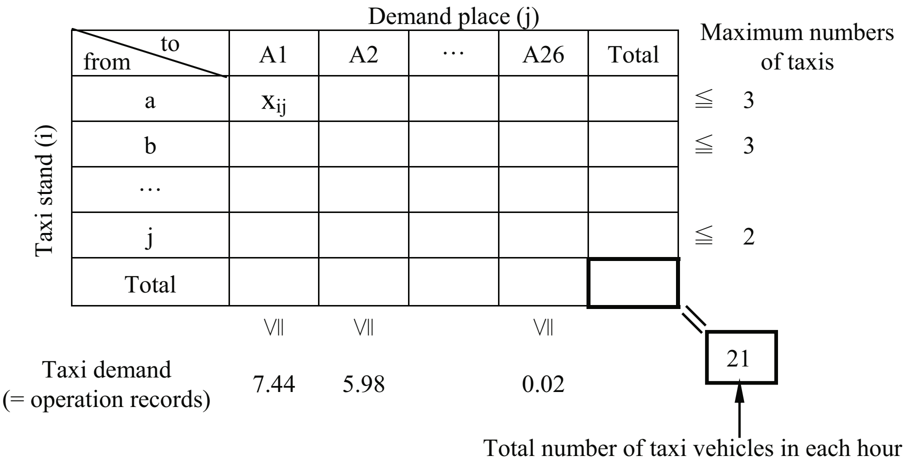

Fig. 1. From – to table

3.1 Notation

The following notations are used to formulate this problem.
i : Taxi stand (i = 1, 2, …,10),
j : Demand place (j = 1, 2, …, 26),
t:Time zone(t = 0, 1, …,23),
x_{ijt} : The number of taxis which move from i to j in time zone t,
c_{ij} : Distance from i to j,
Xt : Total number of taxis in time zone t,
T_i : Maximum numbers of taxis at taxi stand i,
D_{jt} : Taxi demand in demand place j in time zone t.

There are many places where customer takes a taxi in demand place. We decide to make into a representative point the place allocated mostly, as a result of discussion with Company A. We measure the mileage from a taxi stand to the representative point of demand place on the map for c_{ij}.

3.2 Formulation

The objective is to minimize sum total of mileage from taxi stands to demand place for each time zone. The Problem is formulated as follows:

$$\text{Minimize} \sum_{i=1}^{10} \sum_{j=1}^{26} c_{ij} x_{ijt} \quad \text{for each t (t = 0, 1, …, 23)} \tag{1}$$

subject to

$$\sum_{j=1}^{26} x_{ijt} \leq T_i , \tag{2}$$

$$\sum_{i=1}^{10} x_{ijt} \geq D_{jt}, \tag{3}$$

$$\sum_{i=1}^{10}\sum_{j=1}^{26} x_{ijt} = X_t, \tag{4}$$

$$x_{ij} \geq 0. \tag{5}$$

Constraint (2) shows that sum total of taxis which stand by at taxi stand i do not exceed the maximum number of taxis at the taxi stand. Constraint (3) shows that sum total of taxis which move to the demand place j fulfills taxi demand of the place. Constraint (4) shows sum total of taxis which move from i to j is equal to total number of taxis in each time zone.

4 The Application Result to Company A

As shown in 2.2, total number of taxis which can be worked changes for every hour. Therefore, it is necessary to decide optimum allocation of standby taxis at taxi stands in every hour. As shown in 2.1, there are maximum numbers of taxis at each taxi stand. First, we solve the problem in 3.2 to decide optimum allocation of standby taxis at taxi stands in each time zone. Secondly, we analyze the influence on taxi operation caused by the maximum number restrictions of standby taxi at each taxi stand. Therefore we solve the problem in 3.2 without maximum number restrictions at each taxi stand, and solve the ideal optimum allocation. Thirdly, we compare two results with present allocation. For these case studies, we use optimization solution software package using the operation records in 2011/1 to 2011/12 from Company A.

4.1 Calculation Procedure with Maximum Number Restrictions

We solve the optimal solution of the problem in 3.2 under the following conditions.

- T_i and X_t are given in Table1 and Table2.
- D_{jt} is annual average of the operation records in time zone t. If sum of D_{jt} exceeds X_t, D_{jt} is distributed proportionally so that sum of D_{jt} may become equal to X_t (See Fig.2).
- Since the calculation result becomes the real number, sum total of calculating result at each taxi stand is rounded off (See Fig.3).

4.2 Calculation Procedure without Maximum Number Restrictions

We solve the optimal solution of the problem in 3.2 without maximum number restrictions under the following conditions.

- Ti is equal to ∞, X_t is given in Table2.
- D_{jt} is annual average of the operation records in time zone t. If sum of D_{jt} exceeds X_t, D_{jt} is distributed proportionally so that sum of D_{jt} may become equal to X_t (See Fig.2).
- Since the calculation result becomes the real number, sum total of calculating result at each taxi stand is rounded off (See Fig.3)

	Monday (6:00) $X_t = 5$				
Demand place	A1	A2	…	A26	Total
D_{jt}	1.77	0.48		0.44	7.71
	Total>X_t, then distributed				
D_{jt}(Input Data)	1.15	0.31		0.03	5.0

Monday(13:00) $X_t = 26$				
A1	A2	…	A26	Total
4.58	0.52		0.19	22.56
Total < X_t, then not change				
4.58	0.52		0.19	22.56

Fig. 2. Determination of D_j

Demand place

Taxi stand	A1	A2	…	A26	Total		Result
a	3				3		3
b	1.58	0.52			3	round	3
…						off	
i					3.97751		4
j					2		2
Total	4.58	0.52		0.19	26		26

Fig. 3. Caluculation result at each taxi stand by procedure 4.1 & 4.2 (Monday 13:00)

4.3 Calculation Results

The present allocation of taxis at taxi stands, the calculation result on Monday by procedure 4.1 and 4.2 are shown in Fig.4, Fig.5 and Fig.6. We calculate day by day about one week. We show the result of Monday for example. Sum total of mileage on Monday in expression (1) is shown Table 4. From Table 4, sum total of millage is shorter in order of Procedure 4.2, Procedure 4.1, and present allocation. Therefore solving Linear Programming (we call LP in this paper) problem described in 3.2 is effective method to decide optimum allocation of standby taxis.

From Fig.4 and Fig.5, it is effective for mileage reduction to increase taxi at taxi stand d, f, i and to decrease taxi at taxi stand g, h. Since there is hospital near taxi stand d and supermarket near taxi stand f, there is taxi demand. Although there is a university near taxi stands i, there is no transportation from university to Shinkansen express station, therefore there is taxi demand. From Fig.4 and Fig.6, it is effective for mileage reduction to increase taxi at a, c and to reduce taxi at b, g, h. Since there is railroad station near taxi stand a and bar near taxi stand c, there is much taxi demand.

From Table 4, sum total of millage without restrictions is 62% of the best result in present situation (= Procedure 4.1). The maximum number restrictions of standby taxi at taxi stand a have bad influence on the management of company A.

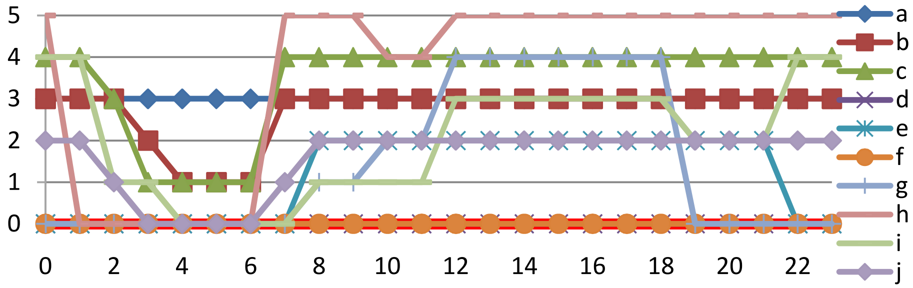

Fig. 4. Present allocation of taxis at taxi stands

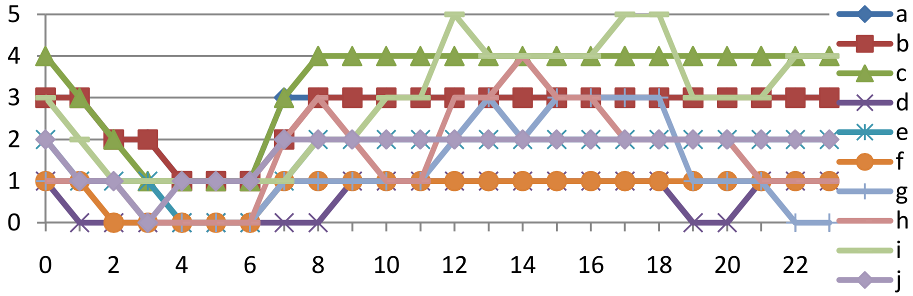

Fig. 5. Calculation result on Monday by procedure 4.1

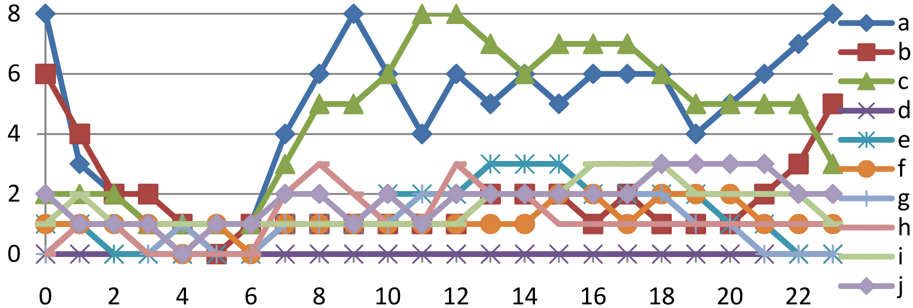

Fig. 6. Calculation result on Monday by procedure 4.2

Table 4. Sum total of millage on Monday

	Present allocation	**Proce-dure 4.1**	**Proce-dure 4.2**		**Present allocation**	**Proce-dure 4.1**	**Proce-dure 4.2**
0	**30648.4**	**18872.6**	**3349.0**	12	35390.5	28832.3	14021.5
1	2438.5	1963.3	1504.7	13	22346.3	18507.0	10757.1
2	1966.7	1487.0	1288.0	14	17343.0	14270.8	10620.5
3	1678.9	1598.1	1349.8	15	20942.2	16875.8	11879.4
4	2141.4	664.5	924.8	16	23447.7	18879.4	12369.9
5	5969.4	2368.2	1981.8	17	39590.7	30318.1	19632.0
6	9020.0	5510.5	5547.1	18	37310.6	27765.9	16700.0
7	20456.4	7816.2	8947.3	19	24766.6	16777.5	14246.4
8	18048.8	14266.1	12665.2	20	22706.8	14707.9	12184.2
9	25866.1	17059.9	11874.9	21	24964.7	17956.2	9717.8
10	25384.9	17886.4	11851.2	22	31614.5	19281.4	7574.5
11	25875.2	17650.0	13610.2	23	36111.6	23713.4	5988.3
			Total		506029.7	355028.3	220585.3

5 Conclusions

We research the optimum allocation method of standby taxis at taxi stands to minimize total millage between taxi stands and the place where customer takes a taxi. In order to minimize the total mileage, fulfilling the taxi demand of all the allocation and maximum number restriction of taxi stands, we formulate this problem as LP problem. Using the operation records in 2011/1 to 2011/12 from Company A, we analyze present situation of Company A, and apply our method to Company A. As a result of numerical calculation, it turns out that solving LP problem is effective method to minimize the total mileage. There are some improving points to change the number of standby taxis at taxi stands, and it turned out that total mileage may be reducible by 30%.

We will research taxi drivers' working hours so as to work many taxis with many taxi delivery demands and incomes using optimum solution method.

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Improving Labor Productivity and Labor Elasticity at Multiproduct Japanese Cuisine Restaurant Introducing Cell-Production System

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Abstract. This study examined improvement of labor productivity and elasticity of labor hour on sales of a multiproduct Japanese cuisine restaurant. Conventionally, multiproduct restaurant operations include a line production system in the kitchen. Japanese chefs are assumed to be low-skilled workers with staff members supported by someone. A cell production system is introduced into a Japanese Cuisine restaurant to improve it. Results show that the cell production system improves both labor productivity and elasticity of labor hours because the system reduces fixed labor hours during less-busy times in the kitchen. To introduce the system, it is important to educate and train kitchen staff members because the system requires preparation of other staff members' food orders during idle time.

1 Introduction

In Japan, service industry organizations account for approximately 73% of Japanese GDP. Therefore, the industry plays important roles in the Japanese economy. The restaurant industry is one of the largest service industries: the industry hires approximately 4 million staff members. Sales revenues were approximately 277 billion dollars in 2011 [1][2].

Although the restaurant industry is a key industry, labor productivity is the lowest among service industries [3]. Moreover, food-service is a typically labor-intensive industry. Many reports have described characteristics of service products preventing service industries from improving labor productivity [4][5]. For instance, service products can not be stocked (intangibility). Therefore, service providers should produce service products at the same time that a customer orders it. The service industry "low productivity problem" is important not only for individual companies but also for the macro economy. As the market share of service industries increases [6], productivity of the entire country will decrease accordingly. To resolve these problems, service industries must improve labor productivity.

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The Japanese restaurant industry has introduced some innovative systems developed to enhance productivity in manufacturing enterprises [7]. For example, restaurants have adopted a central kitchen as a *food factory* to simplify cooking operations at stores [8][9][10]. Additionally, they have introduced information technology (e.g., POS system) to improve cooking operations by sharing order information smoothly among staff [11][12][13]. Moreover, the restaurant industry has introduced cooking machines such as steam convection and sushi-cooking devices to improve cooking capacity at restaurant stores [14]. Recently, restaurants have started to introduce simulation systems to improve the kitchen layout [15][16].

Although the restaurant industry has introduced some systems and methodologies, Japanese cuisine restaurants have not changed traditional cooking systems. The cooking system of Japanese restaurants is similar to line production systems in manufacturing enterprises. Cooking equipment such as fryers, steamers, grills, and ovens are placed separately in the kitchen, and kitchen staff are placed and work separately in front of cooking equipment. When a restaurant is rushed, the production system functions smoothly because the kitchen staff members prepare the same kinds of dishes in bulk. However, the production system does not work well when a restaurant is not busy. While a restaurant is not busy, customers come to the restaurant and order in small numbers. Although the orders are few, cooking staff must be placed specifically in front of cooking equipment.

In addition, customs of Japanese chefs prevent restaurants from improving cooking operations. Traditionally, they do not prefer mutual support in the kitchen because of their pride. They believe that if a chef is supported by another chef, then is the former must be regarded as "less-skilled". As a result, workers labor separately even if the restaurant is not busy. Consequently, a restaurant can not adjust labor sales hours according to fluctuations. To improve labor productivity, restaurants should introduce a new production system and change the chef's consciousness about mutual assistance.

For this study, we introduce a "cell-production system" for a multiple Japanese cuisine restaurant to adjust labor hours related to fluctuation of sales revenues. To introduce it, we educate kitchen staff to make a change "from pride to cooperation". We measured sales per labor hour, and calculated the correlation of sales and labor hours as the KPI of labor productivity and elasticity of labor hour.

2 Introducing the Cell Production System to a Restaurant Preparing Japanese Cuisine

A cell production system is introduced at Japanese restaurant A in Kyoto, operated by Ganko Food Service Co. Ltd. (Osaka, Japan). The restaurant has 250 tatami mat area on two floors, where 100 staff work (70 service staff; 30 kitchen staff). There are 10 positions in the restaurant kitchen: Washer, Salad, Sushi×2, Sashimi, Grill, Boil, Fryer, Noodle, and Set-up / Fig. 1).

Before the cell system was introduced, differences, characteristics, and strong and weak points of both line and production systems were introduced to the store manager and the master chef. A means to introduce a cell production system to the restaurant was discussed. The discussion concluded that chefs should be trained for mutual co-operation, before a cell production system could be introduced.

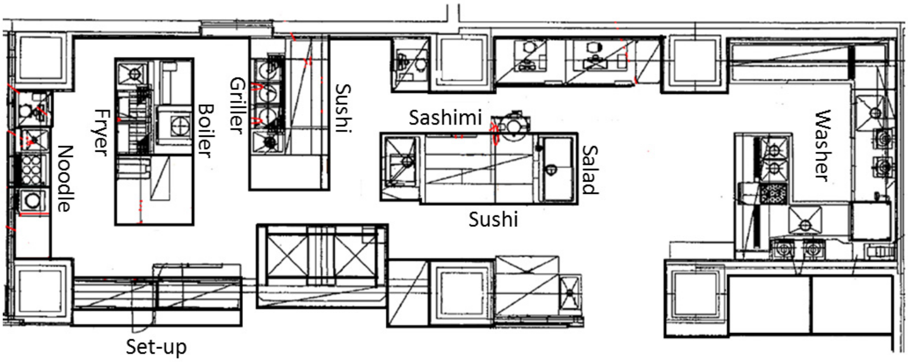

Fig. 1. Layout of restaurant A's kitchen

To change cooking behavior, kitchen staff members were briefed on important aspects of the cell production system. They were also trained to change their conventional work customs. After explanation, the master chef changed work-scheduling and work-shift kitchen to support mutual cooperation for 2 months. To promote cooperation, observers checked kitchen operations and gave advice to the master chef to improve different points. When the restaurant is rushed, kitchen staff members work separately at individual cooking appliances. When restaurant demands are light, a kitchen staff cooks a plural genre of dishes using plural cooking appliances to reduce labor hours of idle time.

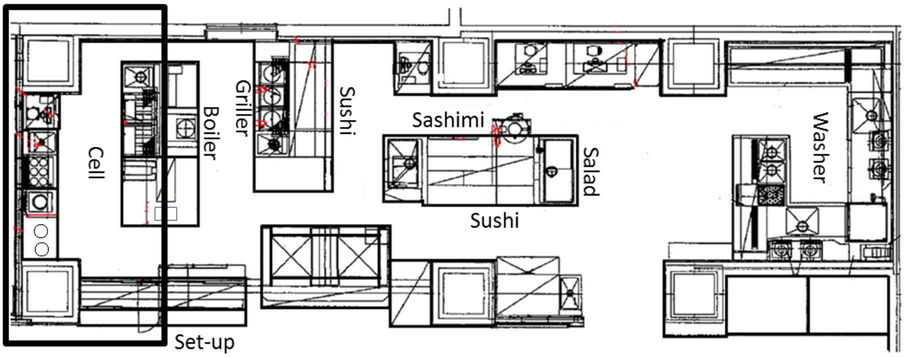

Fig. 2. Location of the cell at restaurant A's kitchen

Two months later, cell cooking positions were introduced to restaurant A. Figure 2 shows the cell location at the restaurant A kitchen. Figure 3 shows placement of cooking equipment of the cell. When the restaurant is rushed, kitchen staff members work separately at individual cooking appliances. When the restaurant demands are light, a kitchen staff member cooks all kinds of dishes at a cell cooking position. The cell production system was operated for 2 months.

After the experiment, revenue data and labor hour data (Before the experiment, for 2 months / after introducing a cell, for 2 months) are downloaded from the POS system and a labor control system. Sales per labor hour and correlation of sales and labor hours were calculated to confirm the availability of the cell production system for improvement of labor productivity and elasticity of labor hours.

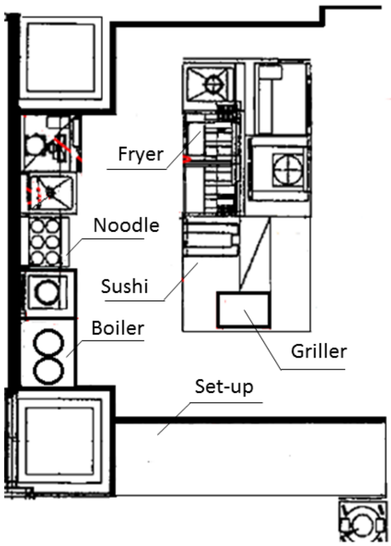

Fig. 3. Layout of cell at restaurant A

3 Results and Discussion

3.1 Results

Before the experiment (for 2 months), average sales per labor hour were 1,707k yen (SD=347k yen), average labor hours were 137.3 hr (SD=16.2 hr), and the coefficient of correlation was 0.44 (Fig. 4). After introducing the cell production system (for 2 months), average sales per labor-hour were 1,661k yen (SD=304k yen), average labor hours were 116.0 hr (SD=12.2 hr), and the coefficient of correlation was 0.69 (Fig. 5). Relevant figures are presented on the next page.

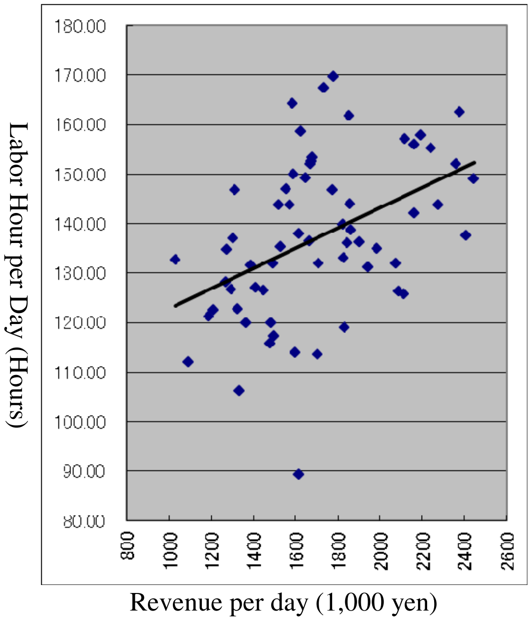

Fig. 4. Scatter diagram of revenue and labor hours (before experiment)

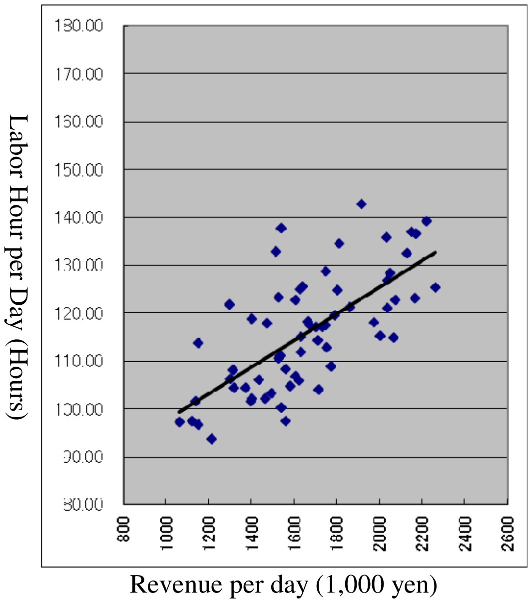

Fig. 5. Scatter diagram of revenue and labor hours (after introducing cell)

3.2 Discussions

First, the cell production system efficacy for labor productivity improvement is discussed. Results show that labor hours of the restaurant were reduced from 137.3 hr to 116.0 hr. The cell production system reduces 21.3 hr (15.5%). Presumably, improved labor productivity occurred because sales revenues of both the pre-experiment and after introducing cell do not change so. Before the experiment, cooking staff work separately even if the restaurant is idle because of the kitchen layout. As Figure 1 shows, cooking equipment is placed discretely. The area is too broad to be crewed by one or even a few kitchen staff members if a full menu of products is to be provided.

The cell production system arranges all kinds of cooking appliances compactly (Fig. 3). When the restaurant is not busy, a kitchen staff member can prepare all kinds of dishes using cooking appliances situated in the cell. It is difficult to operate a cell production system if kitchen staff members are single-trained workers, as at a chain store. By contrast, multiple Japanese cuisine restaurants hire many "Syokunin" (cross-trained workers) who can prepare almost any dish, and it is easy to introduce a cell production system if they change their custom of avoiding mutual cooperation. This experiment trained staff ahead of introducing a cell production system. The training process promotes cooperation, and facilitates introduction of the cell production system.

Second, the elasticity of labor hours for sales revenue shows interesting results. The coefficient of correlation improved from 0.44 to 0.69. Figure 4-1 shows that restaurants require at least 110 hrs to operate the kitchen before experiments. However, the restaurant requires less than about 100 hr to operate because of introduction of the cell production system. The lower limit of kitchen staff was 3 before the experiment. However, that of the cell production system is 1. Reduction of fixed-work hours promotes labor hour elasticity at the restaurant.

4 Conclusions

The study was conducted to improve labor productivity and elasticity of labor hours on sales revenue by introducing a cell production system at a multiproduct Japanese cuisine restaurant. Results shows that cell production systems improve operations: when the restaurant is not busy, a staff member can prepare any dish using cooking appliances situated in the cell. The system reduces fixed-labor hours at idle time, and it promotes a flexible work shift. To realize this system, kitchen staff should be trained to provide mutual support: conventionally, they dislike mutual cooperation because expressing a need for assistance implies inferior skills.

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Does the Carbon Footprint Enhance the Sustainability Food Production and Transportation Service System? Real Buying Experiment in Japan

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Abstract. To examine whether the carbon footprint induce the sustainability local food production and service system, this study investigate the relationship between consumers' environmental consciousness and willingness to pay for carbon dioxide emissions on food products by using a choice experiment under the real buying experiment. The results show that consumers with higher environmental consciousness value the higher WTP for the reduction of carbon dioxides.

Keywords: Carbon footprint, Local food system, Transportation, Choice experiment, Experimental economics.

1 Introduction

A carbon footprint aims to indicate and visualize the amounts of carbon dioxide (CO_2) emissions caused in the process from production to disposal as the life cycle of the food products in order to motivate consumers and producers to buy and produce the food with lower emissions, respectively.

Onozuka and McFadden (2011) show that increasing the CO_2 emissions induces the negative WTP for the food consumption but local labels mitigate that negative impact [1]. Thus, consumers have a preference for the local foods. This is the biggest difference in the carbon footprint between food products and non-food products such as electric products and other daily commodities. The local food system, that is, local productions for local consumptions, maintains the food as more fresh and the taste as better, which attracts consumers more to the local foods than to the foods produced in the far distance. Growing the local food system induces a few energy spending for the transportation and larger consumptions with reducing the waste of disposals, which more advances to mitigating the CO_2 emissions and enhances the sustainable food system. In this meaning, carbon footprints will become important role to disseminate the local food production and service systems to attain the sustainability food system.

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There is, however, still open question whether the consumers want to reduce CO_2 emissions caused from the transportation and local food system is proceeding. To examine this question, a simply hypothesis is tested in this study. It is that consumers with higher environmental consciousness exhibit the higher willingness to pay for the reduction of CO_2. To examine this hypothesis, there are the three steps in this study as follows.

First, the selected consumers' ecological purchase behaviors scale originally developed by Roberts (1996) is used to evaluate environmental consciousness for consumers [2].

Second, the choice experiment is used to estimate the value of the carbon dioxide emissions. The choice experiment consists of three alternative oranges including two attributions; price and amounts of CO_2 emissions. The choice experiment approach used in this study is a type of stated preference method [3] useful for effectively overcoming certain biases (e.g., strategic bias, compliance bias, and warm glow bias).

Following Experimental Economics method, the choice experiment condition is real buying experiment. In this experiment, respondents are given real money and buy one of three oranges in 12 times to take them home.

The seminal experimental study of generally called eco-labels is Cason and Gangadharan (2002), which find the eco-labels clear the market adverse selection caused from the information asymmetric between consumers and producers [4]. In the food markets, for example, experimental studies include fair trade [5, 6] , organic labels [7], genetically modified label [8-11]

The remaining paper is organized as follows. Section 2 explains the survey and experimental design and procedures. Section 3 describes the empirical model structure. Section 4 analyzes the results, and Section 5 summarizes the conclusions and discussions.

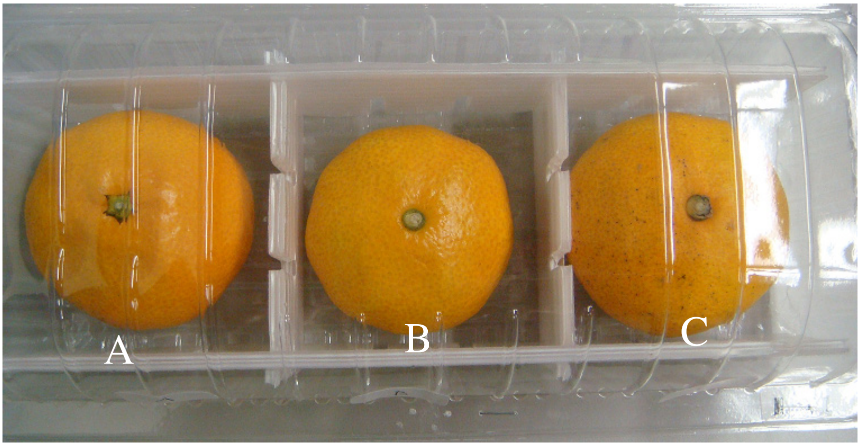
2 Experimental Design and Procedure

The experimental design and procedures replicate the previous study of Aoki et al. (2010), who find the hypothetical bias for the consumers' reactions of information of sodium nitrite on the ham [12].

Figure 1 shows the example of designated choice sets and the alternatives are three types of oranges A, B, and C.[1] The type of oranges is called Satsuma mandarin oranges (Citrus unshiu Marc.),which is the representative domestic fruit in Japan.[2] Each alternative constitutes two types of attributions; the price and the amounts of CO_2 emissions. The levels of the price attribute have three values: 25, 35, and 45 JPY per one unit of orange. These levels are based on the prices of oranges in the three largest supermarkets around Osaka University.

[1] Following Aoki et al. (2010), "no-purchase" alternative is not added in the choice experiment.

[2] Each orange was approximately 7 cm in diameter and its weight was approximately 100g. Its color was orange with a bluish tinge. The sugar content in them was approximately 9 to 11 brix.



	Orange A	Orange B	Orange C
Price	35	25	45
Carbon dioxide emissions	30	20	40
I would choose…	□	□	□
The most important reason affecting my choice	□Price □Carbon dioxide emissions □Appearance □Others [A reason:]		

Fig. 1. An example of choice sets and oranges

The amounts of the CO_2 attribute also have three values; 20g, 30g, and 40g per one unit of orange, which are calculated the four stages of their life cycle: production, fruit sorting and box packing, transportation, and packaging.[3] To cope with a rule for the prohibition of deception in Experimental Economics, three different places producing oranges are actually selected to make the difference of CO_2. Since the carbon footprint is to be prepared in Japan, the CO_2 emissions are first calculated on the life cycle assessment (LCA) to select those places. Then, the oranges are selected three famous places; Kumamoto, Ehime and Wakayama. The experiment is conducted in Osaka prefecture that is the most far from Kumamoto (about 800km), second from Ehime (about 380km) and third from Wakayama (about 100km). Thus, the transportation causes the main difference of CO_2 emissions in this study. The total CO_2 emissions are calculated as 34g, 32g, 23g in Kumamoto, Ehime and Wakayama, respectively. Based on these three values, the three values are employed as 20g, 30g, and 40g. Respondents, however, does not receive the places nor the CO_2 emitted in each process to make respondents focus on only price and the total amounts of CO_2 emissions in the food products.

[3] The levels of CO_2 emissions of oranges during their sale in supermarkets and stores are not added because a number of other goods are present there.

A full factorial design with three levels of prices and three amounts of CO_2 emissions constructed 729 alternative management combinations. Since it constitutes an unreasonably large design in practice, a D-optimal fractional factorial design with 24 alternatives is developed and separated into two blocks of 12 choice sets by using Design Expert (version 7). Therefore, each respondent choose one of three oranges and this repeats 12 rounds. The respondents received 120 JPY as endowment in order to purchase one unit of orange and a plastic package contained three types of oranges. The package was clear to see inside but sealed to keep respondents' hands off. They selected one of the oranges they wanted to buy. The price of the oranges they selected is deducted from the endowments and the total remaining money is paid as their earnings at the end of the experiment.

After twelve choice sets completed, respondents answer the survey questions about environmental consciousness (EC) scale, which is consisted of 10 questions used in Johnston et al. (2001) [13]. These are parts of the consumers' ecological purchase behaviors scale developed by Roberts (1996), which is consisted of 30 items measuring socially responsible consumer behavior using two dimensions; societal and ecological concerns. The question is asking respondents to rate the veracity of various statements with respect to their purchase behavior and its connection to environmental product attributes. It is five-point Likert type scale which denotes 1 as "never agree" to 5 as "always agree."

3 Model Structure

The study is used a random parameter logit (RPL) model [14, 15] based on the random utility theory which is central to the concept of choice modeling. The basic assumption underlying the random utility approach to choice modeling is that decision makers are utility maximizers, which implies that given a set of alternatives, decision makers select the alternative that maximizes their utility. The utility of an alternative for an individual (U) cannot be observed; however, it may be assumed to consist of a deterministic (observable) component (V) and a random error (unobservable) component (ε). Formally, an individual q's utility of alternative i in each of t choice set can be expressed as $U_{iqt} = V_{iqt} + \varepsilon_{iqt} = \beta'_q X_{iqt} + \varepsilon_{iqt}$. The density of β'_q is denoted as $f(\beta|\theta)$, where θ is a vector of the true parameters of the taste distribution. X_{iqt} denotes the explanatory variables of V_{iqt} for alternative i, individual q and choice set t. The random error component ε_{iqt} is assumed to follow a type I extreme value (EV1) distribution and to be independently and identically distributed (IID). The conditional probability of alternative i for individual q in choice set t is expressed as follows:

$$P_{iqt}\left(\beta'_q\right) = \frac{exp\,(\beta'_q X_{iqt})}{\sum_{j=1}^{J} exp\,(\beta'_q X_{jqt})}, \tag{1}$$

The probability of the observed sequence of choices conditional on knowing β'_q is expressed as follows:

$$S_q\left(\beta'_q\right) = \prod_{t=1}^{T} P_{qi(q,t)t}\left(\beta'_q\right), \quad (2)$$

where $i(q,t)$ represents the alternative selected by individual q on choice set t. The unconditional probability of the observed sequence of choices for individual q is the integral of the conditional probability over all possible variables of β'' and can be expressed as follows:

$$P_q(\theta) = \int S_q(\beta) f(\beta|\theta) d\beta. \quad (3)$$

In most applications, the density $f(\beta|\theta)$ is specified to be normal or lognormal: β ~ $N(b, W)$ or $\ln \beta \sim N(b, W)$, where the mean, b, and covariance, W, are estimated. In this study, we use a normal density.

Based on the above discussion, the main effect in Model 1 and the main effect with interaction in Model 2 are estimated using RPL model with the inclusion of socioeconomic characteristics. Therefore, the two indirect utility functions are as follows:

Model 1: $V_{iq} = \beta_1 Price_i + \beta_2 CO2_i$,
Model 2: $V_{iq} = \beta_1 Price_i + \beta_2 CO2_i + \sum_{k=1}^{K} \delta_k CO2_i \times Socio_{kq}$.
where $Price_i$ is the price of orange i, $CO2_i$ is the CO_2 emission from orange i, and $CO2_i \times Socio_{kq}$ is the interaction term of the CO_2 emission from orange i with a dummy variable indicating socioeconomic characteristics k of individual q, including the EC scale. β_1, β_2, and δ_k are parameters that need to be estimated.

4 Results

The laboratory experiment was conducted at the Osaka University with 104 respondents (63 non-students and 41 students) during November at the beginning of the season of the orange. No one participated in more than one session. Each session lasted for approximately 60 minutes. The average earnings in experiment was 1,407 JPY.

Table 2 summarizes the result estimated from LIMDEP 9.0 and NLOGIT 4.0. In the RPL model, a simulated maximum likelihood estimator is used in order to estimate the models by employing Halton draws with 500 replications [16, 17].

First result is the main effect of Price and CO_2. The variable Price is the fix parameter in the model because a price coefficient is known to be negative for every consumer. However, since the variable CO_2 is not known, it is assumed as a random parameter and specified to be normally distributed [14, 16]. The estimates of the two variables, Price and CO_2, indicate significantly negative signs at 1% levels. These results imply that all the respondents prefer to purchase oranges whose price is cheaper and CO_2 is lower. The marginal WTP for the reduction of 1g of CO_2 emission per an orange is 0.57.

Table 1. The random parameter logit regression results

Variable	Main effect	Main effect with interactions
Price	-0.12*** (0.01)	-0.12*** (0.01)
CO_2	-0.07*** (0.01)	-0.04* (0.02)
CO_2: Standard deviation	0.08*** (0.02)	0.07*** (0.02)
CO_2: Marginal WTP (mean)	0.57	0.33
[95% confidential bounds]	[0.55;0.58]	[0.32;0.34]
CO_2*High EC		-0.05*** (0.01)
CO_2*Female		-0.04** (0.02)
CO_2*Over 30		0.02 (0.02)
CO_2*High Income		-0.01 (0.01)
CO_2*University		0.02 (0.02)
Log likelihood	-1107.62	-1093.73
McFadden's R^2	0.19	0.20
Observations	1248	1248

Notes: Standard errors are in parentheses. ***, **, and * denote that the parameters are different from zero at the 1%, 5%, 10% significance levels, respectively.

Table 2. The dummy variables

Variables	Definition	Average
High EC	1: more than the median (30); 0: otherwise.	0.49 (0.50)
Female	1: female; 0: male	0.65 (0.48)
Over 30	1: more than 30 years old; 0: otherwise.	0.58 (0.49)
High Income	1: more than the median; 0: otherwise.	0.49 (0.50)
University	1: graduation university; 0: otherwise	0.86 (0.35)

Notes: Standard errors are in parentheses. Median of high income is 5,500,000 JPY.

Next result is the main effect with the interactions of CO_2. Here there is the main hypothesis such that consumers with higher EC scales exhibit higher WTP for reduction of CO_2. The estimation model is added the five interaction variables to the two variables Price and CO_2; *High EC*, *Female*, *Over 30*, *High Income*, and *University*. These variables are summarized in Table 2. Since spearman correlation rank-tests show significantly positive correlations at the 1% level in any combinations of EC, EK, and EB, EC is used as a representative variable for the evaluation of consumers' environmental consciousness.

The results are as follows. Consumers have significantly negative coefficients for the increasing CO_2. The consumers with higher environmental consciousness exhibit higher WTP for reduction of CO_2 than those with lower environmental consciousness, which supports the main hypothesis. The result implies that the carbon footprint mitigate the emissions caused from the long distance transportation and enhance the local food production and service systems.

5 Conclusions and Discussions

This study investigates the relationship between consumers' environmental consciousness and their valuations for the carbon footprint on daily food products by using the choice method in the real buying experiment. The results support the main hypothesis such that consumers with higher environmental consciousness have a higher WTP for the reduction of CO_2 in the experiment.

The oranges used in this study have the almost same production procedures so that their CO_2 emissions are not so far. The largest difference in the CO_2 emissions caused from the transportation because of the difference from the transportation distances. Although this study does not inform the breakdown of CO_2, the result implies that consumers prefer for foods produced in the near areas because of reducing emissions from the transportation.

In this study, the difference of the distance in the production area causes the difference in the carbon dioxide emissions. The result implies that the carbon footprint has a power to enhance the local food productions for the local consumptions and reduce the emissions caused from the long distance transportation.

Since this study investigates the value of reduction for the CO_2 emissions on foods in the real buying experiment, a question is created as future works. That question is whether the value in the hypothetical condition is more than that in the experiment, which is a hypothetical bias. A choice experiment has a hypothetical bias risk. Harrison and Rutström (2008) surveyed 35 studies and found hypothetical bias in all but 3 cases, which implies that researchers rarely find a situation without hypothetical bias [18]. In the food market, Lusk and Schroeder (2004) found it for beef ribeye steak [19], and Chang et al. (2009), for ground beef and wheat flour [20]. Most recently, Aoki et al. (2010) found it in sodium nitrite information on hams. Hypothetical bias causes policy makers to suspect the credibility of policy evaluation data.

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Does an Information Service Provider Improve the Market?

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Abstract. This study aims to theoretically analyze whether the information service provider improves the market efficiency. We construct a model where a good supplied by a producer has a risk to be harmful for a consumer because of an accident and it brings monetary losses to both consumers and producers. The accident risk is endogenously determined by the efforts of producers and consumers and the information of safety provided by the producers. The information service provider requires producers to provide information and certifies the credibility of information. In the equilibrium, if the entry cost for the information service provider is small, the optimal effort levels spent by the consumer and producer increase and the risk of accident decreases, which improves the market efficiency.

Keywords: Information, Service provider, Double moral hazard, Safety.

1 Introduction

There are several goods including the risk of accidents such as rental car and agricultural products. In these goods, trading is one-shot but it sometimes damages, injures, and makes consumers harmful caused by the accident after the trading and consumption. Consumers can not completely estimate the risk of that good holding. The information of risk and how to treat the good provided by the producer make the consumer pay attention to treat those goods as safety and decrease the risk of accidents. For instance, Product liability (PL) low requires the producers to provide the information how to treat the goods for the consumers.

The information enhances the effort of consumers and reduces not only their damages but also damages or losses for the producers because produces need to pay some compensation to the consumers after the accident or lose the reputation and credibility of their goods. The producer often imposes the cost of providing the information to the consumers. Thus, the producer face the tradeoff cost of providing information and reducing the damage. Additional issue for the producer is trust for the consumers. Even if the producer provides the information, the consumers cannot trust it unless there is a system to monitor the producers' deception. Given this situation,

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the producer does not have an incentive to provide the information since it imposes the cost for non-validity information.

This situation allows information service providers to enter the market and intermediate the information from the producers to the consumers. It requires the producer to provide the information and certifies the validity of the information by paying the monitoring cost. The certified information has a validity that the consumer can trust enough. In this case, the producer has an incentive to incur cost of providing the information. The information service provider imposes the fee of using information both to the consumer and producer to finance their monitoring and certification costs. Both the consumers and producers have incentives to pay this fee if their utility and profits becomes better than the case with no-information.

This study constructs a theoretical model and examines whether the information service provider enhances the effort of producers and consumers and the service provider can make a profit in that market. Our prediction is that the information service provider has an incentive to voluntary enter the market to intermediate the information of safety from the producer to the consumer, which improves the market efficiency.

The situation considered in this study is one of the central issues in the market failure caused by the imperfect information that is called double moral hazard in Economics. In this situation, consumers and producers spend less effort levels than the social optimal levels since the imperfect monitoring causes free riding other's efforts. The seminal paper in this issue is Cooper and Ross (1985) and it has been studied by many researchers (for instance; Bhattacharyya & Lafontaine, 1995; Kim & Wang, 1998; Martimort, & Sand-Zantman, 2006). It is also applied to the supply chain (Corbett, C., DeCroix, G., & Ha, A. (2005a); Ha, A., & Tong, S. (2008); Zhou, J., Zhao, X., Xue, L., & Gargeya, V. (2012)) and food service (Elbasha & Riggs, 2003; Steiner, B., 2012). This study expands the model developed by Elbasha and Riggs (2003) and introduce the information service provider who requires the producers to provide the information of safety for the goods and certifies the validity of the information.

The remaining paper is organized as follows. Section 2 explains the model description and notations. Section 3 theoretically analyzes the equilibrium. Section 4 shows the numerical solutions, and Section 5 summarizes the conclusions and discussions.

2 Model Description and Notations

This study modifies the assumption developed by Elbasha and Riggs (2003). It assumes that there are a consumer and a producer in the market. The producer supplies a good and a consumer consumes it. Let L_c be the level of costs incurred for which the consumer is not compensated and L_f be the losses incurred by the producer. Total costs caused from the accident during using this service (time lost from work, lost product, legal fees, medical costs, pain, and suffering, etc) are denoted by L. A good supplied by the producer has a risk to be harmful to the consumer with a given probability of accident,

$$\theta = 1 - \frac{(e + i + \chi)(m + i + \chi)}{a}$$

where, $e \in [0,1]$ and $m \in [0,1]$ are the levels of efforts expended by the consumer and the producer, respectively. $i \in [0,1]$ is denoted as a information parameter the information service provider provide. The remaining variable, χ, is an potential factor for preventing the accident. As the producer and/or consumer increases their efforts, the risk of accident decreases.

This study assumes that the consumer and the producer are both risk neutral and maximize their own payoffs. The assumption of risk neutrality is made here only to simplify the analysis and not to minimize the importance of risk aversion in the service issue. It assumes that both the consumer and the producer are price-takers in the market for the service, q, which is sold at price, p. There are two justifications for making this assumption. First, assuming that the consumer is price taker is a standard assumption that is commonly made in the economic literature. Second, the assumption of price-taking behavior on the producer's side is synonymous to assuming a perfectly competitive service markets. Modeling the service market as an imperfect competition is more realistic and may lead to richer conclusions, but it is tangential to the purpose of this paper. For simplicity, we exclude the case where the producer has some market power.

The consumer receives utility $V(q)$ from consuming the service q when it does not make her injured. The utility increases with q, but the marginal utility is diminishing. Hence, this model assumes that the utility function is strictly concave. The consumer also receives utility from the remaining money after consuming the good. This utility is given by the term $y - pq$, where y denotes the consumer's income. This model also simplifies the assumption such that the amount of goods consumed does not affect the probability of accident from using the good and the associated losses. Hence, the function $\theta(e, m, i)$ is independent of q. Disutility to the consumer arises from exerting efforts to prevent accidents. Such efforts include getting information and adhering to proper maintenance efforts during consumption of that good. Poor preparations and handling practices cause the accident. Let $g(e) = \frac{1}{2}e^2$ denote the disutility from exerting efforts to handle and prepare the good properly.

This model also assume that the producer incurs cost from productions, $C(q) = \frac{1}{2}q^2$ and cost from implementing safety measures, $H(m) = \frac{1}{2}m^2$. For simplicity, this study focuses on the case where the good and its safety are jointly produced. This study assumes that the cost function of providing information incurred by the producer is $C(i) = \frac{1}{b}i^2$.

Both players need to pay a fee for using the information service provider. Let F_c denote a fee that the consumer pays and F_p a fee that the producer pays. This model assumes that these fees are lump-sum. The service provider monitors the information provided by the producers and certifies it as the information label by spending cost denoted as $t(i) = \frac{1}{d}i^2$. The service provider also imposes the entry cost, k.

Based on this assumption, Section 3 considers the case where the information service provider does not exist and consumer cannot receive the information of the good's safety. Then, Section 4 considers the case where the information service provider enters the market and consumer can receive the information provided by the producer.

3 Non-existence of Information Service Provider

This sections considers the case that the service provider does not exist and no information is provided, that is, $i = 0$. Therefore, the consumer maximizes the following expected utility for given :

$$EU^0 = y - pq + V(q) - \theta(e,m,i)L_c - g(e) = A - \left\{1 - \frac{(e+\chi)(m+\chi)}{a}\right\}L_c - \frac{e^2}{2}$$

where $A = y - pq$.

The first-order condition is

$$e = \frac{(m+\chi)L_c}{a}$$

Simultaneously, the producer maximizes the following expected profits for given e :

$$E\Pi_p^0 = pq - C(q) - \theta(e,m,i)L_f - H(m) = B - \left\{1 - \frac{(e+\chi)(m+\chi)}{a}\right\}L_f - \frac{m^2}{2}$$

where $B = pq$-C(q).

The first-order condition is

$$m = \frac{(e+\chi)L_f}{a}$$

Then, we obtain the Nash equilibrium as the below:

$$e^0 = \frac{\chi L_c(a+L_f)}{a^2 - L_c L_f}, \qquad m^0 = \frac{\chi L_f(a+L_c)}{a^2 - L_c L_f}$$

Next we consider the first best outcomes in this society. We define the social welfare function, W, as the sum of the consumer's expected utility and the producer's expected profits. If the government aims to maximize the social welfare, it solve the following expected welfare:

$$EW^0 = EU^0 + E\Pi^0 = A + B - \left\{1 - \frac{(e+\chi)(m+\chi)}{a}\right\}L - \frac{e^2}{2} - \frac{m^2}{2}$$

The first-order condition is

$$e = \frac{(m+\chi)L}{a}$$

$$m = \frac{(e+\chi)L}{a}$$

We obtain the first best outcome which maximize the social welfare

$$e_{FB}^0 = \frac{\chi L}{a-L}, \qquad m_{FB}^0 = \frac{\chi L}{a-L}$$

4 An Existence of Information Service Provider

Here we consider the information service provider requires the producer to provide the information of good's safety and how to treat it as safety and then it certifies the validity of the information. The consumer trusts the information provided by the producer and maximizes the expected utility for given m and i:

$$EU^i = y - pq + V(q) - \theta(e,m,i)L_c - g(e)$$
$$= A - \left\{1 - \frac{(e+i+\chi)(m+i+\chi)}{a}\right\}L_c - \frac{e^2}{2} - F_c$$

The first-order condition is

$$e = \frac{(m+i+\chi)L_c}{a}$$

Simultaneously, the producer maximizes the expected profits for given e and i:

$$E\Pi_p = pq - C(q) - \theta(e,m,i)L_f - H(m) - c(i) - F_p$$
$$= B - \left\{1 - \frac{(e+i+\chi)(m+i+\chi)}{a}\right\}L_f - \frac{m^2}{2} - \frac{i^2}{b} - F_p$$

The first-order condition is

$$m = \frac{(e+i+\chi)L_f}{a}$$

We obtain the Nash equilibrium, given i as the below.

$$e^i = \frac{(i+\chi)L_c(a+L_f)}{a^2 - L_cL_f}, \qquad m^i = \frac{(i+\chi)L_f(a+L_c)}{a^2 - L_cL_f}$$

Given this equilibrium strategy, now the service provider decides the fees to maximize its expected profit function under the individual rationality condition of consumers and producers.

$$E\Pi_s = F_c + F_p - t(i) = F_c + F_p - \frac{i^2}{d} - k$$

subject to

$$EU^i = A - \left\{1 - \frac{(e^i+i+\chi)(m^i+i+\chi)}{a}\right\}L_c - \frac{{e^i}^2}{2} - F_c$$
$$> EU^0 = A - \left\{1 - \frac{(e^0+\chi)(m^0+\chi)}{a}\right\}L_c - \frac{{e^0}^2}{2}$$
$$E\Pi_p^i = B - \left\{1 - \frac{(e^i+i+\chi)(m^i+i+\chi)}{a}\right\}L_f - \frac{{m^i}^2}{2} - \frac{i^2}{b} - F_p$$
$$> E\Pi_p^0 = B - \left\{1 - \frac{(e^0+\chi)(m^0+\chi)}{a}\right\}L_f - \frac{{m^0}^2}{2}$$

The individual rationality conditions for consumers and producers satisfy the conditions such that their utility and profits is not less than the level when the information service provider does not exist. Thus, the service provider can raise the fees equal to the boundary of the individual rationality condition as follows.

$$F_c = \frac{L_c}{a}\{(e^i + i + \chi)(m^i + i + \chi) - (e^0 + \chi)(m^0 + \chi)\} - \frac{{e^i}^2}{2} + \frac{{e^0}^2}{2}$$

$$F_p = \frac{L_f}{a}\{(e^i + i + \chi)(m^i + i + \chi) - (e^0 + \chi)(m^0 + \chi)\} - \frac{{m^i}^2}{2} + \frac{{m^0}^2}{2} - \frac{i^2}{b}$$

The solution is too complex so that we propose the numerical solutions in the next section and consider whether the information service provider improve the market.

5 Numerical Analysis

To set the numerical values, we consider the following situation. Let $\chi = 1,\ a = 9$, which indicates if the producer and consumer spend the maximum value of their efforts, the probability of the accident becomes zero. Let $b = d = 3$, which means that the cost of providing information of producer is equal to the certification cost of service provider. The producer's profits of selling the good and consumer's benefit after consumption of the good is equal to 1, $A = B = 1$, which are the numeral values as the money. The damage caused from the accident imposes the same losess to the consumer and producer, $L_c = L_f = 1$. But we remain the entry cost k as the variable to discuss the incentives of entry for the service provider.

Thus, we obtain the outcomes in the model without service provider as follows:

$$e^0 = \frac{1}{8}, \qquad m^0 = \frac{1}{8}$$

$$e^0_{FB} = \frac{2}{7}, \qquad m^0_{FB} = \frac{2}{7}$$

$$EU^0 = \frac{17}{128}, \qquad E\Pi^0_p = \frac{17}{128}$$

On the other hand, in the model with service provider, we obtain the outcomes as below.

$$i = \frac{51}{77}, \qquad e^i = \frac{16}{77}, \qquad m^i = \frac{16}{77}$$

$$F_c = \frac{17}{128}, \qquad F_p = \frac{17}{128}$$

$$EU^i = \frac{17}{128}, \qquad E\Pi^i_p = \frac{17}{128}, \qquad E\Pi^i_s = \frac{1581}{4928} - k$$

Comparing the Nash outcomes between two models, the information service provider enhances the effort levels both in the producers and consumers. If the entry cost k is small enough to make the service provider earn the positive profits, since the individual rationality condition for the service provider is satisfied, it can enter the market and the market efficiency is improved.

6 Conclusion and Discussion

This paper theoretically analyzes the impact for the information service provider to intermediate the information of good's safety from the producers and consumers. Our result shows that the information service provider motivate producers to provide the information of good's safety and raise the effort levels for producer and consumers, which improves the market efficiency.

The original study of Elbasha and Riggs (2003) suggest the tax policy and direct restriction of producers for providing information to improve the market efficiency. In that study, producers are directly restricted to provide the information and it is not motivated by the economic incentives. On the other hand, in our study, the service provider voluntary enters the market and has an incentive to motivate producers to provide the information to finance their monitoring and certification cost. The service provider plays a same role as the government direct restriction.

Notice that the voluntary entry of the service provider is supported by the small entry cost that satisfies its individual rationality. If the entry cost is high, the service provider has no incentive to enter the market. In this case, the government regulation has a power to improve the market.

Our remaining issue is solving the general outcomes instead of specific numerical outcomes. Then, we conduct multi-agent simulation or/and human subject experiments to investigate what factors affect the market improvement when the information service provider exists.

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Facility Layout Planning of Central Kitchen in Food Service Industry: Application to the Real-Scale Problem

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Abstract. Central kitchen is a food producing factory to improve productivity in the food-service industry, to pursue scale-merit by aggregation of tasks in multiple stores into one place. However, the central kitchen is still labor intensive production environment because of trade-off between quality and quantity of products, so that the handicraft of skilled workers cannot be eliminated. In addition, there are many part-time workers as well as full-time ones, as a result, operators can be also uncertain factors. Furthermore, customer demand forecast is also difficult according to not only susceptible to weather and seasonal variation but also influence from irregular events held around the restaurant. Due to such characteristics of the food service industry, it is also difficult to plan proper facility layout of the central kitchen to achieve both optimality and adaptability to the complexity. In this study, a new facility layout planning method of the central kitchen is proposed, where not only optimization but simulation is also adopted; flow of workers as well as products can be considered simultaneously. Computer experiments in which the proposed method is applied to the real-scale problem are conducted to confirm the effectiveness of the proposed method.

Keywords: Food service industry, Facility layout, Simulation, Genetic Algorithm.

1 Introduction

Importance of the service industry is increasing because the service industry plays about 70% of GDP in Japan, two-thirds of employment. In spite of the expansion of the role of the service industry, the productivity growth of the service industry is relatively low compared to the manufacturing industry and the overseas service industry [1]. It is not easy to improve the productivity of the service industry because service is complex in nature, so that the quality of production and provision of services depends on experience and intuition of workers. Service Science [2], Product-Service System [3] and Service Engineering [4] have been proposed to improve productivity of service industry.

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Productivity of food service industry is also relatively low among the service industries [5,6]. Central kitchen is a food processing plant in order to improve productivity in the food service industry, to pursue economies of scale. In the central kitchen, efficiency of production due to the automation and process integration is important, however, according to trade-off between quality improvement and quantity acquirement the handicraft of skilled workers cannot be eliminated; the production base labor intensive. In addition, there are many part-time workers as well as full-time ones; unskilled workers may be uncertain factors in production. Moreover, not only variables of central kitchen inside, it is subject to weather and seasonal variation. There is also the impact of irregular events held around the restaurant, so that demand forecasting is intensely difficult. By producing food of high quality while adapting flexibly to the environmental changes of central kitchen internal and external, it is possible to achieve improvement customer satisfaction (CS), employee satisfaction (ES) and management satisfaction (MS).

From the above-mentioned complexities, daily productions of the current central kitchen is carried out by the experience and intuition of skilled workers. Consequently, facility layout does not take into account the movement of workers as well as product flow. Moreover, the production is labor intensive because it is hand-made to create value, so that the load on the worker is large, reduction of the workload by improving the facility layout is also necessary. This study aims at deriving facility layout to minimize the moving mileage of workers as the worker load indicator. Flow line of worker draws a complicated trajectory, calculating the length of moving mileage is difficult by the conventional mathematical programming approach [7]. Therefore, to calculate workers' moving mileage, integration of computer simulations and genetic algorithms is proposed [8]. Fitness calculation of each individual in GA incorporates the computer simulations, as a result, the placement of equipment and workers are obtained to minimize the sum of moving mileage of each worker. However, it is necessary a lot of computation time if experiments with sufficient number of generations are performed assuming evaluate the layout only by the simulation, because the simulations are executed (number of individuals) $\times$ (number of generations) times.

Therefore, simple calculation method of worker's mileage by accumulating mileage of workers along each product flow is introduced, so that a sufficient number of generations can be performed in GA. Subsequently, further GA with computer simulations is performed. The proposed integration method is applied to a real-scale problem in this paper.

2 Integration of Simulation and Genetic Algorithm

2.1 Algorithm of the Proposed Method

The proposed method consists of two stages; simple calculation of worker's mileage is done and the sum of obtained values is used as fitness value of GA in the first stage. In the second stage followed, including some of the solutions obtained in the first stage as initial population, the GA is conducted with calculating fitness value by performing simulations. Perform a sufficient number of generations GA minutes faster in the first stage, then it can create a layout that takes into account both the flow of workers and products further in the second stage. The flowchart of the proposed method is shown in Fig. 1.

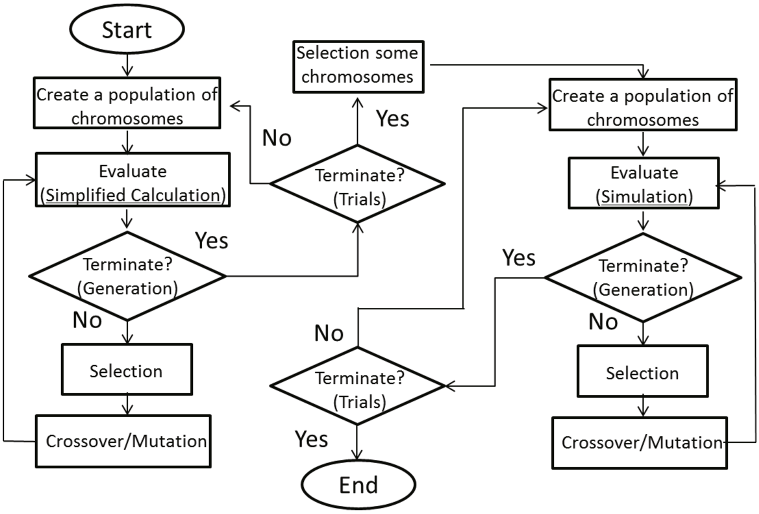

Fig. 1. Algorithm of the proposed method

2.2 Calculation of Workers' Moving Mileage

Simplified calculation of the workers' moving mileage is determined as follows along to each product. The fitness of the GA is calculated by sum of each worker's mileage with respect to all products.

- Mileage between facilities is calculated based on the center coordinates of the facility.
- Worker who performs the next process receives the product at the facility, delivers it to the following facility, processes it and returns to the waiting area.
- Worker who is responsible for the last process is to convey to OUTPUT.
- Alternative facilities and workers are assigned in random manner.

When the operator acts as the rules above, as Fig. 2, a triangle is composed by the flow line of workers among waiting area of the worker, facility of the process and the following facility. Furthermore, since the worker was in charge

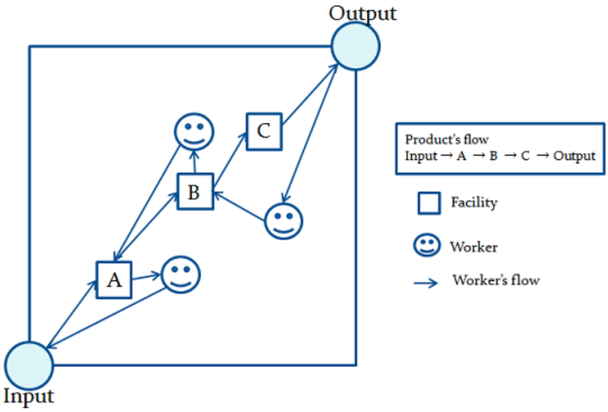

Fig. 2. Calculation method of workers' moving mileage

of the process is transported to the OUTPUT, rectangle as shown in the figure is formed in the final step. The workers' moving mileage are calculated by summing each product minutes triangles and quadrilaterals thereof.

2.3 Coding and Genetic Operation

Each individual in the GA represents the position information of each facility. It is assumed that expressed in numeric position of the partition that discretizing the manufacturing area, separated location information. Fig. 3 depicts an

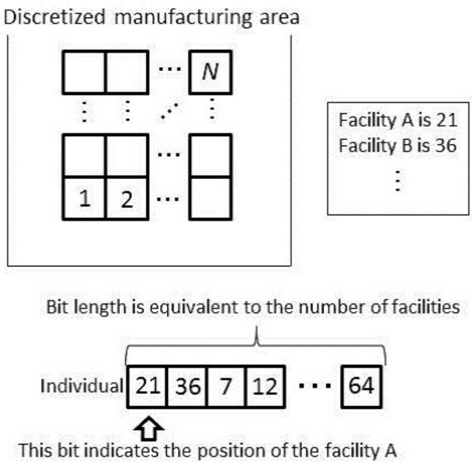

Fig. 3. coding method

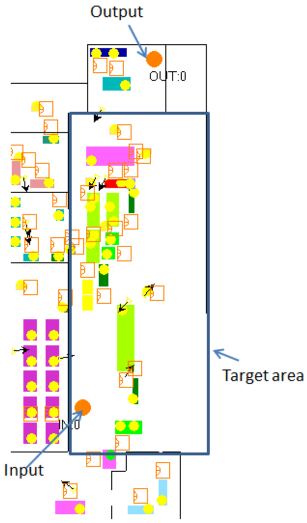

Fig. 4. Current layout of the central kitchen

overview of the coding; each locus represents the position of the corresponding machine in the discretized production floor.

To prevent the facility and worker of two or more are present in one compartment separated, generation of individual, crossover and mutation operation are executed to avoid duplication in each bit of one individual.

- Generation of initial individuals: determine the position number in each individual from the bit head, but avoid duplicate numbers by going to random selection from the set excluding the numbers used in the previous bits.
- Crossover: the two-point crossover is used. Duplicated bits are changed to the random number that does not overlap with other bits.
- Mutation: select at random from the number that does not overlap with any bits itself has.

3 Experimental Results and Discussion

3.1 Experimental Conditions

Fig. 4 illustrates an overview of the central kitchen to target. The target area represents the area of interest of the facility layout plan in this study. Each product is dispatched from the Input location, and is collected at the Output location which is a shipping place. All facility number of plant is 55 units and the worker is 14, however, target area has facilities and workers to act as the planning target, 23 units, five operators, respectively. The target area is separated into 8 $\times$ 16 rectangular areas where each facility and waiting area of worker is allocated

Table 1. Sum of workers mileage in the busy season

BEST (m)	Ave.(m)	S.D.	Time (sec)
22167.90	23581.71	919.89	113365

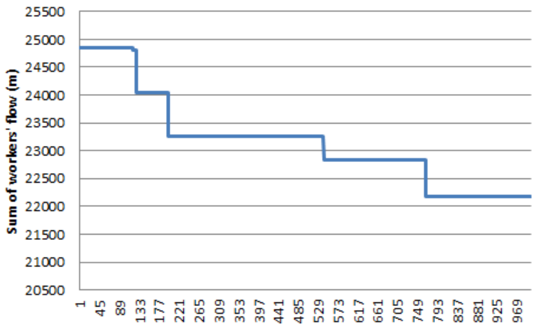

Fig. 5. Transition of mileage in the 2nd step

to one rectangle so as to achieve minimizing sum of workers' moving distance. Product varieties are set to 22.

GA uses different parameters in the first and second stages from the viewpoint of the balance of the calculation time. Each parameter setting is as follows.

- 1st stage: population 1000, generation 20000, crossover rate 0.6, mutation rate 0.01
- 2nd stage: population 100, generation 1000, crossover rate 0.6, mutation rate 0.01

The tournament selection with tournament size 2 and elite selection strategy are also adopted.

3.2 Results and Discussion

100 trials execute in the first stage, subsequently, 10 trials run in the second stage which include 10 best layouts obtained in the first stage as initial individuals. Table 1 represents the resultant best, mean and standard deviation value of obtained workers' moving mileage and the average computation time after the execution of the second stage. In addition, Fig. 5 represents the transition of the workers' mileage of attempts best solution is obtained.

As shown in the figure, compared with the layout obtained in the first stage, the value can be about 2,000 m shortened from 24,800 m. The result reveals that further combination of GA and simulation can obtain a better layout taking into account the flow of product and operators based on the layout determined by GA using a simplified calculation of fitness value.

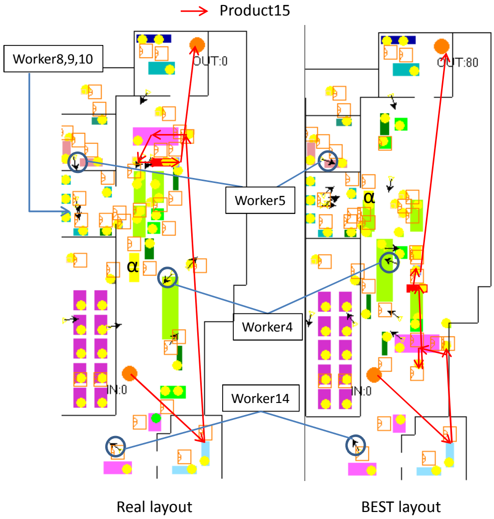

Fig. 6. Current and proposed layout

Table 2. Comparison with the current layout

	Current	Proposed
Worker1 (m)	1145.83	1510.83
Worker2 (m)	1408.99	1772.96
Worker3 (m)	1646.48	1621.69
Worker4 (m)	1909.62	1452.51
Worker5 (m)	1425.84	1128.33
Worker6 (m)	1858.01	1436.33
Worker7 (m)	1809.20	1622.52
Worker8 (m)	1283.34	1374.17
Worker9 (m)	884.78	976.473
Worker10 (m)	1366.49	679.557
Worker11 (m)	1507.92	1346.49
Worker12 (m)	3107.61	3000.16
Worker13 (m)	663.82	663.82
Worker14 (m)	4272.79	3582.59
Sum (m)	24303.39	22167.90

Comparison between the obtained layout and the current layout in the central kitchen is done. Table 2 shows moving mileage of each worker in both layouts. Fig. 6 also indicates the layout obtained by the proposed method (BEST) and the real central kitchen layout (Real). The standby position of each worker to be associated with the product flow of Product 15 is also illustrated in each layout. Looking at the flow diagram, after dispatched from the Input location, Product

15 is processed by Worker 14 below the layout. Transport distance is extended when Worker 14 delivers the product to the next step in the current layout; it requires only transport up to the center in the facility layout of BEST, but the facility of the next process is located above in the current layout.

It can be understood as the difference of transportation during this period has become a difference of Worker 14 between two layouts. It also seems that Worker 4 can obtain shorter distance in the obtained layout because Worker 4 is allocated to near position to the room in the left hand side of the layout where Worker 8, 9 and 10 are arranged; Worker 4 comes and goes to the room frequently during production.

4 Conclusion

This paper presented a new facility layout planning method of the central kitchen in food service industry by combining optimization, GA, and simulation; fitness value calculation was done by simplified numerical method in the first stage, then the simulation was also conducted in the second stage to consider both product and operator flow. Comparison results with the current layout of the central kitchen revealed the effectiveness of the proposed method.

Elaboration of simulation and combination with the shift-scheduling of workers can be pointed out as the further steps of the study.

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Finding the Optimal Operating Point for Service Production Processes via Simulation

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Abstract. This paper presents a simulation approach for service production processes on the basis of which an optimal operating point for service systems can be identified. The approach specifically takes into account the characteristics of human behavior. The simulation is based on a system theory approach to the service delivery process. A specific use case of the simulation approach is presented in detail to illustrate how characteristic curves are deduced and an optimal operating point is obtained.

Keywords: Service production, service process, simulation, service productivity.

1 Introduction

Increasing operational productivity is the basis for improving competitiveness of industrial services [1]. Services are characterized by their intangible nature leading to a lack of storability [2]. Furthermore, the customer is involved in the production process of the service. He is not only especially aware of the service production process, but also participates in the process as an external production factor [3]. An analysis of productivity in service systems should incorporate both the quality and the process character of service delivery [4]. The inclusion of quality into the assessment of productivity consequently leads to the inclusion of the factors time, cost and capacity. For an assessment of service productivity this ultimately means the consideration of all five dimensions and their interactions with one another [5].

Past research results illustrate the ability and the value of simulation in the design of highly flexible business processes [6]. In a service context, specific applications of simulation which aim at improving the operational understanding of the service production process have been researched scientifically [7]. This paper presents a simulation approach for service systems. As a result of the simulation characteristic curves for services systems are obtained in order to find an optimal operating point.

2 The Elasticity of Capacity in Service Systems

The theory for industrial production mostly assumes constant process times which for example do not depend on the amount of load or input on a system [8]. For services,

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the process times are subject to larger fluctuations and actual productivity differs significantly from the theoretically calculated performance [9]. The service delivery process has a determining human component, usually because a service process operates on employee labor as a major resource or capacity [10]. It is therefore essential to include the aspects of human nature into the consideration.

Humans are aware and therefore influenced by their environment and their current situation [11]. The productivity of a human depends not only on the capabilities of the human itself but also on the environmental state in which the human is being put into. For example, the human performance is viewed as a function of its ability and its motivation [12]. According to the Yerkes-Dodson law the performance on a specific task is a direct function of the psychological or mental arousal [13]. Similar relationships are known for the effects of stress on the work performance [14].

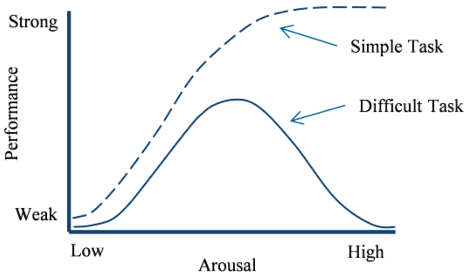

Fig. 1. Yerkes-Dodson law [13]

In recent scientific research the term procrastination describes the impact of the organization of the work on the human performance [15][16]. Humans tend to put off more urgent tasks in order to do something else, which typically brings them more personal pleasure or enjoyment [17]. Ariely (2002) showed that by setting multiple periodic deadlines instead of heaving one single deadline at the end, the performance for a specific task could be increased significantly. At the same time the average delay of the task was reduced [18]. Recent research suggest, that procrastination is not merely an issue of setting deadlines and organizing work, but occurs in various forms in all types of work settings and for most human beings[19][20].

Altogether the implications derived from scientific literature in the field of psychology led to two basic assumptions about the human component in the service delivery processes:

- Depending on the nature of the task, the time and the quality of a service process are not constant but show a certain elasticity towards environmental factors.
- As the human performance depends on a variety of factors (such as motivation, stress, arousal), an examination of service productivity should therefore consider the same factors as they determine the outcome of a service process.

3 Simulation Model Construction

In order to capture the characteristics of human behavior into a simulation model a system theory approach is taken. The system theory is used for modeling relationships in complex organizational structures such as productions systems [21]. A generic tool for structuring a system model is provided by the approach of Negele (1998), which was developed on the basis of system theory. The so-called ZOPH approach divides an overall system into four types of systems [22]: The target system, the object system, the process system and the actor system. Elements outside the system boundaries are part of the system environment. Figure 2 illustrates the elements and aspects of service production that are included in the simulation.

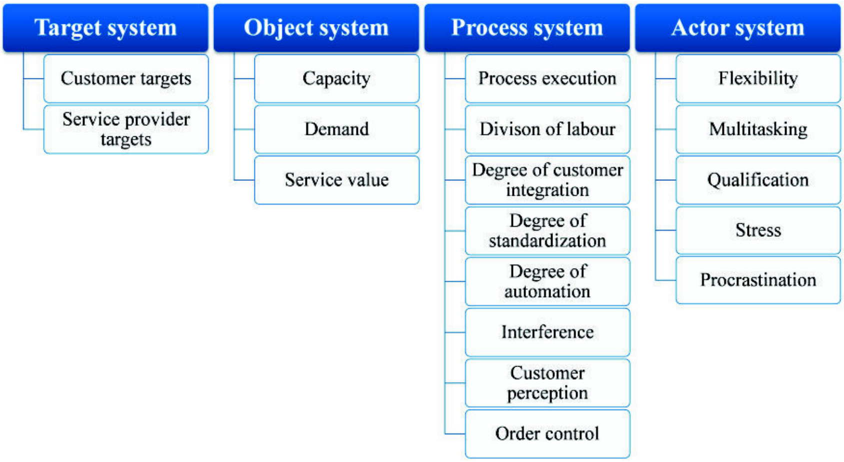

Fig. 2. Elements and aspects included in the simulation model

In this paper an application of the simulation approach for a specific use case is presented. The use case is based on a real technical service center. In the service center, which has the basic characteristics of a call center, technical service for specific technical products such as wireless routers is provided. Owners or operators of the products can call the service center in case of a malfunction of the product. The service center staff helps the customer via telephone and tries to solve the problem together with the customer. Problems can be detected not only in theory but are also addressed in a practical way because the service center staff can reconstruct the real configurations on a special workbench. If a problem solution can't be obtained on the phone, the customer is asked to send in their device. For this use case this is considered as a nonfulfillment of customer requirements.

The following bullet points describe each of the factors included in the simulation model:

- The system has a certain constant capacity. The capacity is derived from the number of staff working in the service center. It's the theoretical amount of work (number of calls) a certain amount of staff can do in a fixed period of time.

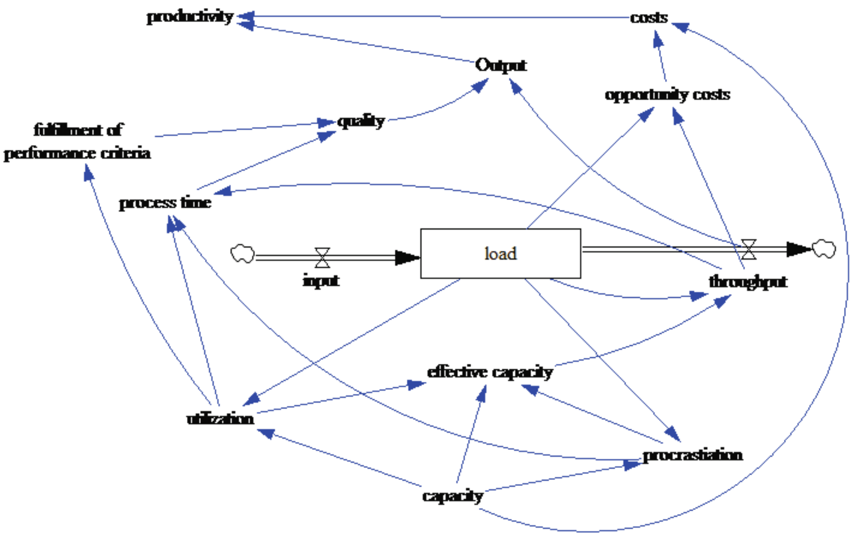

Fig. 3. Simulation model for a service center

- The input represents the amount of calls from customers to the service center. It is a fluctuating demand with a constant mean and standard deviation.
- The input adds to a load for the system for a fixed time period. The load can be viewed as the workload (number of calls) during a fixed period of time.
- The utilization is derived from the comparison of the load and the capacity. The utilization is used to determine the effects of stress due to high workload. For the utilization a maximal value was included since for a given amount of capacity the workload can't be infinitely high. Also the telephone system of the service center has an automatic cap which only allows for a limited number of calls to be forwarded to the staff. Data provided by the service center allowed for the calculation of this utilization cap.
- The procrastination depends on the capacity and the load. If the load is bigger in comparison to the capacity a lesser level of procrastination will occur and vice versa. It is assumed that procrastination occurs while a task is performed (a member of the staff is answering a call from a customer). A practical example for procrastination during task performance in this case is exaggerated chatting with the customer (a certain amount of friendly conversation is imperative). The effects of procrastination will also occur in between tasks (staff taking longer breaks, chatting with other staff, etc.).
- The effective capacity takes into accounts the effects of procrastination and stress due to high workload. It manifests the concept of the elasticity of capacity in service systems. Although the capacity is kept constant the effective capacity varies depending on the workload.

- The throughput is determined by the effective capacity. It is the performance (answered number of calls) in a fixed period of time. The throughput is subtracted from the load.
- The opportunity costs arise, if the load in a fixed period is bigger than the throughput. In this specific case the difference between the load and the throughput (number of unanswered calls) can't be carried over to the next period and thus leads to opportunity costs.
- The costs are the sum of the costs for the capacity and the opportunity costs. In this specific case all other costs are assumed to be constant and do not depend on the number of staff in the service center.
- The process time depends on the utilization and the level of procrastination. High levels of procrastination lead to increased process times. A high utilization leads to a decrease in process time, since a larger amount of work has to be done in the same fixed period of time.
- The fulfillment of performance criteria can be viewed as the number of tasks that are successfully performed. A successful performance depends on the fulfillment of the demands a customer has on a task. In this specific case the customer calls the service center and expects a solution to his or hers problem. If a solution can't be given (the product is still malfunctioning after the call and has to be sent in) there is no fulfillment of performance criteria. A high utilization leads to stress which leads to a lower average performance of the service center staff (diagnosing and solving a technical problem over the phone with the help of the customer with little or no technical expertise is categorized as a difficult task).
- The perceived quality depends on the fulfillment of the performance criteria and the process time. From a customer point of view a lesser fulfillment of performance criteria and longer process time mean a decrease in perceived quality. For this specific case the two factors are weighed against each other in a way that the fulfillment of the performance criteria has a significantly larger effect on the perceived quality than the process time. The effects of a non-fulfillment of the performance criteria for the customer are more significant since the product is still malfunctioning and the customer has to do the extra work of sending it in. Also the customer expects his problem to be solved by the service center but has not a certain expectation towards an amount of time the solution has to be given in (apart from as quick as possible).
- The overall output is determined by the throughput and the quality. For service processes the productivity cannot be judged solely on quantitative values but also has to take into account qualitative aspects (as pointed out in chapter 2). Therefor an output consisting of the quantitative throughput and the perceived quality is calculated.
- The productivity is the given by comparing the output and input (costs) of the service system.

Further key assumptions included in the simulation model are the following:

- For the actor system it was determined that no multitasking occurs (staff do not answer two phonecalls at the same time). Also each staff member is sufficiently qualified for the task and qualification does not differ significantly amongst the staff.

- An order control was assumed in a way that incoming calls into the service center are kept in a queue if no staff was available to answer the call. But only a certain amount of waiting time was allowed for the customer. After the customer has spent that time waiting in the queue he was disconnected and asked to try at a later time. For the simulation model the waiting time of the customer was assumed to not play a significant role, since it was kept relatively small by the queuing system.

4 Finding the Optimal Operating Point via Simulation

For the presentation of the results in this paper all quantitative data was normalized due to data security and privacy issues of the service center's company. The results in this paper were generated in order to show the general principle of the characteristic curves and how an optimal operating point for a service system can be obtained. In order to generate results the capacity was given different values. For each value for the capacity a simulation run over a certain amount of time periods was conducted.

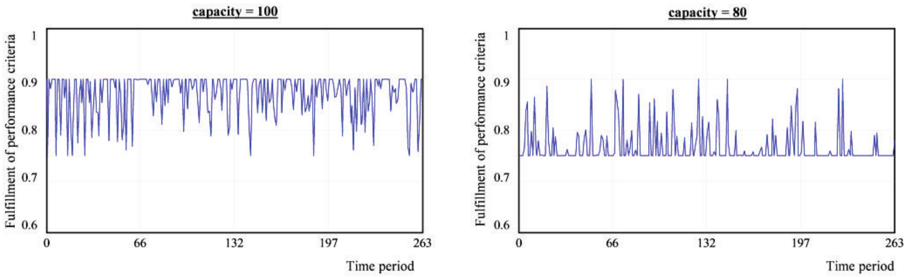

Fig. 4. Fulfillment of performance criteria for different capacities

Figure 4 illustrates how the fulfillment of performance criteria, as a major part of the perceived quality, changed for different values of capacity. For a capacity of 100 the maximal fulfillment of performance criteria is at 0.9 or 90%. This is due to the fact that for 1 out of 10 calls it was assumed that there was no solution to the problem and the product had to be sent in in any case. The fulfillment drops to 0.75 or 75% in periods with high demand and a large load. For a capacity of 80 the maximal fulfillment of performance criteria was seldomly reached. In most periods the fulfillment of performance criteria drops down to 0.75 or 75%. Due to the utilization cap, which was implemented in order to limit the workload for the service center staff, the fulfillment of performance criteria does not drop below this value.

In order to obtain the optimal operating point the productivity has to be maximized. For each value of capacity the resulting average productivity calculated over the time periods. By plotting the different capacities on one scale and the resulting averages for productivity on the other a characteristic curve is obtained. The optimal operating point for the service system is located at the top of the bell shaped curve. It is the point where the capacity of the service center is used most productively taking into account all the factors described in the simulation model.

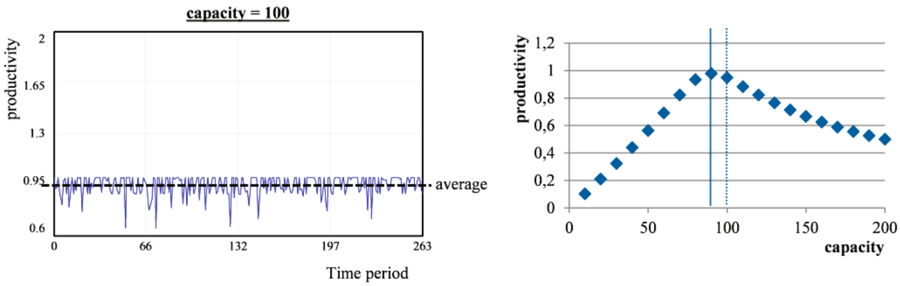

Fig. 5. Obtaining the optimal operating point

5 Summary and Outlook

This paper has presented an approach for simulating service delivery systems. A major assumption for the simulation approach is that capacity derived from human workforce shows the same characteristics as human behavior does. Additionally, a use case for the simulation approach was introduced on the basis of which characteristic curves were described in order to find an optimal operating point for the service system. Further research could focus on including demand which not only fluctuates but also changes its mean over time. Also, a process chain with different types of processes with customer requirements and preferences to quality can be integrated into the simulation approach. The challenge would then be to assess and simulate the interactions between the different processes. Also further research could focus on avoiding or controlling the effects of human behavior (such as procrastination) in order to improve service productivity. For example the application of the principle of tact for service processes can be a solution.

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Information – The Hidden Value of Servitization

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Abstract. Today, in a product-service offering, the product and its related services can represent two main sources of revenue streams for the manufacturer. Tomorrow, information deriving from servitization and exploited on an ecosystem level, could represent the third one, whereas due to their ample potential in sharp market value increase, they could even become the manufacturer's main revenue stream. This article of explorative nature questions the possibility to introduce such disruptive approach. In order to do so, servitization is evinced through a new perspective, through information. In order to exploit this new potential, the concept of an information ecosystem is introduced. Secondly, a new role is proposed, helping manufacturers to span the boundary between product and service. To depict the impact of the introduced concepts while positioning it in relevant literature, a third layer of added value was added to Thoben's representation of servitization levels [1], the information layer.

Keywords: Servitization, product-service, information, product-service boundary spanner, ecosystem, manufacturing.

1 Introduction

In the era of the knowledge economy, knowledge can command price premiums over comparable products with low embedded knowledge or knowledge intensity [2]. It is also the economic counterpart of the so called information society, with dozen of labels suggesting that humans are entering into a new phase of society [3]. Wang [4] describes the same phenomenon which she calls "informatization" as a process of change that features among others the unprecedented growth in the speed, quantity, and popularity of information production and distribution". Though this point of view can be debatable, as for instance Webster [5] explains that society is not entering a new phase. Based on the definitions, manufacturing is part of the knowledge economy and information society. It is even gaining on relevance, which is not due only to the informatization of the manufacturing processes, but also due to the servitization of manufacturing, which is an information intensive process, explained in the continuation.

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As services provide in general a more stable source of revenues [6] and represent an additional one to manufacturers, servitization is a more and more pervasive approach, from which multiple questions derive. An essential one is: “What kind of product-service (P-S) to offer, for to indubitably satisfy the needs of existing customers and, concurrently, to attract new ones?” Therefore the often raised question how to create and offer a P-S is not raised, but how to create and offer a P-S that is of high perceived relevance to the customers, meeting and targeting their needs or even creating new ones? While doing so, what kind of additional added value for the manufacturer and other servitization partakers can be discovered and foremost how it can be captured? In order to answer them, the manufacturers have to relate more closely and intensively and on a longer term with their customers, as many are quite disjoint with them. Therefore this proposes: first a new process called informatization, which will enable manufacturers to create more efficient and of higher added value services in relations to products, hence spanning the P-S boundary. Secondly, a new role is proposed, called the P-S Boundary Spanner (B.S.) that helps manufacturers manage and exploit the informatization process on an enterprise level, as a closed information loop. Thirdly, the B.S. transmits the exploitation of the informatization process onto an ecosystem level; therefore the concept of the information ecosystem is introduced. Herein the data and information are shared and traded, overall exploited by different entities such as manufacturers, service providers, advertising agencies and research institutes. Altogether it aims to maximize and especially capture the added value arising from P-S, which was previously mainly overlooked. Besides creating an additional revenue stream, it enables to span an essential boundary that manufacturers face, the manufacturer-customer boundary.

The article goes as follows. First servitization is presented and the process of informatization positioned within it. Afterwards the role of the P-S boundary spanner is introduced and its information ecosystem. Finally the converged effects of the introduced concepts, which cause an increase in the overall added value derived from servitization, are depicted on Thoben’s representation of servitization levels [1].

2 Servitization and Informatization

Many different classifications and definitions of service oriented strategies can be found in literature, as for instance servitization [7], servicizing [8], product-service systems [9],functional sales [10], full-service contracts [11] etc. P-S systems have the potential to bring changes in production and consumption that might accelerate the shift towards more sustainable practices [12]. Also they all focus on the customer; this focus was gained attention already in the 1970s, in the marketing field, but the manufacturing field did not yet fully grasp the customer concept; understandably, both fields had different limitations and priorities. Manufacturing to produce a solid product and marketing to meet as much as possible the consumers needs [13]. Marketing brought up the customer orientation that was later on in the 1980s adopted by the field of strategic management, by Porter and its value chain concept [14], which provided a mean to systematically understand the sources of buyers’ value, being one of the essence of service oriented strategies. Only in 1988 the definition of servitization was coined by Vandermerwe and Rada [7], which defined it as "market packages or bundles of customer-focused combinations of goods, services, support, self-service and knowledge". It can be deducted that the manufacturer and customer are more and more connected in time through different approaches and that servitization is only a logical consequence of the evolution of this relationship. Among others, it is a mean that enables manufacturers to relate more closely with customers.

2.1 Informatization as Part of Servitization

As the stability of service revenues for many enterprises is higher than from the product [15], this could indicate that manufacturers in order to stabilize their revenues should integrate services into their business models. Though, to provide an innovative P-S is not necessarily satisfying, as the customers have to perceive it also of high relevance. Indubitably, the manufacturers have to relate more closely and on a longer period with their customers. As such the needs of its customers have to be first identified, so the right ones are being met. This can be achieved through longitudinal product or P-S usage observation. The data are then collected, analyzed and the initial offering can be enhanced. The following process is called informatization, which actualizes itself during servitization. More exactly it enables to collect and store data from customers, analysis the data about their habits of product or P-S usage with the goal to discover new needs or identify changes in pattern usage. Those information can be used to enhance the existing offering in terms of product, P-S or their SLAs back to their customers. This means that new information for its customers are generated in form of an enhanced product or P-S; such an example of information of form of a service, can be the offering of personalized best practices related to a product usage based on the analysis of customers' product usage patterns. The figure bellow represents informatization on the enterprise level with its data flow.

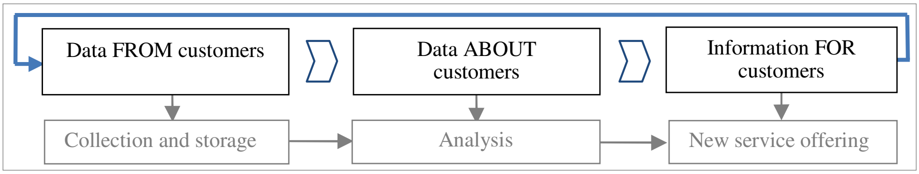

Fig. 1. Informatization on the enterprise level as part of servitization

During the informatization process, the collection of information can be effectuated in two ways at least: a) firstly by creating a smart-product, an example of which can be the monitoring of a refrigerator in its Middle of Life (MOL) sending data to the manufacturer in order to perform predictive maintenance services [16]; in the informatization process, the information are automatically retrieved and collected onto a server; b) secondly by designing such customers incentives that will motivate them to give their information to the manufacturer by themselves (e.g. the customer describes its wardrobe and makes it available to a cloth manufacturer); this possibility can be complementary to the first one (e.g. the usage of an RFID chip integrated into clothes could be additionally used in the latter example, enabling additional retrieval of information). Such collected data can be of the highest quality, as they are collected directly and are longitudinally linked to real customer profiles, making the data even more valuable (e.g. a large data set from a specific segment of customers over a period of time). Afterwards the data are analyzed using data mining techniques to uncover hidden patterns and also business intelligence techniques can be applied. Those information can for instance be relevant to assess machine risk failures, which would increase the capabilities to determine risk, possibly influencing the profitability of a P-S [17]. Consequently, manufacturers can get an incredible glimpse into usage pattern of their products or P-S. It also enables to see in what way the usage habits have changed when the manufacturer is shifting its offer from product to P-S, hence being able to swiftly adapt its value proposition, especially its Service Level Agreements (SLAs). This capability is essential, as otherwise manufacturers can offer a P-S, that will be largely accepted by its customers, while seeing their margin decreasing over time, as it was the case with a manufacturer of printing equipment that moved into services [18]; namely the usage habits of its customers changed when the manufacturer changed its offering from product to P-S; it even prompted a non sustainable product usage.

As seen, informatization depicts servitization from an information point of view, while elucidating that this is an information intensive process prompting the creation of time and contextually relevant information and integrating them into the servitization value creation process. As the offered services around the product target more the needs of customers, they should be perceived of higher added value; as such spurring the creation of additional services. Consequently spurring the informatization process contributes to spanning the product-service boundary. By spanning this boundary through informatization, the manufacturer can more easily, strongly and enduringly relate to its customers, as such spanning the boundary between the manufacturer and customer. Therefore, the next section deals with the question of how to prompt the intensiveness and exploitation of the informatization process.

2.2 The P-S Boundary Spanner and its Information Ecosystem

In order to help manufacturers exploit the informatization process and span the both boundaries, the P-S one and the manufacturer-customer one, a new role is introduced, called the P-S Boundary Spanner (B.S.). The outputs of informatization are information, which can be exploited through the servitization on the enterprise level. The new role can contribute in helping a manufacturer: a) creating the "smartness" of products, hence enabling the extraction of data, b) collect and store the data; c) to analyze the data according to the manufacturer's objectives using data mining and business intelligence techniques. However, the exploitation possibilities of informatization on an enterprise level as a closed information loop are quite limited, therefore transmitting the exploitation of informatization on an ecosystem level. Namely, the networked economy represents the next economic evolution, where the economics of scale stem from the size of the network - not the enterprise [19]. Hence the concept of the information ecosystem is introduced, where multiple closed information loops from servitization are opened among the ecosystem partners.

The ecosystem members are united in the ecosystem by the information from the informatization process and by their high exploitation potential, thus making this an information ecosystem, not a P-S ecosystem or a manufacturing one. It is managed by the B.S. and supported by ICT infrastructure. Its objective is to give additional relevance and value to the data and information, which do not depend solely on their role in informatization on the enterprise level, but also on the demand for those information from the ecosystem partners. The collaboration in the ecosystem is in theory nonhierarchical and global, therefore differing with Camarinha-Matos's [20] definition of a business ecosystem. The information ecosystem is very close to the definition of a service ecosystem embodying the essence of service and is a customer driven ecosystem [21].

By exploiting the informatization process as part of servitization through the B.S.'s ecosystem the following potential benefits per type of member are identified. The first type of member is the manufacturer that performs the informatization: a) selling its data to other members, hence creating a new revenue stream; b) getting an insight into its customer's habits and needs and being able to enhance its products or P-S. The second kind represents manufacturers that acquire the information from other manufacturers, using them to enhance their product or P-S. The third kind are service providers selling or buying information about customers' usage habits and patterns, enabling them to: a) create new independent services or related to an existing product, therefore creating a P-S with another manufacturer, exemplifying that multiple service providers can built a P-S around one product; b) create an additional revenue stream by the exploitation of data. The forth kind are advertising agencies, which by acquiring those information gain access to a very rare and valuable type of information; this enables them to target and segment more efficiently consumers. This would represent an important step in CRM. The fifth kind of members represent research institutes that: a) gain access to an unprecedented type of information, b) increasing the possibility to cooperate with the industry.

2.3 Impact on the Added Value Created during Servitization

Looking at the basic idea behind the concept of the extended product, it is constituted from the tangible part, being the kernel of a product and the product itself, and also from the intangible part, being the service [1]. This means that the benefits for the P-S providers, as also for their customers, derive from the product and its service(s). How much added value is provided by the product or services in different levels of servitization is also depicted by Thoben et al. [1] with its 4 levels, ranging from pure manufacturing of parts on one side to the provision of pure benefits, whereas the level of service relevance in the P-S bundle is rising. As elucidated previously, informatization is part of servitization and through its exploitation on the ecosystem level it creates an additional flux or layer of added value for the P-S providers, customers, as also for other members of the information ecosystem. Those data and information, being the basis for of the informatization process and of the new added value, are consequently inherent with the product and P-S layers (circles) in Thoben's representation of servitization levels. As such, the data and information represent an additional layer of added value; this signifies a new source of added value during servitization. The impact of information exploitation (visible on the figure bellow in orange squares) during servitization is represented using Thoben's representation of servitization levels [1]. The figure bellow depicts the added value from the P-S providers' perspective.

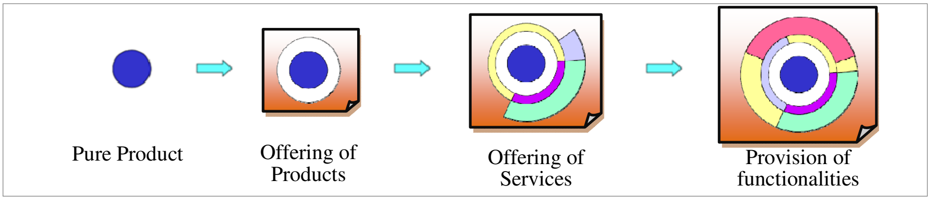

Fig. 2. Information as the nucleus of additional added value in servitization

Insofar the added value for the P-S provider as for the customers derived from the product and its services converged into a P-S offering; whereas, now, an additional layer of benefits is added to this convergence, the information layer. The same concept of adding information as an additional layer of added value, could be depicted also on the Extended Product Concept [22]. The information layer surrounds the existing layers.

3 Discussion

As information potentially represent a third revenue stream, besides products and services, the manufacturer could target more specific customer niches' that otherwise from a financial perspective would not be sensible. This higher level of P-S customization can be seen as a mass customization enabler; being a possible research path.

Regardless that informatization is omnipresent, there probably also exists cases when it is not carried out; the main reasons could be: a) that customers' needs and habits are already known and the product is far from being commoditized, b) the nature of its business does not allow it and c) law (privacy) related restrictions.

Informatization and the exploitation of data and information through the information ecosystem have together the potential to create an additional revenue stream for the information ecosystem's members, including the manufacturer. Accordingly the following questions for future research appear:"Could the exploitation of data and information from informatization through the ecosystem enable a manufacturer to offer its products and P-S with a much lower price that its competitors, while keeping the quality and functionalities unchanged and increasing it overall revenues? Could for instance a car manufacturer offer its product or P-S 10 % cheaper and in return the customers would allow intensifying the informatization process during the usage of their car? What such a model could mean for the European manufacturing industry? Does it mean that this potentially disruptive business model could lead a manufacturer to sustainable competitive advantage and enabling the reach of sustainability if he would so desire?" Obviously, this paper is a conceptual one and explorative in its nature. Though it is based widely approved concepts like Thoben's representation of the servitization levels, its main limitation is that it is conceptual.

4 Conclusion

The article first positioned servitization into a wider context, starting with the knowledge economy, passing by the information society and finishing with the networked economy, while depicting it from an inform point of view. For that, a new procedure had to be introduced called informatization, which is performed on the enterprise level. This closed information loop between the customer and manufacturer has been opened afterwards and the exploitation of data and information has been transmitted onto the ecosystem level. In order to ease the process of data creation and their exploitation, besides introducing the concept of informatization, a new role of P-S B.S. was introduced, as also the concept of an information ecosystem. Consequently, this article directly contributes in spanning the main manufacturer-customer boundary through the spanning of the P-S boundary. In order to depict and position the impact of the introduced concepts, Thoben's representation of servitization was enhanced by adding an additional layer of added value, the information layer. Based on the findings, it would be sensible to call information the nucleus of the third layer of added value in servitization.

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How Advances of ICT will Impact on Service Systems and on the Delivering of Product-Related Services

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Abstract. Using a multiple case study approach, this paper studies how the boundaries of service systems that provide product-related services are shifting towards self-service and/or super-service configurations, as a consequence of the introduction of modern ICT.

Keywords: Service Systems, Augmented Reality, telemetry, product-related services, self-service, super-service.

1 Introduction

Anticipating the age of Internet of Things [1] and smart services [2] leading manufacturers such as Rolls-Royce, IBM and GE [3] recently adopted technologies such as telemetry, condition monitoring and other information and communication technologies (ICTs) that entail to the wider paradigm of e-maintenance [4], to catch real-time data from their installed base of products [5,6]. Captured data can be leveraged to provide customers with more effective life-long support and other product-related services (PRS), such as remote control, optimization, routine maintenance, updates/upgrades, and achieve more competitive advantages [7]. However, the widespread adoption of these technologies is expected to radically change the ways PRS are delivered, favoring super-service (i.e. providers perform autonomously – in isolation from the customer - tasks previously done by/with the customer) rather than self-service (i.e. customers perform on her/his own tasks previously done by/with the provider) [8]. Nonetheless the relevance of this subject [9], there is still paucity of scientific research addressing how the boundaries of service systems will be affected by technological innovation in the next years. This paper aims to fill this gap in the context of industrial goods/equipment. The paper is organized as follows: Section 2 provides a brief literature review on the topic of the study. Section 3 outlines the research methodology, while section 4 synthetized the empirical findings. Implications as well as limitations of the paper are discussed in the last section.

2 Service Systems

In service systems [10] resources as different as people, information, money and technologies are mutually shared by different entities (i.e. customers, providers) that

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create (or co-create) value by accessing to these resources [11]. For instance, in the case of a field-repair, at least two entities interact: on one side, the customer (i.e. product owner/user) opens the door of her/his house/facility and lets the technician access to the broken product; on the other side, the technician provides know-how, efforts, tools and/or materials to fix the product. To determine the value created in the service system, both entities compare the achieved benefits to the sustained costs. The more benefits exceed costs, the more value is perceived in the service system. If value is perceived to be higher than expected, entities are satisfied. Since value is created in the service system as entities share resources and interact to each other, benefits and costs of both sides are strictly intertwined. In the provision of industrial services, costs are mostly related to the consumption of specific resources (e.g. materials, energy, labor time, etc.), but can occur also as a consequence of (mental/physical) efforts sustained by entities during the service provision [12]. For instance: driving/walking to the product site (physical effort), being embarrassed for not being able to provide the requested information to customer support (psychical discomfort); being disturbed by noise/smell/dirt/unpleasant service environments (sensorial discomforts).

On the other side, benefits from the provision of PRS to industrial equipment are manifold [13] and include [14]: a) ensure minimum disruption when the equipment fails; b) ensure maximum availability of the equipment; c) ensure the capabilities requested to achieve the best/expected outcomes by the use of the equipment. Irrespective of the classification/terminology used by each provider to promote and sell its offering, it emerges that a first type of PRS, namely *recovery services*, is focused on assuring product recovery with acceptable performances; a second group, namely *availability services*, is aimed to assure product availability, keeping low disruptions to the customer's processes; lastly, a third category, namely *outcome services*, are purposed to increase (empower) the capabilities (skills) of the product user so that she/he's not prevented from extracting/realizing the value potentially embedded in artefact. As a result, the inputs supplied by customers and providers into the service systems greatly differ across these classes (see Table 1).

To model in detail each step of value creation or co-creation, we adopted the Process-Chain Network (PCN) visual framework [15]. In PCN, service delivery processes pertain to the regions of *direct* (i.e. *person to person*) and *surrogate* (i.e. *person to things*) *interactions*. In the first people interact synchronously and directly (vis-à-vis) or by means of technology mediation (e.g. phone, live chat). In the second, instead, each entity creates value acting on inanimate resources, such as goods, information, etc., as these are provided by other entities. Surrogate interactions from both sides of a service system show that entities can create value in isolation, though using resources supplied by others. As already said, self-services depict situations in which customers are enabled to create value on their own. Conversely, super-service is the case in which providers are allowed to create value on behalf of their customers, acting on their inanimate resources. As technological advances enable new ways of providing PRS, the boundaries between direct and indirect/surrogate interactions, i.e. self- and super-services, may shift. In PCN, technologies that favor super-services and self-service are called, respectively, *relieving-* and *enabling-technologies* [15].

Table 1. Classification of PRS (source: adapted from [14])

PRS types	***Product recovery***	***Product availability***	***Product outcome***
Examples	Installation, preventive and corrective maintenance, provision of spares and consumables, updates and upgrades	Inspection, control & troubleshooting, evaluation of residual lives, definition of maintenance programs	Hot line and help desk, training, consultancy, technical documentation
Resources supplied by customers	Products (broken, deteriorated, etc.)	Mostly information about product/process status, functioning parameters, alerts, etc.	Mostly minds (e.g. knowledge required to interact, understand, learn, etc.)
Resources supplied by service providers	Products (new, repaired, refurbished, etc.), spare parts, consumables, technical skills and know how, methods and tools	Mostly technical skills, methods and tools	Mostly minds (e.g. knowledge required to interact, analyze, teach, etc.)

Before introducing technological innovation in a service system, its impact should be carefully assessed [16]: firstly, identifying existing/potential value expectations of customers; then, modeling the value creation process; finally, investigating how boundary can be shifted due to the adoption of technology. In section 4 we will apply these concepts to the provision of a typical field-repair intervention (i.e. *recovery service*).

3 Research Methodology

Since we needed to explore the rationales behind the scouting and the experimentation of new technologies in service systems (our unit of analysis), we adopted a multiple case study approach [17,18]. Purposive sampling strategy was used to be confident that the selected companies had characteristics pertinent to our aims. Finally, 6 companies carrying out pilot projects and/or introducing ICT in their service systems were selected, whose characteristics are presented in Table 2. For confidentiality reasons, their names have been disguised. Data were collected through in-depth interviews (overall, 15 respondents were interviewed) as well as recurring to secondary sources (e.g. service contracts, balance sheets, etc.). Data from interviews were coded and findings were used to model AS-IS and TO-BE delivery processes. Due to space constraints, only the case of a typical field-service for product repair is presented in the next section.

Table 2. Characteristics of selected companies

Company	*Products*	*Yearly revenues (M€)*	*Employees*	*Served area*	*Installed products*	*Informants*
A	Production printers	83.500	400	National	Less than 100	2 technicians 1 product specialist 1 service manager
B	IT systems: NAS, server, mainframes	3.595.000	15000	National	1000 ÷ 10000	2 technicians 1 product specialist 2 service managers
C	Liquid packaging, bottling lines	570.00	1150	Global	10000 ÷ 50000	1 service manger
D	Service of gas stations	10.200	60	Regional	500 ÷ 1000	1 product specialist 1 service manager
E	Turbine, compressors	2.710.000	2150	Global	10000 ÷ 50000	1 service manager
F	Trains, metro, tram	559.950	2150	Global	500 ÷ 1000	2 service managers

4 Findings and Discussion

All the data gathered during the interviews were coded and classified in order to identify: a) the type of technology object of the scouting, b) the rationale for its introduction and c) the stage of technology introduction (Table 3). The comparison of similarities and differences among cases led to the identification of the following findings.

Finding 1. Two kinds of technology, respectively telemetry and Augmented Reality (AR), emerged as cutting edge technologies that service companies are interested in scouting and/or still introducing. Telemetry includes a set of technologies, such as sensors, SCADA and control systems, secure communication networks, databases, storage systems, etc., that are used to collect data from the field. AR, instead, relates to any technology that, superimposing virtual signs to a real scene, helps to guide its users (e.g. the field technician, the product user) in performing a task through the visualization of the right information in the right place and in real time [19]. To recognize what is viewed, retrieve, transmit and anchor the information on the user's view, software (artificial) rather than human agents can be leveraged. The first is the case of Automatic AR systems (AAR), the latter of Mobile Collaborative AR systems (MCAR) [20].

Finding 2. Since the collection of field data is central to enable the shift towards service-oriented business models, any company has (or is planning to have) telemetry to offer PRS such as condition monitoring and remote support to their products. Conversely, with respect to the adoption of AR, most of the companies can be considered in pre-implementation stages, since they are trying to evaluate the real benefits and costs of its introduction through pilot projects, surveys and consultancies. The reasons for the delay in AR adoption with respect to telemetry are twofold. On one hand AR is an emerging technology that entered the market recently and that it is still in its development phase. On the other hand AR usually needs data and information to work (especially AAR) so companies that are evaluating its introduction/ introduced it, have already started/completed the introduction project of telemetry system.

Finding 3. Rationales that lead companies to scout/introduce new technologies stem from the need to reduce costs, increase productivity or create higher customer value. In the first cases, innovation is pursued to enable higher internal efficiency and to empower the workforce without sustaining remarkable costs. In the latter case, the trigger is mostly external as managers are willing to increase the value proposition of their integrated offerings.

Finding 4. Any innovation that concerns the adoption of both telemetry and AR technology strongly affects the boundaries of service systems, since it enables the provision of new services, rather than new ways of providing the same service, in the form of super- and/or self-service. Due to space limitations, in the following we will only focus on a field-service (repair from faults) and describe how the above technologies are expected to impact on the delivery process.

Table 3. Cross-case analysis

Company	*Technology*	*Innovation rationales*	*Current stage of introduction*
A	Augmented Reality	Improvement of diagnostic skills of field technicians	Pre-implementation assessment through a pilot project
B	Telemetry; Augmented Reality	Guarantee the business continuity 24/7; empower technicians	Implementation of online telemetry as the enabler of condition monitoring services; evaluation of AR technology acceptance by field-force through an internal survey
C	Telemetry; Augmented Reality	Analyze data and determine optimal maintenance policies; improve communication between remote centers and field technicians	Implementation of telemetry (1300 machines monitored); condition monitoring services under development; use of AR to support installation
D	Augmented Reality	Verify the work progress and support technicians in troubleshooting tasks	Use of AR to support installation/repair and control progress of construction site
E	Telemetry	Guarantee the business continuity 24/7; Analyze data and determine optimal maintenance policies; get prepared to propose upgrade to the customers	Large use of telemetry for several services (e.g. maintenance and control, reporting) (approx. 1000 machines monitored)
F	Augmented Reality	Lower costs of field intervention; improve communication between remote centers and field technicians	Pre-implementation assessment through a pilot project

In Fig. 1, the different steps of a "repair from faults" process are presented using the PCN framework. In particular, the left side shows the AS-IS traditional process (i.e. without the adoption of telemetry and AR), while the right side shows the same process as changed by the introduction of such technologies.

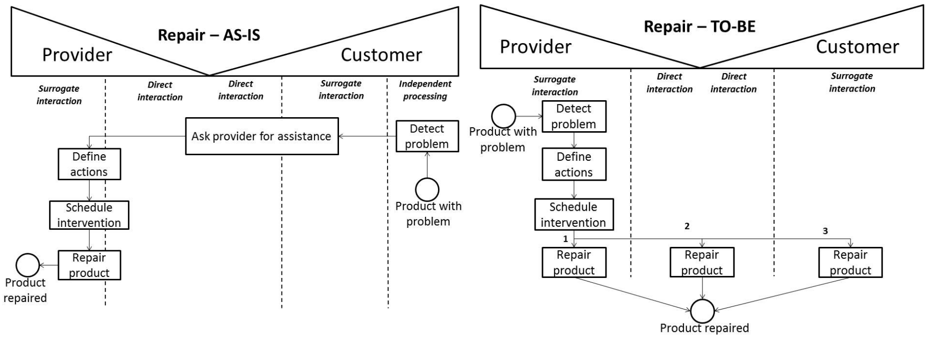

Fig. 1. PCN of field-service "repair from fault" process

In the AS-IS scenario, once problem is detected, customer initiates the service process, asking the provider for assistance. Depending on the way through which the customer contacts the provider and on the type of their interactions, this task could be performed by the customer both interacting directly with provider (*direct interaction*, as in the case of live chats, phone help desks, etc.) or indirectly with its resources (*surrogate interaction*, as in the case of sending e-mail or posting customer support requests via a web site). Since discussing the ways through which, traditionally, customers may ask for assistance, is out of the scope of the paper, we represent this task with a box that crosses direct and surrogate interactions. Once assistance is requested, the provider takes on the responsibility of the process, defines the action plan, schedules and then executes the field intervention for repairing the product. Even in this case, the level of interaction with the customer can be different; for instance, in certain cases only surrogate interactions may happen (e.g. the provider has free access to the customer facility, thus no direct interactions are required with the customer personnel) while, conversely, in other cases direct and recursive interactions are unavoidable. In this situation, super-services arise the more the adoption of telemetry spreads. In fact, through telemetry definition of action plans, scheduling and execution of interventions could be performed, to a certain extent, without direct interactions with the customer. For example, in case restoration requires only to take remote control of product (e.g. fix software bugs, optimize/administer computing power/disk allocation, release updates, etc.) the boundary of super-services can greatly be extended. For instance, this is the case of 24-hr always-on tele-control and remote maintenance services of company B. With respect to the adoption of AR, its introduction affects more the responsibility of the "repair product" task, since this technology can assist the execution of the intervention. However, three situations emerged from the analysis of the cases. i) companies that are experimenting/introducing AR in their service systems state that the first application of this technology is focused on supporting their own technicians in performing technical tasks on the field. In this case (Fig.1, right side, case 1), boundary does not shift, since the provider keeps the ownership of the "repair product" task. However, the adoption of AR is expected to lead to several improvements. ii) Some companies showed interest in understanding how and when AR systems could be used to enable value co-creation (see Fig. 1, right side, case 2); MCAR, in fact, can be leveraged to establish easier/more effective communications among remote specialists (service provider's personnel) that provide assistance to product users (customer's personnel). In case customer agrees to take under its responsibility some tasks related to fixing and corrective maintenance, and execute field interventions under the supervision/support of some remote experts, the system boundary shifts towards assisted self-service by means of the introduction of AR as an enabling technology. From this situation both the provider and the customer could benefit. The first, in fact, could reduce the number of experienced technicians that are deployed on the field, and consequently the costs sustained to provide services. The second, instead, whether favored by some incentives (e.g. lower costs of service contracts, lower response time) could enable situations in which repair tasks are performed by unskilled operators, since the missing know-hows could be remotely provided by specialists. iii) A third option concerns the case in which AAR systems automatically guide customers in performing product repair, with no needs to interact with the provider anymore (see Fig. 1, right side, case 3). This is clearly a case in which the customer takes on responsibility to perform a service task previously done by the provider, thus the self-service boundary can be extended. Most of informants report that neither technology nor customers/markets seem sufficiently mature to shift towards self-repair services. Anyway, they did not deny this transition could be implemented in a nearest future, in certain circumstances, such as to replace user-manuals or to provide services in countries where no technicians reside or can be easily sent.

5 Conclusions

Recent advances of ICTs, and the lowering of their introduction costs, are favoring new (more efficient/effective) ways to deliver PRS. Hence, the service departments of manufacturing companies are carrying out several pilot/implementation projects to assess the benefits of adopting these technologies against the related costs. To this aim, it is essential to understand how technological innovations within service systems may enable self-services and/or super-services. This paper represents a first attempt to generate, through a multiple case-study, insights about service systems' modification and to suggest how to study the impact of ICT in service delivery. This paper has managerial implications as well, since the findings from case-studies can be useful to inform service directors, CIOs, etc., about the impacts expected by investments in new technologies.

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Requirements for Servitization in Manufacturing Service Ecosystems

Results of a Requirements Analysis of Four Manufacturing Use Cases

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Abstract. As tangible products can be easily copied and customers ask for individual solutions, the European manufacturing industry increasingly bundles their products with associated services to so called "Extended Products" (EP). Missing competencies for this servitization have to be acquired by involving partners from the companies' environment, the "Manufacturing Service Ecosystem" (MSE). However, traditional manufacturers lack the appropriate models, methods and tools for collaborative innovation, development and provision of EP. This paper presents the results of a requirements analysis of four manufacturing use cases that indicates the need for support in the area of servitization and collaboration in MSE.

Keywords: Servitization, Manufacturing Service Ecosystem, Requirements Engineering, Collaborative Tools, MSEE Integrated Project.

1 Introduction

The gap of the technological advance of the European manufacturing industry is currently shrinking, reducing the competitiveness of traditional business strategies like cost leadership and differentiation [1]. On the one hand, even innovative tangible products can be easily copied and are no longer usable as a unique selling proposition. On the other hand, new customer needs emerge that cannot be satisfied by a traditional product [2]. To understand and answer the customers' problem, manufacturers begin to add services to their products to create holistic and individual solutions and benefits. Such an offering of complementary product and service components is commonly named as a Product-Service System, or "Extended Product" (EP) [3]. This servitization strategy starts with simple services that support the functionality of the product, like spare part delivery, extends over services that ensure the availability of the product, like predictive maintenance and culminates in selling the benefits of product application as a service in the sense of an operator model [4].

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However, following a servitization strategy, from integrated product and service idea generation to realization and commercialization, requires additional competencies compared to the manufacturing of a tangible product. The involvement of the customers as partners to identify their needs and collaborative arrangements with other enterprises like service providers become more and more important [5,6]. As the solution for the customer will be configured individually, the required competencies will change each time. A promising concept to tackle the challenges of servitization is the "Manufacturing Service Ecosystem" (MSE). As a non-hierarchical form of collaboration, it allows the incorporation of new partners according to changing requirements for a solution [7]. Manufacturing enterprises are typically neither prepared for servitization, nor for collaboration in dynamic non-hierarchical networks like MSE. They are missing the right models and methods for service innovation, the required physical resources, organizational structures, as well as IT tools. In order to support the manufacturing industry in this transformation, their requirements for the needed models, methods and tools have to be determined.

This paper presents the results of a requirements analysis of four use cases from different branches of the manufacturing sector. First, the theoretical background on servitization and collaboration in MSE is presented in chapter two. Following, chapter three describes the methodology for the requirements analysis. The resulting requirements for the support of servitization in MSE in the manufacturing industry are specified in chapter four. Finally, a conclusion and outlook on the development of solutions based on the requirements is given.

2 Theoretical Background

2.1 Servitization

The demand for high individual solutions has led to the situation that satisfying customer needs only through tangible products is no longer possible [8]. Value adding services are combined with the tangible product to Extended Products. This process has first been called "servitization" by Vandermerwe and Rada [9]. They describe the increasing customer demand-driven offering of product-service "bundles" (consisting of goods, services, support, knowledge and self service) by manufacturing enterprises to create a competitive edge.

Different options for servitization can be identified, creating a number of challenges for the manufacturer of the tangible product. Below, possible options for servitization are described along with the inherent challenges [10]:

- **New combinations** of existing products with existing services
  The tangible product can be combined with already existing services. In this case, the manufacturer has to be able to identify promising services on the market and create the necessary interfaces for combination with the product.
- **New services** for existing products
  A new service can be developed for the existing product. Therefore competencies for service innovation, development and delivery are required in addition to the manufacturing of the tangible product.

- **New products** for existing services
  The manufacturer can also decide to develop a new product for an existing service on the market. In this case, the product design has to be aligned with the service specification to ensure interoperability.
- Combinations of **new products with new services**
  Finally, the tangible product and the services can be developed in parallel to create an integrated solution. This requires competencies in both product and service design, but also the ability to merge the results from both domains.

The analysis of servitization options shows the challenges and additional competencies required for the manufacturer of the tangible product. Besides the existing experiences in developing, producing and maintaining a tangible product, a service life cycle (SLM) has to be aligned and managed as well. But manufacturing enterprises are usually inexperienced in service ideation, design and delivery and fear the competition outside their natural domain [11]. Thus, they require support to successfully align and manage the phases of the SLM:

- *Service ideation*
- *Service specification and design*
- *Service implementation and testing*
- *Service delivery and decommission*

Nevertheless, the complexity behind the provision of services and flexibility required at the same time leads to the outsourcing of services [12]. Therefore, the implementation of new organizational models, based on collaboration between product and service providers and the customer is also required. The Manufacturing Service Ecosystem described in the next section is such a model.

2.2 Manufacturing Service Ecosystems

The currently dominating hierarchical supply chains in the manufacturing sector are not supporting the transformation from a tangible product perspective towards an Extended Product perspective. More flexible arrangements between manufacturers and other partners are required. In parallel with servitization, collaboration models in manufacturing will have to change to support the innovation of Extended Products, the required organizational structures and processes for their provision and the appropriate supporting tools and techniques.

As a more flexible and less hierarchical form of collaboration for servitization, the establishment of a Manufacturing Service Ecosystem is proposed. The concept of comparing the business environment of an enterprise to a biological ecosystem has been introduced by Moore [13]. In such a Business Ecosystem, members who might become new business partners or new customers are able to share knowledge, innovate and collaborate together, interact or connect with each other, design new products, communicate globally and develop projects [14]. Within this ecosystem, different and heterogeneous entities like big OEMs, SMEs, universities, research centers, individual professionals, employees, citizens and consumers etc. are left free to evolve and to network as they like, just following the market evolutionary law that it is the fittest species which survives. The main characteristics of a Business Ecosystem include complexity, self-organization, emergence, co-evolution and adaptation [15].

The Manufacturing Service Ecosystem concept builds on the Business Ecosystem idea, but adds characteristics typical for the servitization of manufacturing. Innovation in this environment is driven by the fact that business opportunities might be generated and identified within the MSE and not brought by the outside market. This is due to the customers also being part of the ecosystem and participating in value co-creation: *"The MSE is a non-hierarchical form of collaboration where various different organizations and individuals work together with common or complementary objectives on new value added combinations of manufactured products and product-related services. This includes the promotion, the development and the provision of new ideas, new products, new processes or new markets. Future Internet architectures and platforms enable the active participation of all stakeholders in all the phases of the product and service life cycle."* [10]

The MSE concept features four dimensions, which have to be supported with the appropriate models, methods and tools:

- *Organisational dimension*
  How to describe the constituting elements of a MSE – its participants and roles?
- *Componential dimension*
  How to manage the tangible and intangible assets and resources of the MSE?
- *Functional dimension*
  How to support the execution of inter-organizational processes in the MSE?
- *Governance dimension*
  How to implement the principles, policies and governance rules for the MSE?

There is little previous work providing guidelines, tools or techniques that can support manufacturing enterprises for the above issues in MSE. According to Baines et al., *"the principal research need is to engineer tools or techniques that practitioners can apply to help in service design, organisational design and organisational transformation"* [12]. Therefore, the requirements of the manufacturing industry towards these supporting tools and techniques have to be determined.

3 Methodology

The requirements analysis in this paper has been conducted on the basis of the servitization use cases from four different manufacturing enterprises. The cases come from different branches of the European manufacturing sector and represent SME's as well as large OEM's. In particular, the cases represent:

- A Dutch OEM of consumer electronics
- An Italian OEM of white goods
- A Belgian SME in the garments sector
- A Spanish SME in the machine tool sector

Due to the high innovation potential and complexity of servitization in MSE, manufacturing enterprises might not be immediately aware of the required supporting models, methods and tools. Therefore, a collaborative methodology has been applied, supported by Serious Gaming (see Fig. 1).

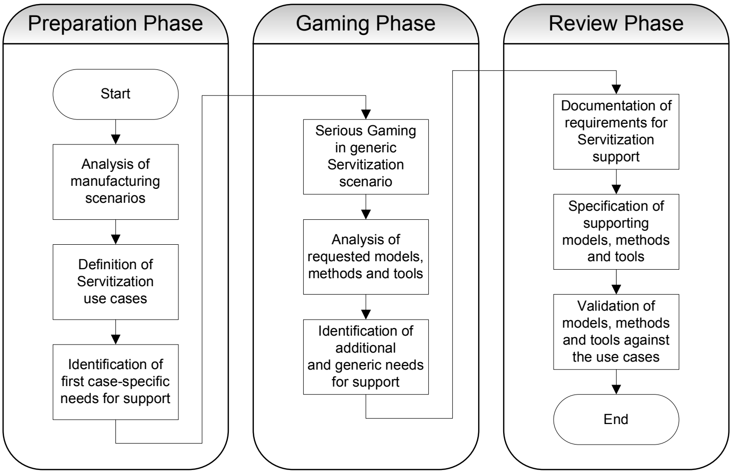

Fig. 1. Methodology for Requirements Analysis

The methodology is based on a three phase approach presented by Zarvic et al. [17]. In a preparation phase, based on the analysis of the manufacturing scenarios, concrete servitization use cases were determined for each enterprise. A workshop featuring focus group and brainstorming sessions has identified first case-specific needs for supporting models, methods and tools.

In order to meet the necessity of a non-limiting methodology, Serious Gaming was adopted for the second phase. The game used for this purpose is SECONDS [17], a game which simulates a complex business environment that consists of several systems, and allows the end users to reflect upon their own internal processes, even though playing in a common generic scenario. The main objective of the scenario is to develop and sell a car with mobility services. In order to provide this value proposition, the players need to collaborate in their ecosystem. The game is lead by a facilitator, to which the players are able to report missing or insufficient support for their servitization processes. An analysis of these reports has delivered additional and generic needs for supporting models, methods and tools.

During the review phase, the needs of the manufacturing enterprises are analysed and documented as a requirements list for servitization support. These requirements have then been used for the final specification of the supporting models, methods and tools for servitization. The specification has been validated against the servitization use cases and the final developments will be evaluated in pilot implementations at the four manufacturing enterprises.

4 Results of the Requirements Analysis

For the analysis, the requirements determined for supporting the four servitization use cases in MSE have been combined with the additional requirements coming from the generic Serious Gaming manufacturing scenario. The documented requirements have been assigned to the eight areas described for the service life cycle and the MSE dimensions in chapter 2. The results of this aggregation are listed below in Table 1.

Table 1. Aggregated List of Requirements for servitization in MSE

#	Aggregated Requirements per Area	CR[1]	GR[2]	Σ
1.	Service delivery and decommission	13	8	**21**
2.	Service specification and design	14	3	**17**
3.	MSE – componential dimension	7	4	**11**
4.	Service implementation and testing	7	3	**10**
5.	MSE – organizational dimension	5	3	**8**
6.	MSE – functional dimension	5	2	**7**
7.	MSE – governance dimension	6	-	**6**
8.	Service ideation	3	2	**5**

For the *service* life cycle, many requirements can be assigned to the *delivery and decommission* area, which indicates a lack of knowledge in the manufacturing enterprises on how to provide additional services to their tangible products. The main supporting tool developed will provide ecosystem members with a way to browse and search service offerings from several federated marketplace instances. As a service has to be designed before it can be delivered, *service specification and design* is another important aspect. Therefore, a collaborative service engineering methodology is being developed, comprising methods for service modeling and platforms for service development. In *service implementation and testing,* the requirements have led to the development of a feedback management tool to collect information on the usability of a service from the customers' viewpoint. Finally, *ideation* is the last *service* area needing support. Here, a tool to support service idea generation is developed, allowing sharing ideas in the ecosystem and validation by other MSE members. The relatively low number of requirements in this area should not lead to the impression that the topic of service ideation is not important for the manufacturing enterprises. However, due to the low experience in this field, it was not easy for the use cases to phrase concrete requirements.

For the *MSE* in general, an Innovation Ecosystem Platform (IEP) is developed. The IEP is the backbone of the MSE Service-System, providing a platform to manage the MSE in terms of level of activity, interactions, roles and flow of information between its members. *In the componential dimension,* a model to define the tangible and intangible assets in the MSE, to be able to compose the right assets for a desired

[1] Mentioned as requirement for the specific servitization case.
[2] Mentioned as general requirement for the manufacturing industry.

product-service combination will be included. The need for support in the *organizational, functional and governance dimensions of the MSE* requires the developments of a methodology for management and governance of MSEs, which also supports the set-up of a Virtual Manufacturing Enterprise (VME) for a specific Extended Product business opportunity.

The ranking of the areas for support of servitization in MSE should not be misunderstood as a prioritization of needs. It rather shows where the manufacturing enterprises were able to communicate concrete requirements and where it was hard for them to clearly express their need for support. The models, methods and tools developed on the basis of these requirements will be tested and verified by the use cases, which may lead to more and detailed requirements in the future.

5 Conclusion

The European manufacturing in industry is under pressure to rethink their traditional strategies of cost leadership or differentiation of tangible products. Servitization has been identified as a promising approach to satisfy new customer demands and prevail against competitors, implying the combination of tangible products and intangible services to Extended Products. The required additional competencies for the innovation, development and provision of EP have to be selected individually for each customer demand. This arrangement can be facilitated by the introduction of the Manufacturing Service Ecosystem concept.

However, manufacturing enterprises are typically experienced in the production of physical goods in fixed supply chains. Adding advanced services to their products and collaborating in a flexible ecosystem environment creates new challenges for them. The analysis of the requirements collected from four manufacturing companies clearly shows the need for support for servitization and MSE collaboration. The collected requirements have been used for the specification of supporting models, methods and tools for servitization in MSE, which are now being developed. In a future work, the developments will be applied to the real servitization use cases of the manufacturing companies and evaluated for their benefit in an MSE environment.

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Service Supply Chain Planning for Industrial Services – Design and Application of a Decision Support Tool

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Abstract. Industrial services such as classical MRO-services and also advanced offerings, e.g. performance based contracting, are gaining importance in the machine and equipment industry. From a niche the business units responsible for service have grown to major contributors to the success of the company. Meanwhile operations have grown historically and service manager struggle to professionalize their service operations to improve efficiency. In this contribution we provide an overview of 3 cases of companies trying to gain competitiveness by using a simulation-based decision support system for field service supply networks.

Keywords: Service supply chain, field service, network planning, decision support, case study, after-sales.

1 Introduction

In the last years many companies have shifted away from the traditional business of offering manufactured goods only to create more customer value by selling industrial product-service systems based on a the trend called "servitization"[1]. The reasons for that are manifold. Financially services contribute to a high ratio of the profit in most companies as the service business still provides the opportunities for high margins for reactive repairs or critical spare parts [2]. Additionally services allow to maintain a customer relationship during the life cycle of the sold product and provide increased customer value which benefits customer loyalty and the potential to react on the feedback of the customer for future product developments [3].

Therefore industrial field services have gained importance in the business of western manufacturing companies for years and became a critical factor for the profitability and competiveness in many cases. These services include basic contracts for pro- und reactive maintenance activities as well as advances offerings such as technical consulting or retrofitting [4].

Field service supply networks (FSSNs), as a special kind of service delivery systems, incorporate the technical support in form of service technicians in and off the field and a supply network for the delivery of spare parts. Both parts of the field

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service network have to work cooperatively to fulfill SLAs at lowest cost. Thereby service mangers face among other problems uncertain and lumpy demand, heterogenic technical and customer requirements with different performance targets, a highly scattered installed base with a variety of technologies and generations of asset from different centuries [5]. This requires a highly skilled and flexible workforce that can provide service in a timely manner over a certain region. But many companies still struggle with historical structures, lack of transparency and rising costs while customer demand more complex services, e.g. availability or performance based contracting, for reasonable prices.

Though the importance of the service business for manufacturing companies is beyond dispute, and many researcher and practitioners have stressed the “urgency for rigorous study to guide service managers in improving the design, competitiveness, efficiency and effectiveness of service delivery” decision makers today are still missing decision support tools [6]. Most methods used to investigate or improve service operations to professionalize service operations in field service networks are outdated and overly simplistic [7]. Therefore we will investigate the area of FSSNs planning and decision support in the following.

2 Literature Review

2.1 Field Service Network Planning

Decision support systems are “interactive computer-based systems that help people use computer communications, data, documents, knowledge, and models to solve problems and make decisions” [8]. Their purpose is to support decision-making without before any kind of changes is conducted. This is of upmost importance for the service business, as changes in the field service network are costly while their effects on the performance of the systems, e.g. in terms of responsiveness or costs, can hardly be anticipated. In the following we want to detail the different decisions to be made in FSSN design and planning shortly, before we will analysis contributions from literature and practices in industry.

Similarly to Advanced Planning in Supply Chain Management, field service planning includes different varies planning tasks that need to be conducted to design the “people and parts” network over different time horizons [9]. On a strategic and long-term horizon this includes districting of the installed base into decoupled territories which that are covered by a common a set of resources for a certain service [7, 10], the definition of skill sets for technicians and the right target mix in the workforce [11, 12], as well as the selection of locations for facilities [13]. Mid-term process design, including the definition of dispatching rules for the assignment of tickets to technicians [14, 15], and capacity, e.g. manpower and inventory, planning for each location becomes relevant [7]. All these planning tasks are highly interrelated and therefore hard to optimize individually. Furthermore, small changes in such a complex system might lead to a totally different behavior of the entire system [16, 17]. Therefore also high-level decision support should rely on the analysis of the realistic behavior of the complex system as a whole.

2.2 Decision Support for Field Service Network Planning

State of the art software packages mostly offer planning support on an operational level by providing optimization algorithms or visual presentations of the work load based on real time data to enhance the information that is available for dispatchers. On a strategic or tactical level these software packages offer only limited support (Rapaccini et al., 2008).

In literature a variety of contribution of different authors can be found that have developed mathematical programming or queuing models to support single or multiple planning tasks of FSSN design [13, 17–20]. Based on shortcomings of these approaches such as the limited the problem's complexity [7, 16] or the use of deterministic model parameters in such a uncertain environment which make most contributions only moderately applicable, simulation has been chosen as underlying technique to provide heuristic "("What-If") support" by applying proper design of experiment [21, 22]. The most relevant contributions based on the use of simulation to support decision making in this context can be clustered in different parts. On a tactical level support staffing, process design, or more specifically dispatching policies, are investigated based on response time and utilization indicators by Hill [15], Watson et al. [7], Dear [16], Visser [23] and Duffuaa and Raouf [24]. Another important class of contributions focuses on the optimal qualification and dispatching strategies in manpower planning for different scenarios [25–27]. Focus here lies on the degree of cross training and pooling effects within the workforce. Only a few contributions integrate several aspects of field service network design as for example Rapaccini et al. [28].

Though all contributions provide important insides into the challenges of operations management for field services, they lack important characteristics to be applicable for modeling and analyzing a FSSN holistically. An overview of the evaluation of the most important contributions is given in table 1.

Table 1. Relevant contributions in FSSN simulation

Author	***Focus***	***Modeling Detail***							
		Demand	***Network structure***	***Product***	***Services***	***Process***	***Dispatch & routing***	***Employees***	***Spare parts***
Homer	S, Dist, RT	◔	○	◑	◑	◑	◑	◑	○
Watson et al.	S, RT	◕	◑	◕	◕	◔	◑	◕	○
Dear	S, Disp	◑	◔	◑	◔	◔	◑	◑	○
Rapaccini et al.	Dist, Disp, CT	◑	◔	◑	◑	◔	◑	◑	◔
Colen and Lambrecht	CT	◕	◔	◔	◑	◔	◔	◕	○

Underline:
S=Staffing, Disp=Dispatching, RT=Response time, Dist=Districing, C=contracting, CT=cross-training
○ not considered ◔ rudimental ◑ moderate ◕ advanced ● fully

3 Project Background and Methodology

The introduction and literature review have revealed a gap in academia and practice alike in regard to appropriate methods to assist service managers in designing and planning their FSSN. Based on the decision prior made to use discrete event simulation as a technique to support decision making, the following research questions have been formulated in regard to the development of a DSS:

1. How can decision making for designing an industrial FSSN in different industries be supported adequately by a DSS based on discrete event simulation?
   a. What are the different entities that have to be considered in such a model and how do they interact?
   b. Which performance indicators are needed to support decision making for the different planning problems?
2. Which insights can be drawn from the application of such a DSS?

The project AsPlanned provided the starting point for this research. The aim of the project was to develop a decision support tool based on discrete-event simulation. The software should support decision-making in field service network planning for different planning tasks, e.g. the districting of field service networks or location and capacity planning for the technical field support and the spare parts supply chain. Efforts for modeling and using the software should be reduced by explicitly adapting it to the needs of FSSN planning while the generalizability and therefore wide applicability should be assured based on the use of reference models for the processes and resources inside a FSSN. Therefore five different companies offering field services were included in the project to assist the software design as depicted in table 2.

Table 2. Companies participating in the project

	Company 1	Company 2	Company 3	Company 4	Company 5
Employees	> 4,000	> 4,000	> 1,000	> 1,000	< 150
Revenue (CHF)	> 1 bn.	> 500 mio.	> 500 mio.	> 300 mio.	< 100 mio.
Industry	Industrial conglomerate	Infrastructure/ Construction	Machine tool manufacturing	Machine tool manufacturing	Medical equipment

The main methodology for the development of the simulation framework embedded in the DSS was based on the guidelines provided by Bertrand (2002). The life cycle of a simulation study approach by Pidd [29] was used while guidelines proposed by Law and McComas [30] were considered as well. Different stakeholders, as for example service managers and field technicians, were already involved in the design phase of the DSS to support internal validity of the simulation framework and the usability of the software.

4 Decision Support System for Field Service Supply Networks

The DSS is intended to support decision-making by the use of a discrete-event simulation framework to model FSSN. The process of service delivery can be designed based on predefined activities and includes normally at least the generation of random or planned service demand from machines in the field, the allocation these service tickets to technicians who then transfer to the assets, perform the required service and leave for home or the next asset. The input for the simulation model can be inputted via an adapted version of the Activiti process mapper, which represents a visual process mapping interface that includes drag-and-drop functionality and a data input interface including different tables and drop down cells that can be filled manually or imported from MS Excel. The simulation engine running in the background is based on the DesmoJ [31]. Next to the modules for data input, the DSS support the geographical visualization of assets, service technicians, and facilities based on OpenStreetMap and allows for performance analysis of the simulation runs in a comprehensive KPI module. Figure 1 shows the most important modules of the DSS.

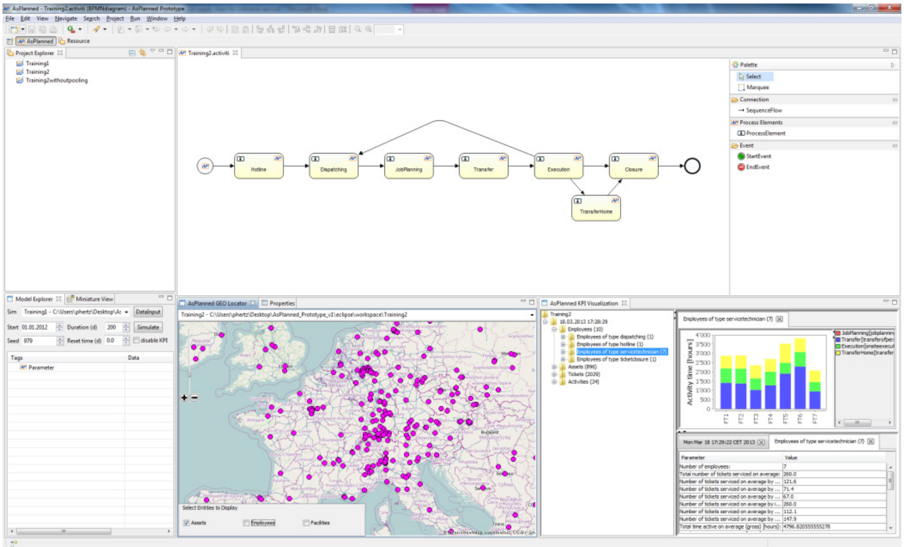

Fig. 1. General user interface of the AsPlanned Software

The simulation models are configured automatically based on the input of the user. The service delivery process is obtained from the Activiti process drawing while the data input data, e.g. for assets and technicians, are needed to create the different entities interacting in the FSSN. The main entities of the simulation framework are employees, assets, spare parts and service tickets. Only a few parameters are mandatory to construct a basic simulation model while a lot of detail can be added by including optional parameters in the models. Each predefined and enumerable parameter of an entity may also define the dimension for the calculation of operational parameters in the service delivery process (e.g. mean of processing time based on product and service type). Employees can be of different types, e.g. field technicians (FTs) or off-field staff (technical or non-technical). Various parameters include the skill, home location, shift, break and capabilities to perform the different activities. Assets consist of different items, which might represent modules of a machine, e.g. drive or control unit, and represent technical equipment as part of the installed base. Item may generate service tickets of different types based on the user input. Tickets represent service requests of a certain type for a specific item of an asset. Daily and weekly demand patterns can be inputted for each service type to allow for a realistic workload during the week while the time between the generations of two tickets can be modeled by various probability distributions. In addition to immaterial services, service parts (e.g. spares and tools) can also be modeled including parameters such as availability and replenishment time.

Activities are parts of the process and can be of 10 unique types that all have different parameters, e.g. the travel speed for transfer activities or the activity time for on-site service execution. During the activity "dispatching" tickets are assigned to FTs and placed in their job list. After finishing a job the employee conducts the activity "job planning" which refers to the selection of the next ticket for execution in the field. Various assignment algorithms for different service and shift types can be selected for both of these activities. Tickets in the field can be interrupted by breaks, the non-availability of parts, escalations in regard to capabilities or interruptions by high priority jobs. Transfer times are calculated based on the geographical distance that is obtained automatically by converting addresses in GPS coordinates via Google Maps.

5 Improving Operations in the Field Service Supply Network

The DSS has been used for evaluating different scenarios for all five companies being part of the project. In general the investigations can be clustered as local, with networks stretching over an area of less than 100 km2 up to the size of one country, and global for networks operating world or continent-wide. Performance was evaluated based on the response times and the total hours spent in the different activities.

In the following we will highlight three different investigations, two on a local (2 years simulation time) and one on global level (10 years simulation time). In a high density local network company 2 wanted to investigate the change of districting and qualification strategy by moving from a generalist's qualification profile with many decoupled districts to a specialist profile where up to 6 districts were accumulated on a regional layer. FTs were now dispatched based on their skill, distance to the customer and work load instead having a fixed assignment to their assets. While on-site execution times and therefore total hours spent on-site could be reduced by more than 6% due to better skill-job matches, travel time and response time were increasing by 14%, respectively 13%. On a global level the result of a generalization of the workforce and therefore better geographical dispatching was investigated as well and in a reduction of average response times by 23% while transfer times were 33% shorter. Another local network investigation was focused on the reduction of the number of technicians being able to conduct field work (with 32% of total work time spent in the field on average) by 10% and therefore increasing the time spent in the field for specialized FTs by 12.5%. This resulted in the simulation in an increase of the response time for critical interventions with high priority by more than 22% and an increase in transfer times of 3%.

6 Limitations and Outlook

The last paragraph has shown that the simulation-based DSS provides a huge potential to obtain meaningful quantitative results for difficult questions regarding the operations of FSSNs. Without a question results have to be investigated and understood well enough. During the projects the models have been improved in the level of detail in multiple cycles until results were obtained that could be understood in every detail. During the application of the tool as well as during the investigation of historical data for the data input interesting results were obtained, that improved the transparency of the service operations and capabilities of decision makers to improve operations.

Next to all benefits there are still limitations. Though the software reduces the time and cost effort for modeling significantly by building upon a generic framework, investigations with the DSS still mean a lot of work due to the data that was often not available in the required quality. Additionally the software is still at a prototype stage and has its limitations in respect to models sizes and simulation durations depending on the hardware used.

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Mass Customization in Supply Chain Level: Development of a Conceptual Framework to Manage and Assess Performance

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Abstract. Recent market interest on customized offers and intensive competition on attracting market globally, lead companies to implement supply chain management to improve performance and gain competitive advantage. To this aim, Supply chain management in customer-oriented environment is pursuing the transition from traditional supply chain into concurrent flexible and efficient one. This paper aims to understand specifically how supply chain within this environment needs to be configured and managed in order to enable efficient customization for mass market. To reach this goal, a conceptual framework and list of indicators to support the framework have been developed and tested.

Keywords: Mass customization, Supply chain management, Performance measurement.

1 Introduction and Research Objectives

There is a growing recognition among scholars and practitioners that individual businesses no longer compete as stand-alone entities, but rather as supply chains [3]. Recently, we are now entering the area of "network competition," where the awards will go to those organizations who can better structure, coordinate, and manage the relationships with partners in a network which is committed for a better, closer, and more agile relationships with final customers [3]. It can be argued that in today's challenging global markets, the route to sustainable advantage lies in being able to leverage the respective strengths and competencies of network partners to achieve greater responsiveness to market needs [3]. Evidently market interest on more customized offers better aligned to individual's needs, brings further challenges in terms of complexity and uncertainty. Being competitive in this environment requires concurrent efficiency and flexibility [8]; accordingly enables the ability to provide higher variety at lower cost, enabling strategies of mass customization to be pursued [3]. Mass customization is defined differently by many scholars time after time [5], [27], [29], [41] but the most well-known definition used by this study, is given by Piller as "Customer co-design process of products and services, which meet the needs of each individual

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customer with regard to certain product features. All operations are performed within a fixed solution space, characterized by stable but still flexible and responsive processes"[28].

Inspired by extensive literature review, we recognized that the literature on mass customization in supply chain level has been growing recently and there are still some areas that need further research. In particular we believe that more understanding is needed on how to configure and manage a supply chain in such environment. Therefore, the purpose of this paper is to analyze the configuration and management of supply chain while implementing mass customization. More specifically, the research objectives of this paper are (1) understanding factors necessary to be considered in order to configure and manage the supply chain while implementing mass customization; and (2) recognizing how these factors can be measured. To reach these goals, we first did the literature review and tried to cluster it into research areas to construct our understandings. Four research areas relevant to our objectives were identified. Afterwards relevant factors and indicators related to each research areas were identified and structured in a consistent and understandable framework. In this framework, factors were structured from literature while indicators were developed by this study. As last step we tried to validate the framework by three case studies that employed mass customization at the time of data collection in diverse industries. We shaped this paper as follows: first, we delivered a literature review, next we explained the methodology employed. Then, we presented the framework and finally, we explained validation phase and made the conclusion.

2 Literature Review

With the aim of mass customization, customer needs to be involved into value creation processes. This involvement can happen in different stages, in relation to different actors within supply chain The degree of customer involvement in literature is known as *customization level* and has been discussed extremely by scholars [6], [18], [30], [36, 37]. Moreover, the capability of supply chain in implementing it is known as *postponement*. Graman defines postponement as the capability of supply chain in delaying the activities associated to differentiation of product_ customization processes_ closer to the time that demand is known [8]. Literature positions postponement differently. Some recognize it only in manufacturing operations [2], [11], [32, 33] while some others take a broad view and distinguish it in supply chain level specially emphasize on differentiation in distribution point [39]. Within those who consider postponement in supply chain level, many discuss about issues such as the conflict between product variety and quick response time [16], or product growth and cost control at certain point [32, 33]. Generally literature discusses about postponement by either focusing on types of postponement (time, form and place), their evaluation and comparison [11], [17], [39, 40]; or targeting management of inventory to set optimal level of inventory [2], [8], [24], [32, 33]. In both of these groups modularization has been recognized as an enabling method for efficient customization. Based on our literature review, this study analyses modularization to the aim of a better understanding about this method by focusing on its characteristics and advantages [4], [19], [35], [44]. It specifically discusses about the need for a more intimate relationship among supply chain partners to produce, supply and manage the inventory of modules for customization [13], [20], [22, 23]. Literature has put more attention on relationships among partners in customer oriented environments where a more flexible and efficient supply chain is requested. The relationship is interpreted as integration and cooperation between supplier-manufacturer, manufacturer-customer; and among internal divisions of manufacturer [15], [22], [25], [34], [45, 46]. Literature rarely differentiates cooperation and integration and draws the line between them. Some studies, like Pan and Holland [4], defines cooperation as a beneficial relationship between actors namely customer, manufacturer and other partners such as supplier and distributers. It is believed that this relationship aims to improve outcomes like customer satisfaction, time to market or resource usage by setting common objectives and reducing duplicated activities for increasing value added activities [46]. Integration is a more rigorous concept which aims to integrate the actors in both ends (downstream and upstream) to achieve an optimal output. It includes integration of processes, activities, locations and etc. to optimize the performance of all actors as a whole [15], [20, 21]. Moreover, it decreases uncertainties and increases flexibility and responsiveness [20, 21].

3 Methodology

In the first step of this research "supply chain" and "mass customization" were searched in keywords and abstract sections without any restriction or preference over journals. In total 71 articles from 39 different journals were selected to be reviewed. Papers were analyzed in a more detailed level and their main focuses in supply chain were recognized and subsequently clustered (e.g. postponement, modularity and etc.). The output of this step was twelve clusters covering different strategies and methods, called research areas. These research areas have been the starting point for the construction of our framework. Since the conceptual framework was based on literature, this study validated it empirically by three case studies in different industries. Unit of analysis was manufacturer supply chain (only including first layer suppliers), research domain was manufacturing industry/sector implementing mass customization at the time of data collection, regardless of the size or the level of customization; and expected respondents were operation manager and owner. Validation phase was done by online questionnaire. In particular, the questionnaire consisted of four parts representing framework subjects and aimed to test associated factors and indicators. Questions were multiple choice (without restriction on number of choices) and open-end. Multiple choice questions were used for validation of factors and indicators while open-end questions aimed to initiate respondents to add missing impacting factors and/or indicators.

4 Conceptual Framework

A conceptual framework was developed to support configuration and management of supply chain. It identifies four main decision areas that are about relationship management, postponement, level of customization, and modularity level. To reach our objectives, by conceptual framework, we tried to understand relevant elements to be considered for each decision area. For instance in order to manage relationship along a supply chain, this study expects that an industry needs to consider elements such as customer integration level and supplier selection criteria. By following, we structure the work in four sections associated to the framework decision areas. In each section, first we briefly define the decision area and associated elements. Afterwards, we specify relevant impacting factors and indicators for each element (see Table 1).

4.1 Relationship Management

The first decision area is related to different relations that a company (manufacturer) should have with players in supply chain. The aim is to primarily understand who is considered as key partner and is necessary to build close relationship; and how to manage these different kinds of relationships while practicing mass customization. To reach this goal, four types of elements are necessary to be considered. These elements are briefly defined by following:

Internal integration level: This element refers to relations inside the manufacturer and points out the importance of internal capabilities in satisfying customer needs responsively. In particular, this element brings out level of interaction between internal departments and employees.

Customer integration level: This element highlights the importance of customer and their value-adding contribution inside the supply chain processes. Specifically this element deals with the extension of customer contribution and management of the transferred knowledge.

Cooperation level with partners: This element focuses on how to define the extent of relation and then how to manage it with different actors such as suppliers and distributors.

Partners' selection criteria: This element emphasizes on the basics which needs to be considered in order to select some partners over the others.

4.2 Customization Level

The second area relates to the marginal value that customization brings to the end customer. Definition of this value impacts on the way supply chain operates and creates the customization marginal value. Mass customization levels can be driven from tailored customization (customization in fabrication), customized standardization (customization in assembly); and segmented standardization (customization in package and distribution) [18]. In order to identify the customization level, a company needs to consider three elements. These elements are briefly defined by following:

Product characteristics: This element refers to product features that support decisions related to customization.

Partners' characteristics: This element refers to capabilities, characteristics and relationships of actors inside the supply chain.

Market characteristics: This element refers to extent of customization in relation to market need.

4.3 Modularity Level

Third decision area is related to a method known as modularization that enables a company to efficiently customize products. This study considers only the set of elements, related to the production process and supply chain characteristics, that impacts on product modularization, hence excluding elements related to other types of modularization (such as organizational modularity). The impacting elements are briefly defined by following:

Product characteristics: This element refers to product features that support decisions related to customization.

Partners' characteristics: This element refers to capabilities of actors inside the supply chain which operationally support modularization.

Production system characteristics: This element refers to production capabilities inside of the manufacturing which operationally support modularization.

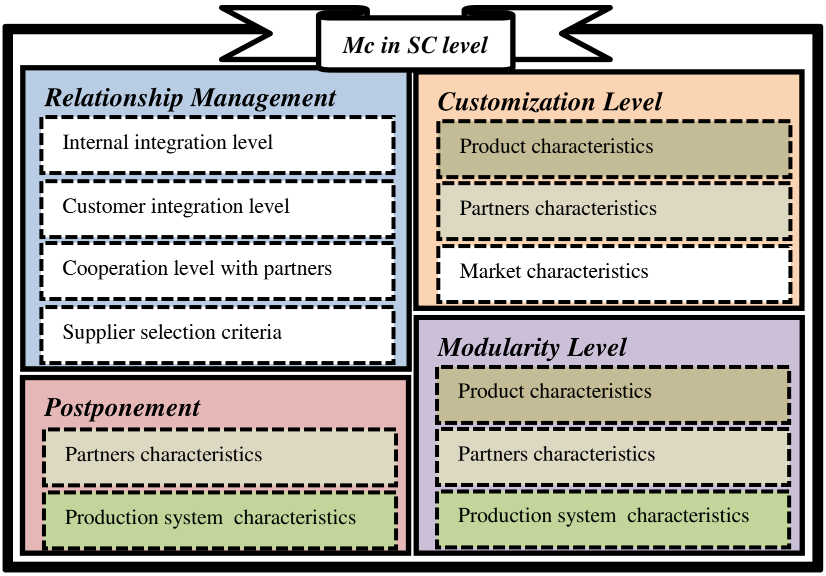

Fig. 1. Conceptual Framework

Table 1. List of Indicators dedicated to conceptual framework

Decision area	*Elements*	*Impacting factors*	*Factor Description*	*Indicator*
Relationship Management	Internal integration level	Capability in exchanging information [20], [21], [25], [45]	This factor impacts on ability of a company to exchange information internally and be responsive to final customers	Number of times that information has been exchanged between departments on a time base (e.g. weekly/ monthly)
		Organizational readiness [25]	This factor refers to employees' skill in understanding the end customer needs and their ability in translating it into know-hows	Order response time
	Customer integration level	Customer willingness in participation [15]	This factor refers to customer willingness in sharing actual demand and in providing feedbacks to issues such as product development	Percentage of customers participating in data collection phase via employed methods/mechanisms/tools
		Information exchange level [15], [25], [26], [45]	This factor focuses on the actual level of information exchanged which has a direct impact on effective implementation of mass customization	Number of methods/mechanisms/tools employed to gather data from customers
	Cooperation level with partners	Joint profits [46]	This factor refers to decisions made jointly to bring out better results in set of aspects such as profit	Percentage of partners with joint profit agreement
		Type of shared information [34]	This factor refers to set of information that its sharing can bring advantages to partners. Sharing information such as delivery due date, cost of delay, total time of manufacturing; and distribution with partners, are some examples which beside profit, brings improvements in service level, quality and etc.	Percentage of partners with shared information with core manufacturer
	Supplier selection criteria	Agility of supplier [45]	This factor refers to dynamic characteristics of a customer-oriented environment. Consequently, concurrent flexible and responsive suppliers are required	Percentage of orders committed to be fulfilled on time
		Capacity of supplier [19]	This factor refers to power of manufacturer on supplier. In particular it focuses on portion of capacity allocated to the manufacturer	Percentage of capacity allocated to manufacturer
		Information exchange level [20], [21], [22], [25], [26], [45]	This factor refers to internal capability of supplier in sharing information	Expected time interval in sharing information between supplier and manufacturer (e.g. weekly/ monthly)
Customization level	Product characteristics	Product architecture [16], [38]	This factor refers to architecture of the product which can impact on its customizability in different levels	Percentage of customizable modules/parts
	Partners characteristics	Supply chain information exchange level [38]	This factor refers to level of information integration among partners	Expected time interval in sharing information between partners(e.g. weekly/ monthly)
		Cost of customization [16]	This factor refers to the trade-off between cost and value of customization. In particular it highlights the advantage of customization, by comparing the cost of customization with the advantages coming from customization	Ratio of cost of customization and customization marginal price
	Market characteristics	Market demand [31], [38], [42]	This factor refers to market interest on customized product. It points out the market enthusiasm on type of customization	Percentage of customer interested to aesthetic/function/fitting features
Modularity level	Product characteristics	Product architecture [19]	This factor refers to the product architecture and points out the feasibility of translating customer requirements into modules	Percentage of customizable modules/parts
	Partners characteristics	Cooperation with supplier [13], [19], [20], [21], [44]	This factor refers to partners' capability in collaborating in customization by considering level of information integration	Percentage of partners with shared information with core manufacturer
	Production System characteristics	Production capability [23]	This factor refers to production capability in manufacturing and assembling modules efficiently. In particular it targets efficiency by considering cost of production	Ration of customization cost on unitary production cost
Postponement	Partners characteristics	Cost of postponement [8], [10], [17], [32], [33], [39]	This factor refers to the cost associated to customization and is faced by supplier	Utilization rate of customization processes/resources (e.g. machine) in supplier plant
		Supply chain information exchange level [38]	This factor refers to level of information integration among partners	Expected time interval in sharing information between partners(e.g. weekly/ monthly)
		Inventory levels [1], [2], [9], [12]	This factor refers to the inventory level of partners. It is assumed that the inventory is used for uncertainties and it highlights the impact of penetration point on partners	Inventory level of customized parts/modules on total inventory
	Production System characteristics	Production capability [10], [40]	This factor refers to manufacturing capability in manufacturing and assembling final products efficiently. In particular it targets to highlights the efficient integration of customers by considering its impact on time	Ratio of point of customization time to delivery and production time

4.4 Postponement

Last subject is related to the postponement strategy known as capability of a supply chain to perform customization in a way to delay differentiation or customization closer to the time that demand for the product is known [8]. The aim of this group is to understand appropriate position of customer integration point. To reach this goal, we identify two elements necessary to be considered. These elements are briefly defined by following:

Partners' characteristics: This element refers to partners' capability in either carrying out the customization in their location (e.g. distributors' ability in customizing products) or being collaborative and responsive to support core company postponement strategy.

Production system characteristics: This element refers to production capabilities inside of the manufacturing which operationally support customer intervention.

5 Validation and Conclusion

As a final step this study conducted three case studies to validate its findings. In particular by case studies, we tried to understand if impacting factors are practically considered in configuration and management of supply chain. Moreover we tried to test indicators relevance by asking if they are already applied in practice or can be considered beneficial. Based on our case studies, all impacting factors were validated but certain indicators were not. Customer willingness in participation was never measured and its measurement was believed challenging. Moreover, although all three cases had modular product, but believed that proposed indicator for product architecture was not representative; instead they assert that ration of customizable modules cost on production cost was suggested to be substitute. As a result of this study we create a better understanding of how different factors impact on configuration and management of supply chain in customer-oriented environment. Moreover, we suggest a list of indicators that can support decisions with a better indication on circumstances.

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Development of a Training System for Lathe Operation Using a Simulator

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Abstract. Recently, the manufacturing industry in especially Japan has found it difficult to transfer skills from trained workers to inexperienced workers because the former ages and then retires. This is a particular problem for lathe process, as this operation requires explicit and tacit knowledge, and defining the skills clearly in a manual is difficult. This study aimed to develop a training system for lathe operation by using a simulator; this includes formulas that help define the relationship between the speed of tool feed and cutting sound/shape of chips that were proposed in the preceding study. The present study verified the effectiveness of the proposed training system.

Keywords: Lathe operation, Training, Simulator, Cutting sound, Cutting shape.

1 Introduction

Recently, the manpower, time, and money that the manufacturing industry in Japan can afford are decreasing because the youth are moving away from this industry. Many trained skilled workers had retired around 2007 and it caused their skills disappear. We call it the 2007 problem in Japan. In addition, trained skilled workers are advancing in age and retiring; transferring their skills accumulated over the years is difficult. The Ministry of Economy, Trade and Industry [1] says that 49.4% of new workers require 2–3 years of training, and 28.1% require 4–5 years. In the manufacturing industry, it can take years before a worker becomes sufficiently skilled at his/her work, and even more years are needed by trained workers to acquire advanced skills. In small- and medium-sized manufacturing industries, there is no established system for the transfer of skills, so cost and time have become large problems. The personnel expenses to train a new worker alongside a trained worker are said to double to maintain the production volume and sales at the same level as the previous year [2]. Owing to the lack of technical personnel responsible for the technology infrastructure in terms of both quantity and quality, an education and training method to effectively improve the skill level of a worker in a short period of time is required.

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This study considered the lathe operation, which was also targeted in the preceding study; this process involves cutting stainless steel into shapes and is performed frequently. The preceding study proposed a method and formulas describing the relationship between the speed of tool feed and cutting sound/shape of chips for the lathe operation based on an experiment with a trained worker [3][4].

The aims of the present study were to develop a training system for lathe operation with a simulator using the formulas proposed in the preceding study, conduct an experiment with the proposed system, and verify the effectiveness of the proposed system.

2 Devising a Training Method

The devised training method consists of the following content: explicit and tacit knowledge. Explicit knowledge is transferred by training evaluation, and tacit knowledge is transferred by simulator training [5].

2.1 Transfer of Explicit Knowledge

Three aspects of explicit knowledge are described here: sound, handling, and chips.

2.1.1 Transfer of Sound as Explicit Knowledge

Sound is transferred as explicit knowledge through a display of the musical scale for the sound frequency [6]. The sound frequency varies depending on the amount of cutting feed; this is converted to a musical scale and displayed. The sound is expressed on the musical scale rather than as a frequency to facilitate better and easier visualization. For example, people can more easily understand the expression "fa ♯7 octave" rather than "sound of a 3000 Hz frequency." A trainee can receive feedback from the musical scale according to the amount of handle feed and difference with the target [7].This item is the original point of this study.

2.1.2 Transfer of Handling as Explicit Knowledge

Handling is transferred as explicit knowledge based on the average feed amount, stability of feed rate, difference in feed rate amount, and feed time series average of a trained worker and through a graph of the cumulative amount of feed. The average feed amount is obtained from the simulated feed results [8]. The stability of the feed rate is evaluated according to the standard deviation of five levels: a score of 5 is the best. The differences in the amount of feed rate and feed time series average of a trained worker imply the difference between the absolute value of the time series feed and the objective value of 0.05 mm/rev feed. These are evaluated on four levels: best, good, bad, and others. They are also calculated according to the ratio of the previous three items. The total score is calculated on a scale of 100 points using the amount of average feed and stability of the feed rate as base values and the difference in feeding time series feed rate and average of a trained worker as an additional value. The average feed is evaluated on five levels: fast, slightly faster, just right, somewhat slow, and slow in the comments column. The stability is similarly evaluated on five levels:

very good, good, a little more, bad, and very bad. The graph of the cumulative amount of feed is displayed by pressing a button on the right-hand side of the screen; it compares the results for a trainee and trained worker. The trainee obtains feedback on handling from these items.

2.1.3 Transfer of Chips as Explicit Knowledge

Chips are transferred as explicit knowledge based on the diameter and interval of the simulated helix for 3D chip configuration and the thickness and width for the volume of one spiral chip. The 3D simulator shows chips corresponding to the average feed amount being handled. The trainee receives feedback by comparing this figure and the goals.

2.2 Transfer of Tacit Knowledge

Three aspects of tacit knowledge are described here: sound, handling, and chips. The transfer of tacit knowledge requires direct communication of the represented sense instead of a numerical representation as for explicit knowledge.

2.2.1 Transfer of Sound as Tacit Knowledge

Sound is transferred as tacit knowledge by listening to the simulated sound of cutting. Sound travels from PC speakers (or the equivalent) according to the amount of feed being handled. The trainee judges the quality of the feed by listening to the sound of the pseudo-cutting.

2.2.2 Transfer of Handling as Tacit Knowledge

Handling is transferred as tacit knowledge by manipulating handle of the simulator. The amount of handling to feed is acquired by moving a mouse attached to the lathe bench according to the blade movement and handle rotation. The trainee can understand the amount of feed handling by looking at the screen. The black line extends from right to left according to the amount of rotation of the handling and represents the workpiece cutting status. The red line shows the feed amount by a trained worker. The trainee can perform training exercises by comparing his or her feed with the trained worker's feed and level up in rank by adjusting the display after becoming accustomed to a given exercise. The sound frequency of cutting decreases when oil is injected; in the simulation, this is done by left-clicking the mouse. The trainee can acquire the proper amount of feed while actually operating the handle using tacit knowledge.

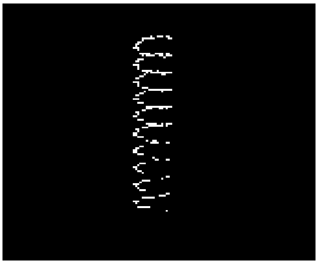

Fig. 1. The shape of the chips

2.2.3 Transfer of Chips as Tacit Knowledge

Chips are transferred as tacit knowledge by looking at the shape. When transferring chips as explicit knowledge, the chip shape is represented by a numerical value. However, actually measuring the diameter and spacing of the chips in actual practice is not desirable because this takes time and effort.

Ideally, the quality should be judged at a glance (Figure 1). The trainee obtains the chip form as tacit knowledge by visualizing the chip shape according to the amount of feed on the display screen.

3 The Developed Training System

The training system consists of the tabletop lathe shown in Figure 2 (Amini No.1100). This tabletop lathe can be used with a household power supply and can create workpieces up to 60 mm in diameter. This lathe also has processing functions such as cutting an outer diameter and machining chestnut holes as well as a large conventional lathe. It has sufficient functions for training on lathe operations. Figure 3 shows the developed training system with this lathe. A mouse is used with this lathe to obtain data on the feeding amount being handled and to simulate lathe operation. The sound of pseudo-cutting can be heard during the simulation, and explicit knowledge on the sound, handling, and chips can be obtained after the simulation. This allows trainees to obtain feedback from the simulated results and learn on their own. The training system is effective and no unnecessary material costs are incurred. On the other hand, possible disadvantages include the time and effort needed for development. Therefore, the training system should have a realistic simulation and additional functions not found in practice. In this study, we developed a training system using the free software Eclipse 3.2 and Java.

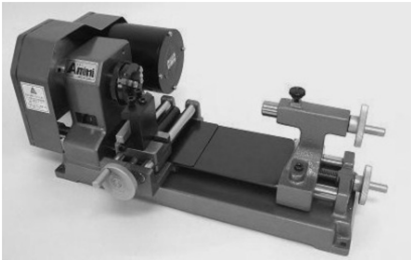

Fig. 2. Tabletop lathe

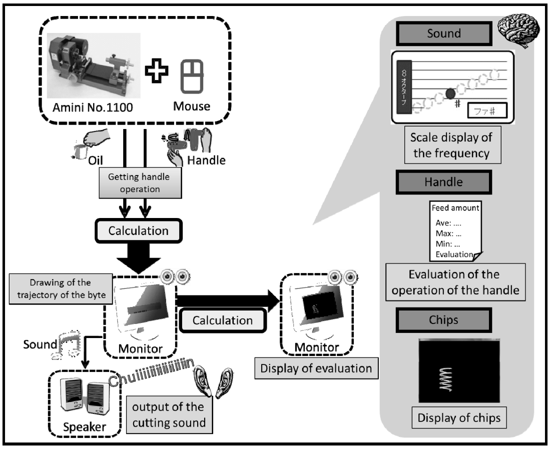

Fig. 3. Overall picture of the training system

4 Experiment Design

Using the training system described in the previous section, the training system was experimentally verified as to whether it effectively improved a trainee's skills by transferring tacit and explicit knowledge on topics such as sound, handling, and chips. Eight university students were selected as subjects and classified into three groups based on the preliminary grouping experiment. Two groups of subjects practiced lathe operations with the training system, and the other group practiced without it. The results were then used to compare the degrees of improvement in skills of the three groups.

4.1 Grouping Experiment

Eight subjects were classified into three groups based on dexterity so that no differences caused by a subject's individual ability would appear in the subsequent experiment. For the grouping experiment, subjects were asked to make a minicar run on the scoreboard using their hand and guess the number where it would stop in three trials. This experiment measure the subjects' dexterity, coordination, and nerves. These abilities are required for lathe operation.

4.2 Verification Experiment

In this experiment, the effectiveness of the developed training system was verified. Two of the three groups (i.e., groups A and B) used the training systems, and group C did not. Group A conducted training using the training system and receiving tips for lathe operation and VTR of feeding behavior from a trained worker. The tips simply summarized the cutting chip sound and how to achieve this or change it with a constant feed rate, how to maintain low resistance during cutting, and how to clean the surface of the workpiece. Group B conducted training using the training system and VTR of the feeding behavior from a trained worker. Group C only saw VTR of the feeding behavior from a trained worker. Viewing VTR is equivalent to the traditional teaching method of apprenticeship; the superiority of the proposed system can be verified through this experiment. Subjects performed lathe operations three times; this involved cutting outlines in stainless steel. They received training during each operation. The termination condition for the training system was more than 85 points for the first time, more than 90 points for the second time, and being successful three times in a row. The upper time limit was 10 min. The training effect for lathe operation was verified based on four criteria: resulting feed amount of the handle, cutting sound frequency, chip thickness, and workpiece surface.

5 Experiment Result and Discussion

The eight subjects were put into three groups. The subjects were classified so that the groups would have similar average results. Group A had three subjects with an average of 180.0 points, Group B had two subjects with an average of 180.0 points, and Group C had three subjects with an average of 173.3 points.

The verification experiment was conducted as described above for the three groups. Figure 4 shows a box-whisker plot with the changes in the amount of feed being handled by group A for three lathe operation trials.

The graph shows the average amount of feed handled by the subjects in the group and the average maximum and minimum values. Group A reached a proper and stable speed for the feed amount being handled after repeated trials. The results for group B were almost the same as those of group A. On the other hand, group C used a faster speed for the feed amount being handled than the other groups, and the speed was unstable throughout the trials.

The changes in the cutting sound frequency show the average frequency of the subjects in each group and the average maximum and minimum values. For groups A and B, the lower limit of the frequency decreased in the second trial and increased in the third trial. Confusion over the modified feed amount during training and blank time in the feed amount might have led to the above result in the second trial. For groups A and B, their skills improved based on the slight decrease in the upper limit of the frequency. For group C, the average frequency decreased, and the upper limit of the frequency was higher than that for the other groups.

Figures 5, 6, and 7 show the changes in the chip thickness. The chip shape is determined by the amount of feed being handled; the chip

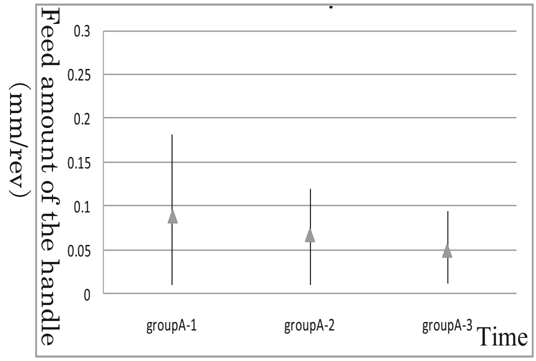

Fig. 4. Amount of feed of the handle of the group A

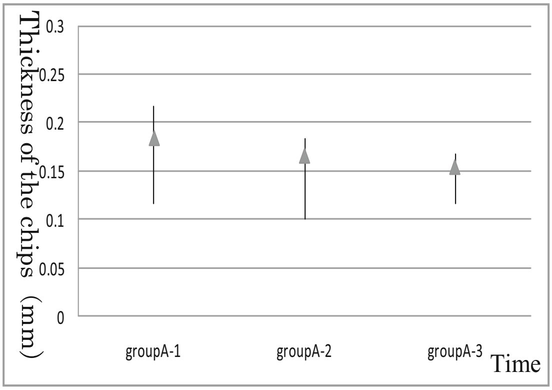

Fig. 5. Changes in the thickness of the chips of group A

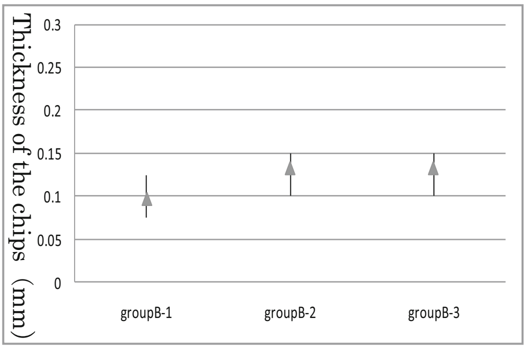

Fig. 6. Changes in the thickness of the chips of group B

shape thickness is determined independently by the entry spiral and spacing of the front line for the circle width. Only the chip thickness is discussed here. The graphs show the average chip thickness and the average maximum and minimum values of each group. For group A, the average chip thickness decreased. For group B, the value increased. For groups A and B, the maximum and minimum widths in the third trial were smaller than in the first trial. This means that the training system improved the trainees' skills with regard to chip thickness.

For group C, the average chip thickness was stable, but the value was larger than that of the other two groups, and the maximum and minimum widths showed no tendencies. These graphs were very similar to the transition of the feed amount being handled as shown in Figures 4. Thus, groups A and B, showed improved skill with regard to chip thickness, similar to the improvement in skill for feed amount being handled.

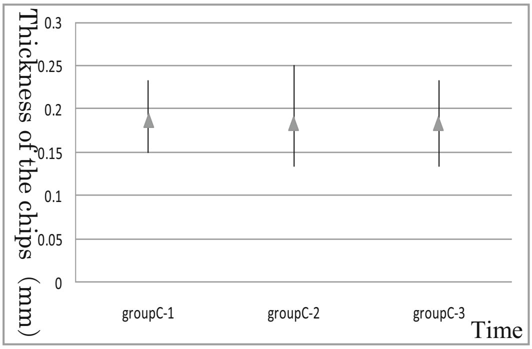

Fig. 7. Changes in the thickness of the chips of group C

Based on the above, the skills of groups A and B improved, whereas those of group C did not. The same results were shown on the workpiece surface after machining (i.e., processed surface). Figure 8 shows the surface processed by a subject in group A. The processed surface in the first trial had chatter owing to linear cracks, but the surfaces in the second and third trials were cleaner and had less chatter. The results for group B, were almost the same as those for group A. For group C, whose results are shown in Figure 9, although the chatter of the processed surface in the third trial was thin, the roughness of the surface showed no change. Thus, the skill of groups A and B with regard to the roughness of the processed surface was improved by the training system.

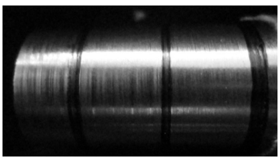

Fig. 8. Group A

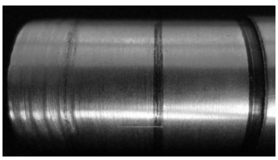

Fig. 9. Group C

6 Conclusion

This study proposed a method for transferring explicit and tacit knowledge on lathe operation; a training system was developed with a simulator that uses relationship formulas between the speed of the tool feed and cutting sound/shape of chips on lathe operation based on an experiment with a trained worker. The effectiveness of the system was verified through an experiment.

Future work will involve examining the work conditions for lathe operation in detail, improving the training system, and implementing it in actual factories.

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Using Serious Game in Sustainable Global Manufacturing Education

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Abstract. Having multi-skilled engineers who can master the complexity associated to sustainable manufacturing is a strategic requirement for manufacturing companies wanting to compete in the global market. The current approaches to manufacturing education and training, both at university and at industry, need to be revisited to improve the learning effectiveness of manufacturing engineers. An important factor in the learning effectiveness is the delivery mechanism and recently Serious Game (SG) is a promising suitable supplementary method to enhance the learning experience in engineering schools and industry.

Keywords: Serious Games, Sustainable Global Manufacturing.

1 Introduction

The manufacturing industry continues to grow due to globalization, customized products, green production, etc. However, there is a paradigm shift where cost is no longer the driving factor in the industry, with the social and environment increasing in importance for driving the business. This brings a challenge to the education and training, in particular with regards to higher education, because engineering schools are regarded as the supplier of future qualified engineers and consequently are responsible to transform students into graduates who are practitioners capable of ensuring sustainable manufacturing (Sibbel, 2009).

The advent of SGs brings the promise of a novel instructional method to manufacturing and engineering education. The use of SGs provides the opportunity of situated learning, where the learner is emerged in the actual context and therefore increasing the retention rate whilst improving the potential for transformation of the learner. There is growing evidence of the relevance and impact of SG in education in various domains, such as health, business, cultural heritage, etc. However, the same cannot be said with regards to engineering and manufacturing in particular. McLean et al., (2005) conducted a study to understand whether video games technology can be useful in manufacturing education. The result demonstrated both, significant advantages in learning process and also students' interest with learning by playing.

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Sustainable Global Manufacturing (SGM) game has been designed based on the innovative Technology Enhanced Learning (TEL) platform developed within the context of the TARGET[1] project. Sustainable manufacturing involves broadly life-cycle stages from pre-manufacturing to end consuming and consequently several partners get involved to manage at each of these stages. Therefore, knowing environmental impacts on end product, which can be identified by Life Cycle Assessment (LCA), is quietly essential. This game aims to improve learners' competence in sustainable manufacturing by performing LCA tool.

In this study a SG focused on Sustainable Global Manufacturing was evaluated based on teachers' perspective who taught in department of industrial engineering at Politecnico di Milano. 16 teachers participated in a study where they played the first version of the game (0.41.04) and then, each individually took part of a deep interview in which they responded to 23 questions. The results demonstrated that SGM has strong potential for adoption by the teachers in their classes. In addition they highlighted the ability of game to enhance social and personal skill of engineers apart from acquired knowledge about sustainable manufacturing, even though they believed SG attributes have not integrated well at SGM yet.

2 Relation to the Existing Theories and Works

SGs may belong to any category (e.g. Health, Business, Military, etc.) and they are being considered as a way of edutainment They are designed as virtual environments which plainly have the intention of education or training with two key attributes; being educative and immersive (Poplin, 2012). In manufacturing education, Hague et al (2010) stated that SGs can be extremely successful while teaching sustainability to engineers, because they facilitate the acquisition of not only technical skills, but also soft skills like collaboration, creativity and communication.

SGs attributes are borrowed from computer games, while they are blurred to instructional concepts in order for make education and entertainment simultaneously. So far, some prominent studies have been done to identify SGs attributes (Charseky, 2010; Gariss et al., 2002; Asgari and Kaufman, 2009; Gunter et al., 2007). In the Table 1, five attributes of SGs and their performance indicators, those are relevant to manufacturing education, are identified.

On the other hand, the effectiveness of SGs to enhance the learning outcomes is usually under discussion, and significant efforts have been done so far to define relevant indicator to measure the learning outcomes. They are mostly presented as a design or evaluation frameworks. Prominent ones obviously pinpoint the importance of considering not only engineering knowledge, but also professional skills. The latter is extremely demanded by industry in order to employ engineers who are able to work at dynamic environment. See table 2.

[1] TARGET (Transformative, Adaptive, Responsive and enGaging EnvironmenT) was an integrated project funded by EU, which concluded in October 2012.

Table 1. Attributes of SGs and their performance indicators for manufacturing and engineering education

Rule and Goal	Identifying winning conditions, providing various ways to achieve goals based on players action and specific situations, defining clear goals and rules, identifying specific learning outcomes, providing different kinds of feedbacks (constructive, clear and frequent).
Sensory Stimuli	Providing a virtual manufacturing and engineering process in similar to reality, and integrating fantasies attributes to learnt material (visual and sound effects, colors and graphics).
Control	Providing a responsive learning environment, providing different level of choices, making a sense of control among players, providing different kind of solutions to solve problems, permitting learners to produce powerful effects.
Challenge	Producing multiple levels of goals, providing an optimal level of information and using hidden information, providing positive feedbacks to promote feeling of competence.
Interactivity	Using game mechanics regarding communication (e.g. dialogue tool) to improve the professional skills (negotiation, active listener, conflict, etc.). Providing optimum level of competition (i.e. neither boring nor anxious).

Table 2. Description of three frameworks to design and evaluate SGs

Krikpartck Model (1994)	There are identified four aspects to evaluate learning outcomes where three of them are related manufacturing. Reaction" resembles to what extent players' satisfaction is supported by game which is a point under special attention because of some complicated course at this domain. "Knowledge change" is a critical point to teach contemporary demanding skills at engineering education such as communication and team working. SGs are expected to moderately enable players to transfer acquired engineering knowledge in a reality. This is named "Transfer ability" here.
Game Baesd Learning-GBL Evaluation Framework (Hainey, 2010)	This focuses on both teachers and learners to design SGs. Among seven main aspects, motivation, preferences and collaboration are fully in relation to engineering education. Considering motivation elements can stimulate players to be involved and, at higher level, to be engaged the game. Considering the preferences of tutors to use SGs in which way and method and also considering students preference to play the game in which context (e.g. at class, home, etc.) are essential parts of game design. Communication can strongly impact on learning effectiveness. The ability of students to work as a team member and deal with happening challenges (decision making, conflict, etc.) at industry is pinpointed
Four Dimensional Framework-FDF (de Freitas and Oliver, 2006)	This concentrates both on tutors and learners. "Context" represents where the game can be run to be useful, the structure of its application and how it is supported by technical tools. "Mode of representation" is greatly necessary to take consider at design SGs in the domain. Players should feel optimum level of immersion, fidelity and interactivity generated by game attributes and supportive discussion before and after play.

3 Methodology

In this study we evaluate the Sustainable Global Manufacturing (SGM) scenario of the TARGET platform. The scenario provides a situated learning context for engineering students to learn SGM concepts, with focus on “communication and negotiation skills”; “system thinking”; “ability to see the big picture”; “short versus long term strategies” and “critical thinking”. In the game scenario the player is assigned as a Sustainability Manager of an internationally operating manufacturing company. The company produces household appliances such as coffee machines. He needs to deal with different challenges to acquire the main goal, delivering green products to the market. In this situation, he is expected to fill in Life Cycle Assessment tool regarding not only his own background, but also taken information from three none player-characters. CEO, Production manager and Shift manager.

In this study two research questions have been addressed to reveal teachers’ point of views about SGM effectiveness at PLM (Product Lifecycle Management) course.

- RQ1: How well SGs attributes are integrated in SGM?
- RQ2: To what extent learning outcomes can be achievable by playing SGM?

A deep study was designed to answer these research questions in which 16 teachers from industrial engineering group of DIG (Dipartimento Ingeneria Gestionale) at Politecnico di Milano participated. At first, they took part at briefing session to be introduced with game scenario, content and structure. Then a game session was run where they played the first version (0.41.04) of the SGM. At the end each teacher individually was requested for a deep interview to gather data to respond the research questions. In order to prevent missing any data, all interviews were recorded with respect to their permission.

To answer first research question, we employed attributes extracted from literature review at section two (see table 1). Teachers completely were informed about the practical definition of each attribute and then they were questioned to recognize those were integrated at game. By considering expected learning outcomes “Positive reaction”, “Information gathering”, “Performing LCA”, “Decision making”, “Transferability”, and “Supportive method” were identified to be asked so that teachers explain to what extent each learning outcome can be supported by SGM.

4 Results

4.1 How Well SGs Attributes Are Integrated in SGM?

Analyzing collected data about the serious game attributes demonstrated that the score being 0, 55 out of 1(see figure 1). “Rules and Goal” and “Interactivity” were mostly selected (12 out of 16), in versus just 4 participants felt “Sensory Stimuli”. Teachers mostly, around 63%, expressed that there was not a specific objective to be controlled. For instance sometimes players are perverted by given wrong information from non-player characters, but there is not any mechanism (e.g. feedback) to inform them so that they are able to correct their performance at a right direction. However, teachers admired SGM to presents rules and goals clearly as well as its ability to provide an interaction environment in which the player needs to communicate and negotiate efficiently with NPCs in order to complete LCA tool. Being some contradiction ideas was a noticeable point at deep interviews. For instance, one participant believed that game attributes are integrated well, *"...I have seen Rules & Goals when I saw the order of things that you have to do, for instance start with talking to CEO, then go to production manager, and so on. Challenge exists when you try to find the right person who can explain things better…"* even though another teacher oppositely believed attributes were not clear at the game, *"…There do not seem to be much challenge because everything is predefined already. I do not think also that this game has clear rules and goals feature because there are not many options unlike in good serious games…"*

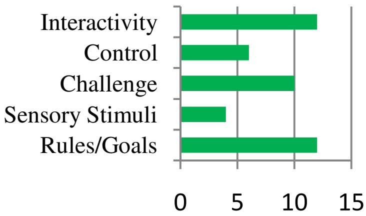

Fig. 1. Results of essential game features

4.2 To What Extent Learning Outcomes Can Be Achievable by Playing SGM?

In deep interviews participant were asked by 13 questions to uncover to what extent learning outcomes are achievable by playing SGM. In Table 2 questions are identified and for each a short abstract of two or three teachers' point of views is shown.

Table 3. List of questions used to measure to what extent learning outcomes can be achievable, and a short abstract of some answers

Questions	Answers
Do you think students would reflect positively and enjoy exploring the virtual environments and interacting with the game characters?	*"Yes, they will enjoy but maybe it is not successful."(P5)* *"It needs to be more interesting. It is a bit confusing not so much clear to reach best solution."(P7)* *"I will go neutral for this because according to me it depends on the character of the students. For example girls can be bored with such a game quicker than boys."(P11)*
The game aims to increase the ability of the students in performing a Life Cycle Assessment (LCA) competence. Do you think playing SGM Serious Game and reflecting on their experience will help students learn about performing LCA?	*"They can first of all visualize what does it mean, get more into context rather than just seeing on the paper or listening to the lecture, and visualization helps them to understand it better."(P4)* *"They cannot see the all aspects of LCA, it is a really big topic. They can learn something from the game, but not comprehensive details. What is missing I think is it must be more comprehensive."(P10)*

Table 3. (*continued*)

The game aims to increase the ability of the students in Information Gathering competence. Do you think playing SGM Serious Game and reflecting on their experience will help students learn about Information Gathering?	*"Students do not know if the information they gather is correct or wrong, and this feature can be developed."(P2)* *"The dialogues are in primary school level. In the companies, you do not talk with this language. In the game it is like some sentences are taken from text books and put as dialogues. This game does not reflect the real way of communication in business environment."(P3)* *"Information gathering seems a bit easy in the game. You just ask the question and there is an answer, more or less the same all the time."(P8)*
The game aims to increase the ability of the students in Decision Making. Do you think playing SGM Game and reflecting on their experience will help them learn about Decision Making?	*"The game seems to be mainly on decision making and then performing LCA but still it is simplified. "(P1)* *"At this virtual situation, students will start making decision"(P9)* *"I am not able to evaluate it."(P15)*
Do you think the knowledge acquired and learning outcomes achieved by your students after playing SGM Serious Game can be transferred to other situations?	*"Up to now I focused on negative points but to this question I will say yes. Because it provides a 3-D environment as a second life close to reality, you talk to people. I think it's always good to hear some theory and then to apply them in practice."(P3)* *"Imagine that you will play this game a thousand times, and after that u will know how to do an LCA."(P12)*
What do you think of SGM Serious Game as a learning tool	*"The overall game puts students in real life context although it does not work properly with all the functions but still it s much better than just sitting in the class and listening or reading a book about it."(P6)* *"Measurement of results does not exist in the game, what should do student to after computing LCA? Would not it be better if they were able to discuss results they obtain with other characters?"(P7)* *"It has a great role to improve the attendance's skills in making communication."(P16)*
What do you think about the future potential of SGM Serious Game as a learning tool?	*"If it is complete you will have a really good game about how to conduct an LCA!"(P1)* *"If the algorithm behind, I mean details of LCA is improved, it can be a very good tool to be used in the lectures. Because when you talk about LCA in a lecture, not many students understand it."(P5)*

Table 3. (*continued*)

Do you think that playing SGM Serious Game will facilitate learning for your students? Why / why not?	*"Yes, if new options are provided to let them create their own rules in the beginning of the game."(P5)* *"Yes, somehow, but they have to be familiar with this topic."(P14)* *"Yes, but now it is difficult. I would say absolutely if we had more time"(P16)*
Would you like to use SGM Serious Game in your classroom? Why/why not?	*"Yes, but it maybe is difficult because of time limitations because I have other things to teach as well."(P2)* *"Right now, it is not very desirable. It has to be improved and definitely it will be used."(P10)* *"I would use it but it must be difficult to implement."(P13)*
Do you think that context affects learning? What is the typical context of learning for your students? E.g. do they work mostly at home or at university?	*"If it is not confidential, students should play the game themselves at their homes as well and explore different solutions, ways."(P2)* *"Absolutely! Where you start learning, how you work. Environment is so important; studying in the kitchen of your place when you have your friends around you is completely different then studying in a library with a 3D game."(P6)*
To what extent SGM Serious Game will be useful for students whose backgrounds are from different disciplines? E.g. do you think that students with prior knowledge about LCA and students without LCA background can have the same knowledge after playing the game?	*"They might have the same level of knowledge at the end."(P10)* *"Absolutely yes, if they simplify the wordings it will be useful. Even if somebody who does not have idea about LCA can play this game and understand things and somehow changes his behavior."(P11)* *"It can be applied to more than one specific discipline and if the student is interested he can play no matter what his background is. I think broadly applicable."(P16)*
How can your students use SGM Serious Game platform most effectively? E.g. playing SGM game in groups or individually	*"It is absolutely more effective in teams, because different people have different ideas. Maybe the game can create an environment where students can discuss answers and probably that is the most important thing that can be made in this game."(P9)* *"I think they have to play in single players, but they must compete with each other because competing makes it more interesting and interactive."(P14)*
What level of fidelity and immersion has been used in SGM game to support learning activities and outcomes?	*"It is very low. Because you achieve the goals very fast. In games, you need to create levels. Maybe in this case, production levels first and then the whole company."(P7)* *"To get more involvement, there must be more challenge about how to deal with different characters"* *"If complexity is enhanced a bit more I would say that fidelity and immersion would occur more."(P12)*

5 Conclusion

The main purpose of this study was to evaluate the effectiveness of SGM game based on teachers' perspective. A deep study was done among 16 teachers at Industrial engineering group of Politecnico di Milano. They have experienced to teach PLM course at graduated level and most of them have used other SGs to teach. They played the first version of the SGM and then each individually took part at a deep interview. In general, teachers mostly believed that game attributes have not been integrated well at SGM, the score was 0.45 out of 1, and proposed specially to make the virtual environment more similar to reality, however; they optimistically emphasized the potential of SGM to be a supportive learning method.

Players to some extent agreed that SGM helps students to enhance own knowledge of LCA performance. They highlighted the game could not provide enough complicated situation as engineers experience at real industry. The result for the ability of the game to make positive reaction was also demonstrated that teachers found some vague and unclear points that need to be clarified in the further versions. Teachers were not consensus about the ability of SGM to improve information gathering and decision making skills of students. Some teachers believed that pre-determined dialogue tool can enable players to gather enough amount of information and prevent them to be confused. In versus, some criticized pre-determined dialogue due of blacking students' creativity to take different types of decisions. On the other hand, teachers raised the ability of SGM as a learning tool and supportive method at PLM course, while they stressed that it is still far from its maximum potential. Teachers also pinpoint the potential of SGM to provide an environment where students can transfer acquired knowledge and skills in a practical way.

In conclusion, the results provided invaluable information for designer before launching the final version. They were pinpointed by both negative and positive comments. Also teachers were interested to play the final version of SGM in order to be able to decide whether employ it in class. As a technical point, frequent happening problem in dialogue tool made teachers exhausted and consequently influence negatively on their replies. Therefore, solving the technical problems probably will have significant impact on players' interest to be fully engaged in the game.

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Simulator Based Training to Improve Tradeoffs Analysis and Decision Making in Lean Development Environment

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Abstract. Challenging timetables, extreme requirements and increasing needs and expectations of stakeholders requires a new approach to project management and system engineering. Lean project development (i.e. Agile) is an emerging, promising methodology adapted by leading project management and systems engineering communities. The tools and techniques that can support this new methodology are being developed and tested by universities and industry.

This article focuses on the use of Simulation Based Training (SBT) as a tool for training Systems Engineers and Project Managers in a Lean project environment.

The Simulation Based Training (SBT) performed in this study is based on the Project Team Builder (PTB) simulator, which is an innovative project management and system engineering simulator designed as both a training/ teaching tool and a decision support system for project teams.

Keywords: SBT, tradeoff analysis, decision making, lean development.

1 Introduction

Project teams face complex decisions on a daily basis. In order to meet or exceed stake holders' needs and expectations project teams must plan and replant their project to keep it on track. Their decisions are made in an uncertain, dynamic and constrained environment spanning a large variety of areas such as outsourcing decisions, design decisions, risk management decisions, resource related decisions, budgets and schedule related decisions etc. Teamwork is essential in this challenging environment and shared understanding of the project goals and constraints is the foundation of teamwork.

Since erroneous Decisions are often costly, organizations invest considerably in training project managers and project teams and in decision support systems.

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The main focus of this article is on the following questions:

Q1: Does Simulation Based Training yield clearer insights regarding project tradeoffs?

Q2: Does Simulation Based Training improve decision making?

Specifically, the following hypotheses will be tested in controlled experiments and field studies:

H1: Simulation Based Training improves tradeoff analysis.

H2: Simulation Based Training improves decision making.

1.1 Decision Making

The process of decision making is of a cognitive nature. A prevalent model [1] lists the following four stages:

- Collecting relevant data as a baseline for making a decision.
- Assessing all possible alternatives.
- Contemplating the various alternatives – comparing the different possibilities by anticipating the advantages and disadvantages of each of them.
- Choosing the preferred alternative = making a decision and committing to its performance while taking its specific consequences into consideration.

This model is applicable to the process of decision making both by individuals and by groups. The quality of decision making can be measured in two ways: the quality of the process and the quality of the decision.

Process quality – may be assessed by examining the alternatives considered, the methodology used, the way different parties are involved etc.

Decision quality – may be assessed by the results stemming from the decisions, i.e., adherence to requirements, the efficiency of using resources, the actual cost, the level of stake holders' satisfaction, etc.

1.2 Simulation Based Training (SBT)

Simulators are an effective tool for learning, practice and development of appropriate skills for problem solving and they have obvious advantages over other learning methods [2].

In recent years the use of simulators for learning and for supporting the decision making process has become very popular in various fields such as medical sciences, sociology, the military and engineering i.e., supply chain management and quality control [3].

Much research deals with the use of simulators in the learning process. [4] have raised ten hypotheses regarding the advantages of using simulators over other learning methodologies:

1. A simulator provides the user with applicable tools from the learned theory to its practical aspects.

2. Using a simulator accelerates skill acquisition and specialization, as well as shortens learning duration, due to the simulator's ability to contract time and space dimensions.
3. A simulator provides a more realistic environment, closer to the "real world" working environment.
4. A simulator is able to simplify complex realistic problems so that they correspond to the users' level of knowledge and experience.
5. A simulator encourages critical thinking. Engaging in practice while using a simulator enables the users to make "risk free" errors and even to receive these errors implications as outputs without causing any real damage.
6. A simulator enables the user to run extreme scenarios which are rarely practiced, yet still are important to experience.
7. Using a simulator is of relatively low cost as compared to other learning and training methodologies that are in use to help make professionals more effective.
8. Simulators are usually simple to learn and to operate.
9. Controlled learning – the simulator enables each user to advance according to their own pace.
10. The experience of learning – the simulator is based on a learning game which creates interest and pleasure for the user, who in turn maintains a higher learning motivation level than the level displayed in passive learning methodologies.

A host of project simulators have been developed for various purposes. Notable examples are: SimProject, Project Scheduling Game, Topsim, PEG (Project Execution Game), Simultrain and others. The Simulation Based Training (SBT) that will be performed in this study is based on the Project Team Builder (PTB) simulator.

1.3 The Project Team Builder Simulator

The Project Team Builder (PTB) is based on a simulation approach; the simulator can simulate one or more projects or case studies. Each case study is a project or a collection of projects performed under schedule, budget, and resource constraints, with a given set of requirements in a dynamic stochastic environment. A user-friendly case study generator facilitates the development of new case studies as required. The simulations are dynamic: the "real" situation changes over time while running the scenario. A random effect is introduced to simulate the uncertainty in the environment. The user can plan the activities of the project in several ways (modes). The various modes represent the technological or operational alternatives. The selections of modes affect the time, the cost and the performances of the simulated project. The simulator contains a model base with well-known models for scheduling, budgeting, resource management and monitoring, and control.

The PTB simulator is unique because it is designed as a teaching tool and as a decision support system for project managers and their teams. The user can develop and analyze scenarios for a range of real projects that should be analyzed (construction projects, R&D projects, software development projects and infrastructure projects such as those in the chemical and energy industries). By separating the simulator engine from the scenario building module any real project can be developed into a scenario and used to train and/or to support decision making processes as explained next.

PTB contains widely used models of project management—e.g., Network and Gantt charts for project scheduling, cash flow charts for budget planning, resource load charts for resource planning, Monte Carlo simulation for risk management, and a monitoring and control module for tracking project performance.

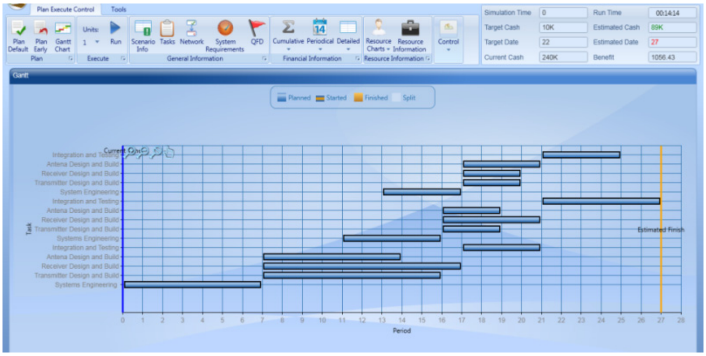

Fig. 1. Screen caption from PTB showing an example of a project Gantt chart

Trainee success in the PTB simulation is determined by the quality of their decisions and the time required running the scenario. The quality of decisions is measured by the compliance with the required performance of the developed system, project duration and by the total project cost at the completion of the simulation.

The simulator measures the runtime of each scenario from start to finish.

We hypothesize that use of the PTB simulator for training project managers and system engineers improves the decision making process so that the results obtained at the end of the project are better in terms of cost, performance and duration.

The paper is organized as follows: The next section presents typical decisions in the area of project management. Next we present the research questions and hypotheses.

The following chapter describes the research methodology. Finally, the results of the experiments are discussed and conclusions are presented.

2 Methods

Two experiments were performed. The first was performed on individual participants whereas the second was performed on project teams, as described above.

2.1 Scenario Description

For this research, real project-based scenarios were developed. For example, the "Transceiver" scenario (see Fig. 2) is based on a real-life project of an airborne communications system.

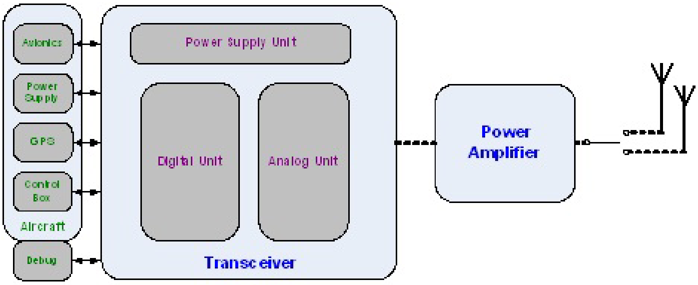

Fig. 2. "Transceiver" system block diagram

The simulated scenario reflects two typical design alternatives:

1. Improvement of receiver reception sensitivity ("listening more carefully").
2. Transmission power increase ("shouting louder").

2.2 Activities and Modes in the Scenario

Table 1 presents an example of the possible modes (viz. performance) alternatives for each activity in the scenario.

Table 1. Activities and Modes in the Scenario

Activity Number	Activity Name	Reception Improvement Alternative	Transmission Power Increase Alternative	Influence on System Performance – Schedule/Cost
1	Modem card developmen t	Highly complex	Standard	More expensive and longer schedule
2	Power supply	Standard – off shelf	Assigned power supply	Investing in design, schedule. Designated supplier provides higher performance
3	Power amplifier	Standard Reuse	Redevelopment	More expensive and longer schedule

2.3 Measurements

The measurements performed in the experiment are:

1. System performance requirements – a weighted score given at the end of the simulator run. This score is termed "benefit".
2. Cost at project completion.

3. Project duration.
4. Simulator run-time.

These measurements are the result of the decisions made by the trainee. Additional information was collected by questionnaires.

2.4 Experiment Description

2.4.1 Experiment #1: Individual Participants

Three groups participated in this experiment:

- A group of 16 very experienced project managers with experience of over 5 years.
- A group of 17 experienced project managers with fewer than 5 years of experience.
- 18 graduate students

The essence of the experiment is to let the trainees "manage" the project themselves. Their goal is to optimize the ratio between system performance and costs (cost benefit analysis). Upon completion of the simulation, each participant was handed a questionnaire focused on tradeoffs analysis and decision making.

2.4.2 Experiment #2: Project teams

Nineteen project teams participated in this experiment with a sample size (i.e., the number of participants) of N=57.

A crossover (PTB/MSP) experiment was designed to test whether SBT improves tradeoff analysis and decision making.

Participants were randomly divided into teams and roles, each including a Project Manager, a Systems Engineer, and a Quality Assurance Engineer. The teams' target was to optimize the ratio between system performance and costs.

Upon completion of the PTB/MSP project plans and runs, participants were requested to record the plan results: duration, cost, performance, as well as to fill out a questionnaire focused on tradeoffs analysis and decision making.

2.5 Data Analysis

The data were analyzed using two statistical procedures: the Chi-square test and the Analysis of Variance (ANOVA). ANOVA is aimed at testing the differences between the means of more than two samples, and is based on the partitioning of the variance in the data into different sources.

The results of the analysis are reported below in the following format: Chi-square=XX; df=XX, P<XX. The value of the statistic in the test was performed, Chi-square is presented first. This is followed by the number of Degrees of Freedom (df) that were used in the test. Finally, the significance is indicated by P, which is the probability of making an error in claiming that the difference is significant. Any probability less than 5% is interpreted in Behavioral Science as a significant difference.

3 Results

There are three clusters of compliance with performance: low (benefit under 20,000), moderate (benefit between 20,000 and 80,000) and high (benefit over 80,000).

1. The effect on tradeoffs analysis is shown by a significant correlation between performance and cost as shown in Fig. 3. (Chi Square = 5.99, df=2, P<0.05). The better the performance, the higher the cost**.**

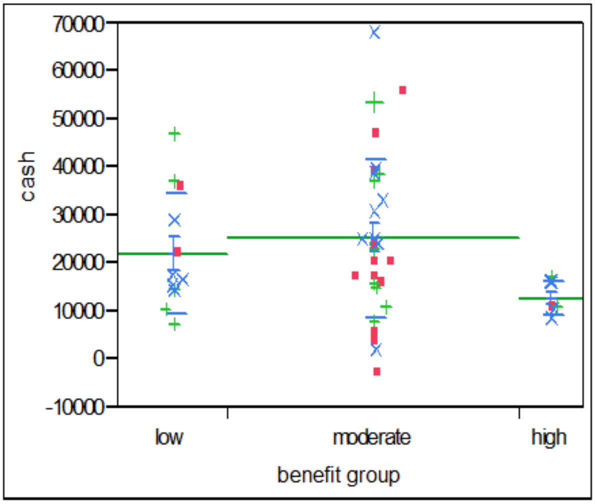

Fig. 3. One-way analysis of cash by benefit group

2. The relationship between the notion that the tool supports decision making and the will to integrate it before or during project life: There is a significant correlation (F=3.5, df=4, P<0.05) between perceiving the simulator as a supporting tool for making decisions and the will to integrate it as a tool for making decisions before or during project performance.
3. The influence of the tool used on the tradeoff analysis was determined by statistically analyzing the questionnaire answers. A Signed-Rank test was performed on two independent samples. This test resembles a single t-test. The differences (PTB-MSP) between the answer given following use of the PTB and the answer given following use of MSP were analyzed. In case the mean value is positive and the P value < 0.05 (indicating significant statistic), the result is in favor of PTB. In other cases, the average result was negative, but the P value was not significant (>0.05). In these cases no conclusion could be drawn in favor of the MSP. An example of the analysis results is depicted in Table 2.

Table 2. Difference analysis results summary on the question level. Significant results are indicated by yellow highlight

Question number	Question description	Average difference (PTB-MSP)	Std Error difference (PTB-MSP)	P_Value (2 sides)	P_Value (1 side)
2 (2A)	How well do you understand the project work process?	0.0023	0.0045	0.1213211	0.3508772
3	How well do you understand the possible trade-offs within the project?	0.0359	0.0718	0.1301087	0.2280702
4	How clear are the decisions you are required to make?	0.0165	0.0330	0.1270308	0.2807018
6	How well do you believe the other team members understand the relationship between time and performance within the project?	0.2982456	0.1250687	0.0204	0.0102

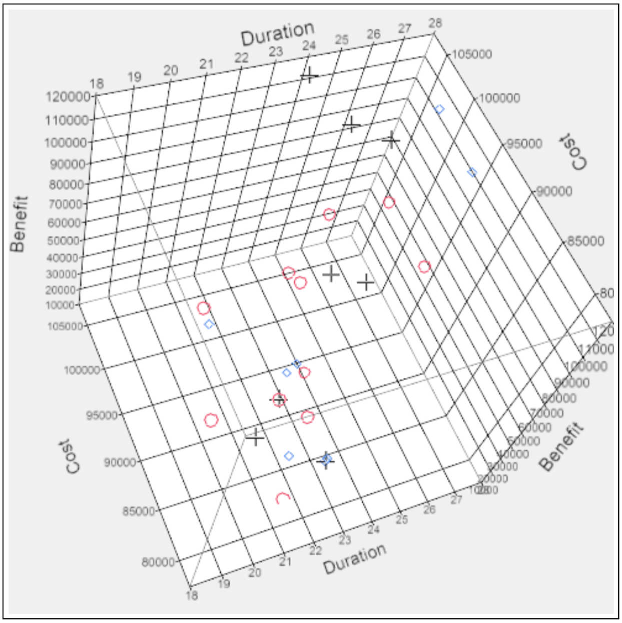

Fig. 4. Team results upon completion of simulation runs with aspects of timing, cost and performance, as compared to the efficiency frontier

Ten out of 16 questions (over 60%) yielded statistical significance with regard to using SBT. However, even when there is no significance, no advantage is seen in favor of the MSP. Even when the observed difference is negative, no significance is detected.

The conclusion is, therefore, that SBT improves tradeoffs analysis and decision making.

Fig. 4 simultaneously compares three dimensions: cost, performance and duration. The results are seen to be clustered in three performance levels: Low, Moderate, and High Benefits. Result analysis shows that in the High performance level teams that opened with SBT tend to achieve higher performance than teams that opened with the MSP tool. The conclusion is, therefore, that SBT contributes to improved project outcomes.

Legend:

+ Efficiency Frontier

º Sample 1

◊ Sample 2

4 Discussion and Conclusions

- The results show that as performance increases, cost increases. These parameters reflect an existing and expected tradeoff.
- The performance requirements for this project could have been implemented in a number of ways and each way provides some compliance with performance requirements. In the real project, the customer is demanding, familiar with the technology and its limits, so that the actual implementation was taken to its technology limit. We had only 6 participants who finished with high end performances, 3 of them were system engineering Master's students, 2 experienced project managers and only one was a very experienced project manager.
- The participants who were interested in providing a fully compliant system did actually achieve this goal in the simulation. However, the price paid for performance improvement (full compliance vs. partial compliance) was higher cost. In other words, project managers who insist on completing the project with full compliance with performance requirements (for various reasons) should take into consideration that the project cost will be higher compared to the cost they may reach with nearly full performance compliance.
- The results of this research demonstrate that SBT improves tradeoff analysis and decision making. SBT can be used effectively to build project teams in a Lean environment. Teams can be trained using SBT with a focus on the real project assigned to the team. By simulating a scenario based on the real project, the team can learn how to integrate the different aspects of project management, and—more importantly—can learn to work and solve problems together. As a result, the project is expected to be managed more efficiently.

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A Simulation Enabled Procedure for Eco-efficiency Optimization in Production Systems

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Abstract. Environmental sustainability in manufacturing has been experiencing increasing attention in practice and academia over the last decades. Manufacturing companies strive to improve their eco-efficiency, which is commonly understood as delivering high value products at lower cost and environmental impact. They need tools and methods to translate this strategic goal onto the operational shop floor level. This paper presents a procedure for optimizing the eco-efficiency of production systems, supported by a discrete-event material flow simulation model. Its application is shown in a case with a company from the Swiss consumer goods industry.

Keywords: Eco-Efficiency, Manufacturing, Sustainability, Simulation.

1 Introduction

Sustainability considerations have gained importance in the public over the last decades. Especially for manufacturing companies, responsible for over 36% of worldwide CO2 emissions [1], increasing the energy and resource efficiency has become a major challenge and success factor. Reasons are steadily rising material and energy prices, increasing customer demand for environmentally friendly goods and legislative pressure holding companies accountable for their environmental impact.

Although measures to improve their environmental impact can be taken along the whole supply chain, SMEs typically lack the bargaining power to influence their supply chain partners. Improvement measures have to be found within their own operations for being the only area they can influence. The main issue for manufacturing SMEs thus is translating a strategic goal to increase their environmental sustainability into concrete improvement measures on a shop floor level, while still ensuring their profitability. This is understood as the optimization of their eco-efficiency [2].

Manufacturing companies need pragmatic analysis and decision support tools to solve this problem. This paper proposes a procedure to assess and optimize the eco-efficiency of production systems. The procedure is supported by a newly developed simulation approach, which couples the static material flow assessment (environmental perspective, MFA) with a dynamic discrete-event simulation (economic perspective, DES) in one model.

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2 Project Background and Methodology

The findings presented in this paper stem from a two year Swiss national project called “EcoFactory”. It is funded by the Swiss Commission for Technology and Innovation and carried out by the BWI Center for Industrial Management (project lead), the Swiss Federal Institute for Material Sciences (EMPA) and the University of Applied Sciences HTW Berlin.

Case study research was chosen as the methodology in order to derive theories from practice [3]. As such, the project encompassed four case companies, as shown in Table 1. For the case selection, random companies were first approached for their interest in participating in the project. The four case companies were then selected for the sake of covering different industry sectors and company sizes. The purpose of the research can be categorized as theory building [4]. In a first step the state of the art in the field was assessed through exploratory literature reviews. Data from the case companies was further gathered mainly through semi-structured interviews. The research resulted in conceptual models for the simulation approach and the analysis procedure.

Table 1. Overview of case companies in EcoFactory project

Case Company	A	B	C	D
Industry	Consumer Goods	Packaging	Food	Metal Working
Size	55	115	800	3500

3 State of the Art

Assessing and monitoring the economic performance of their production system has become a mature process for most manufacturing companies. The system boundaries for the analysis are clear and a broad consensus exists on which performance measures should be used for specific purposes. Further, the availability of data for the economic assessment is usually very good, since they can commonly be derived from data (semi-)automatically collected and updated from ERP or MRP systems.

An assessment of the environmental performance of a production system on the other hand is by far more challenging, since the environmental impact of a production system has different dimensions (e.g. air and water pollution, toxicity)and is driven by manifold aspects (e.g. energy and material consumption rates, support processes) [5]. Furthermore, there are different methods available to assess the environmental performance, each well suited for a different purpose (for an overview see [6]), while Life Cycle Assessment (LCA) represents the predominant one.

Thiede and Herrmann state that an integrated assessment of environmental and economic performance of a production system requires a system-oriented approach in order to identify the truly relevant fields of action for improvements [7]. Discrete-event simulation (DES) models have been acknowledged as powerful tools for increasing the understanding of complex systems. They allow the user to gain insights into interactions between important variables in the performance of the system through their ability to reflect the dynamics of a system [8]. Since commercially available simulation tools do not yet consider environmental aspects, some effort has been undertaken in research during the last years to develop simulation models that aid the environmental assessment of production systems. A comprehensive overview of different approaches can be found in [9].

However, most developed approaches are still based on different model representations for the economic and environmental assessments. As such, they first use a DES model to investigate time-sensitivity and stochastic effects in regard to the economic perspective. Although based on the same object of reference, a material-flow assessment model is additionally required as a basis for the LCA of the manufacturing system, resulting in additional modeling efforts and is inconsistent when aiming at an integrated assessment of the production system.

For overcoming this gap, a simulation model needed to be developed that integrates both the environmental and the economic perspective in one unified model. The simulation model is preceded by a system analysis procedure reducing modeling efforts and ensuring that environmentally relevant consumption parameters are made available in the required granularity. The results will be explained in the following.

4 Project Findings and Results

4.1 System Analysis

The developed system analysis procedure is based on the standard process of a simulation study, as originally formulated by Nance [10]. Figure 1 shows the basic steps of the system analysis, which will be described in the following.

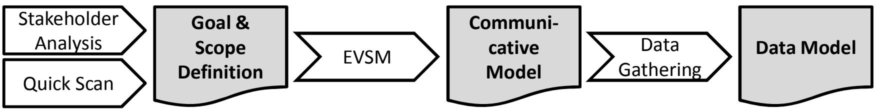

Fig. 1. System analysis procedure

The strategic goal to improve the eco-efficiency of a manufacturing company can be motivated externally or internally. Therefore, as a first step, it is important to understand the area of conflict the company is operating in. An extended stakeholder analysis was deemed a viable tool to identify which stakeholders impose pressure upon the company to improve their eco-efficiency. The most relevant aspects analyzed in this context are customers, suppliers, competitors, government, employees, society, technology and environment.

In addition to external pressures, manufacturing companies may have a proactive attitude towards the environmental sustainability of their business. In such cases, companies search for the activities and aspects that mainly drive the environmental impact of their production. In order to identify the production processes yielding the highest optimization potential, a qualitative analysis is conducted of the whole production facility. For this purpose, the Cleaner Production Quick-Scan was adapted

[11-12]. It is based on semi-structured interviews, checklists and a thorough factory walk-through. All production processes are assessed according to their economic and environmental optimization potential. The results of the Quick-Scan help to delimit the system that will later be analyzed in detail and modeled for the simulation. These two first steps lead to the Goal and Scope Definition, which serves as a basis and guidance for the further analysis and the whole simulation study.

For the in-depth analysis of the previously defined area of intervention, the Environmental Value Stream Map (EVSM) has been developed. It is based on the traditional Value Stream Mapping technique known from the Lean Production/ Just in Time Toolkit. The purpose of a traditional VSM is to illustrate the material and information flows along the value stream of a product in order to identify the sources of wasted productivity [13]. It has been extended to include an input-output perspective on each of the production processes in order to additionally capture their environmentally relevant aspects. The structure of the EVSM is shown in Figure 2.

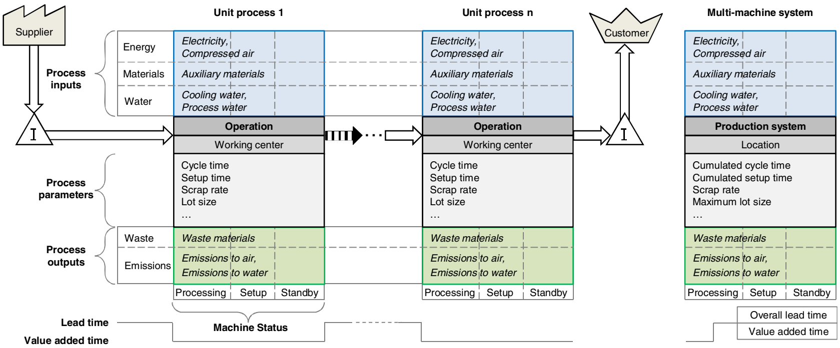

Fig. 2. Structure of the Environmental Value Stream Map [14][15]

The blue boxes on the top capture all environmentally relevant inputs into a production process, sub-categorized into energy, material and water inputs. The green boxes on the bottom capture all outputs of the process not related to the actual product or component produced. These are categorized into waste and emissions (air and water). As a result, the EVSM delivers a clear and accurate picture of all parameters needed to assess the eco-efficiency of the system. It is thus a suitable basis for the application of the simulation model that will be introduced in section 4.2.

Experience has shown that most environmentally relevant parameters, such as consumption rates of electricity, are only seldom available on a process level, so that measurements become necessary. For this purpose, a measuring procedure was developed together with the Institute for Machine Tools and Manufacturing of the ETH Zurich. Details on the measuring procedure can be found in [15-16].

4.2 Simulation Model

To overcome the shortcomings of current simulation models, a new model was developed in close cooperation with the University of Applied Sciences HTW Berlin within the EcoFactory project. The model is based on a prototype architecture previously developed by HTW [17-18]. The approach focuses on integrating DES and MFA into one simulation model.

The model focuses on a cradle-to-gate perspective considering the environmental impacts of the production system. As such, the production facility is considered as the foreground system, which is explicitly represented and parameterized in the simulation model. The environmental impact of the upstream supply chain of the production is considered as the background system and not explicitly modeled. Within the simulation model, this aspect is accounted for through the integration of LCI data. Figure 3 shows the structural model of the simulation approach.

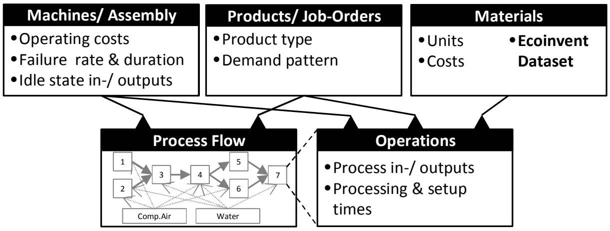

Fig. 3. Structural model of the simulation approach

As the illustration shows, the production system is modeled as a workflow of interlinked manufacturing operations. Each operation is determined by the workstation it takes place on (e.g. machine, assembly station), the product type being processed and the materials required as inputs (e.g. energy, water, auxiliary) or generated as outputs (emissions, waste). LCI datasets are imported for the definition of the material in- and outputs through an interface to the "ecoinvent" database, which is hosted and managed by EMPA. For this purpose, a search function for the LCI flows is incorporated in the simulation software. This interface also allows for the use of all LCA methods available in "ecoinvent" to support the evaluation of the environmental impacts. Hence, the structure of the simulation model is able to deliver a dynamic, job oriented LCA of the production system. The architecture further entails a definite attribution of workstations, products and materials. This enables the assessment of both the environmental and economic performance. For further details on the simulation software see [19-20].

5 Case Study Application

In this section, the application of the before described system analysis procedure and simulation model is shown on the example of case company A. The company counts 55 employees and produces made-to-order eyeglass lenses from specialist plastic billets. The billets are first milled to their required size and geometry before surface finishing and coating processes are applied according to customer specifications.

The stakeholder analysis and the Quick Scan showed that, while being an integral part of the company's proactive strategy, there is no significant pressure from stakeholders to reduce environmental impact. Reducing the material waste generation and electricity consumption were targeted as the main objectives. Figure 4 shows the EVSM of the company's production system as well as the simulation model in the graphical user interface of the software.

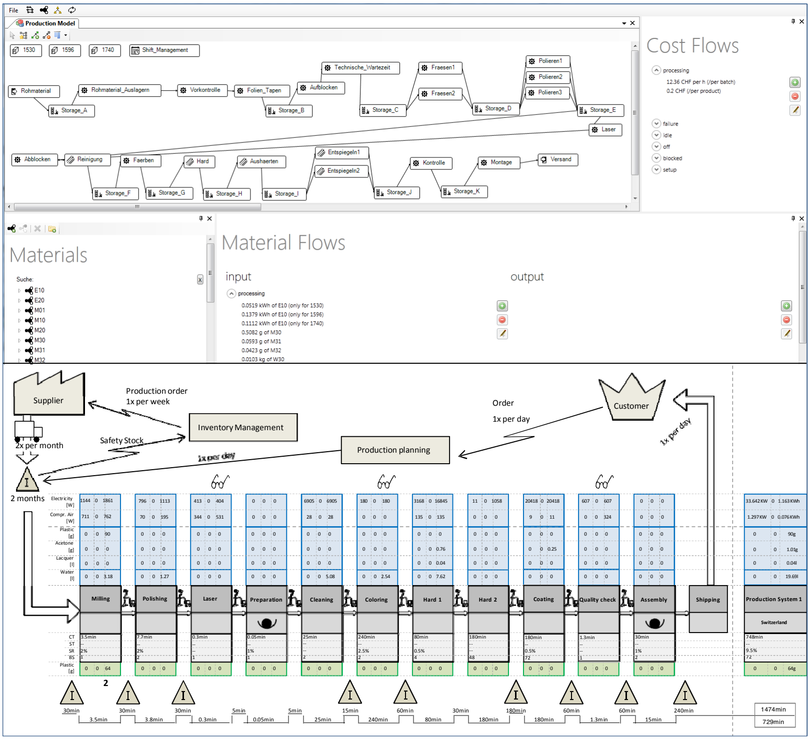

Fig. 4. EVSM and screenshot of the simulation model

The computed eco-efficiency per workstation for company A is shown in Figure 5. It is evident that the highest optimization potential lies in the antireflection finishing, milling and polishing processes. Figure 5 further shows an analysis of the eco-efficiency of the most relevant materials consumed within the production system. For this purpose, GWP100a (Global Warming Potential, in tons of CO2 equivalents) was chosen as the environmental performance indicator. This analysis shows that electricity consumption is the most relevant environmental impact factor, whereas the coating material use is the biggest cost driver. The simulation results further showed a rather poor capacity utilization of the antireflection finishing and polishing processes with idle times accounting up to 30-40% of total time respectively. An improved job-order planning for these processes, allowing to switch off the machines for longer idle periods, is being tested at the company. Based on simulation experiments, this measure has an estimated potential to reduce the overall electricity consumption by up to 10%.

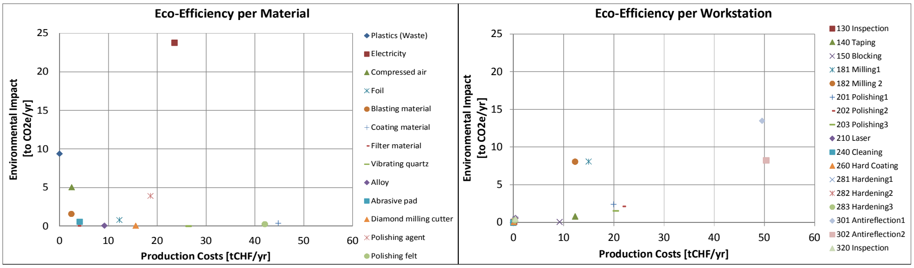

Fig. 5. Eco-efficiency of materials and workstations

6 Discussion and Conclusion

This paper presented a novel simulation approach, which combines discrete-event simulation with LCA in one unified model. Its architecture allows for a definite attribution of materials, workstations and products, delivering a higher degree of transparency to the production processes than current approaches. Further, a system analysis procedure was presented, designed to deliver all relevant data and information for building the simulation model of a production system with minimum efforts.

The main limitation to the presented approach is the commonly limited data availability at a process level, especially concerning environmentally relevant parameters. To unfold its full potential, the simulation model requires product-specific material consumption parameters on a process level. The lack of this data calls for dedicated measurements, which can result in significant efforts for the company. Nevertheless, at the case companies these measurements alone increased the awareness and transparency of consumption patterns within the production system and were by themselves deemed useful by the responsible production managers.

In summary, the application of the approach in company A resulted in time efforts of 10 days (6 days for the system analysis, 4 days for modeling activities), that were deemed acceptable by the company representatives. The simulation analysis pointed to an improvement measure estimated to reduce the electricity consumption in production by about 10%, while further measures are currently being evaluated.

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Teaching Supply Chain Management: Mixed vs. Pure Strategies in Simulation Based Training

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Abstract. We investigate two inter-entity strategies for using SBT by teams—a competitive strategy and a cooperative strategy within the supply chain management domain. We examine how a combination of these inter-entity strategies would work at situations wherein both are used, one following the other. The goal is to investigate from a pedagogical and practical perspective which strategy is the most effective using SBT techniques for business education—pure strategy (strictly cooperative/competitive) or mixed (a combination of both). The results indicate that it is better to teach with mixed strategies when using SBT by teams, than to teach only one (pure) strategy. Moreover, if both strategies are used, then the order of teaching is significant. It is better to start with a competitive strategy and then move to a cooperative strategy rather than the reverse.

Keywords: Management Education, Simulation Based Training, Competitive, Cooperative.

1 Introduction

Over the past decade, there has been an enormous growth and development in business education. New programs have emerged while existing ones have been extended and enriched with upgraded content. These educational programs include courses that are taught using various pedagogical methods that include frontal lectures, books, recorded presentations, seminars, group learning, etc. by virtue of being confined to a classroom environment traditional methods have struggled to transform expert intuition and theoretical knowledge into practical experience. An emulation of a real physical environment is one way to aid in this transformation. However, efficiently and effectively providing this emulation is an important challenge of management education which has yet to be answered [1, 2]. Nonetheless, over the past decade spectacular advances in infrastructure technologies that enable the use of modern tools to enhance learning have been proposed.

One tool that has been extensively investigated is computerized automated simulators. Simulation creates an artificial environment that reflects and illustrates real-life experiences [3]. Of particular interest to us is the use of simulation for knowledge

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transfer. This process is typified by the knowledge a trainee gains during his experience with the artificial environment (simulation) and the subsequent implementation of the knowledge. One characteristic of an efficient simulation tool is its ability to facilitate learning that can be transferred to a real-life environment [4]. In the context of education, using simulation as a teaching methodology is commonly referred to in the literature as Simulation Based Training – SBT.

SBT for business education provides several advantages over traditional techniques, such as supplying hands-on practice and allowing for the development of skills at a faster pace [5]. Salas et al. delineated seven basic stages of SBT development in business education [6]. Other researchers provided some practical guidelines as to how best to implement and use SBT in business education—e.g., offer detailed focused feedback, and directly measure outcomes [5]. Some researchers [5, 7] asserted that SBT can be an efficient tool for business education, but only when the gap between the trainee's *a priori* knowledge and the difficulty of the simulation exercise are matched. Inasmuch as SBT is important for current and future education, it is essential to identify the circumstances under which SBT is most effective.

In this paper, we investigate two inter-entity strategies for using SBT by teams—a competitive strategy and a cooperative strategy. Research has attempted to determine which strategy is better for training teams [8, 9, 10, 11]. Sherman's study [11] showed no significant differences in cooperative and competitive learning. A recent study on these SBT inter-entity strategies was carried out within the project management domain [12] and indicated that cooperative strategies yield better results in the overall outcome. There are pros and cons for each strategy [11], yet the cooperative one is considered to be more effective [12, 13]. Students who were trained using a cooperative strategy, which is better for long term relationships [14], tend to employ this strategy in their professional life. The parties involved are usually more satisfied, and as a result, the overall business profit rises [15]. To the best of our knowledge, no study has examined how a combination of these inter-entity strategies would work. That is to say, research has looked at the results of using one or the other strategy but not at situations wherein both are used, one following the other. This is a lacuna that we come to fill in. Unlike past research that focused on finding the best strategy we look at a combination of the two strategies. We investigate this issue within the supply chain management domain. The goal of this paper is to investigate from a pedagogical and practical perspective which strategy is the most effective using SBT techniques for business education—pure strategy (strictly cooperative/competitive) or mixed (a combination of both).

2 Experiment Research Design

In this section we present our experimental design, starting with our hypothesis and culminating in a detailed experimental design. In Section 3 we report on the results of the experiment and analyze the data.

2.1 Hypothesis

Different parties comprise the supply chain, each desiring to meet their own goals. In this pursuit they can adopt omnifarious inter-entity strategies, including competitive and cooperative ones, in regard to the interrelationships with their colleagues. When students are being taught about the interdependence among the supply chain parties, the teacher can choose to teach using one or both of these inter-entity strategies. Our experiment tests the following hypotheses in regard to cooperative and competitive inter-entity strategies in using SBT by teams:

Hypothesis 1: Using a mixed strategy (cooperative and competitive) achieves better learning outcomes than using a pure (single) strategy.

Hypothesis 2: When using a mixed strategy, the order of the two strategies affects the learning outcomes.

2.2 Experiment Design

To examine these pedagogical hypotheses we use a new advanced SBT computerized simulation environment. The software, Supply Chain Simulator (SCS), is a web based computer simulation application developed at the Technion. It is designed as an educational platform to enable students to gain better understanding and experience in managing supply chains. SCS is based on the following principles: Ease of use, Scenario based training, Flexibility, and Supportive data.

Two classes (I and II) of freshman undergraduates in the Industrial Engineering and Management Faculty of the Technion participated in the experiment. Class I consisted of 134 students and Class II consisted of 121 students. None of the students had theoretical or formal training with supply chain management. Prior to their first task using SCS the students received an introduction to supply chain management and SCS. The introduction included an oral presentation and live demonstration of how to use SCS, instructions on how to run scenarios and an explanation of the performance measure used (i.e., profit) and how it is calculated. The students were motivated to pursue the highest profit possible as this performance measure determined their grade in each task. The students ran four scenarios, two of them were individual tasks (the first and fourth scenarios) and the other two were run in pairs. The nature of the four scenarios was as follows.

Scenario 1: Managing a supply chain with an intermediate level of difficulty. The supply chain scenario comprised seven facilities (two manufacturers, two warehouses and three retailers). In the beginning of each period the students had to make several managerial decisions such as the quantity to produce at each manufacturing facility, the order quantity of each warehouse and retailer, and the supply priority in case of a conflict between external demand (customers) and internal demand (orders from another facility within the supply chain). The students' goal was to maximize the overall profit over twelve time periods. Each student had ten trials and the best performance was recorded. The purpose of this scenario, as far as this research is concerned, was to expose the students to the simulator and allow them to practice so that all groups of students would be aligned in their ability to operate the simulator.

Scenarios 2 and 3: For these scenarios (2 and 3) each class (I and II) was divided into teams of two students. Additional segmentation was done as the teams were divided randomly into two groups (A and B). The teams and the groups remained unchanged. Each scenario included a supply chain with an advanced level of difficulty that needed to be managed by the team. Each supply chain scenario comprised several facilities (manufacturers, warehouses and retailers). One student was in charge of the "manufacturing division," which included the manufacturers and the warehouses, and the second student was in charge of the "marketing division," which included the retailers. Each student had an individual goal to maximize his own facilities' profit over twelve time periods; nonetheless the students had to work together as a team to manage the same scenario.

The nature of the work relationship between the team members was sometimes competitive or cooperative. The different inter-entity strategies were realized in the way the students were graded. Every team had twenty trials for each scenario. In the competitive strategy, the students had to decide by themselves which trial was the one used as their grade. They had to choose the same trial for both team members even though this trial would not necessarily represent the supply chain's best overall performance. The students in the same team were nonetheless individually graded according to their individual performance, regardless of the overall team performance. Clearly, the two students on each team were at odds with each other since each team member wanted to choose the trial that was best for him and this was generally not the best for his partner. When the team members were unable to agree upon a specific trial, the average performance over the last ten trials was used as the grade.

In contrast, in the cooperative strategy the students did not have to decide which trial would be considered for their grade; the trial that produced the maximum overall profit for the entire supply chain was used. The students in the same team were still individually graded according to their individual performance.

The assignment of the teams is as follows. In Class I, the teams in Group A were assigned a competitive strategy for Scenario 2 and a cooperative strategy for Scenario 3. The assignment to Group B was reversed: the teams used a cooperative strategy in Scenario 2 and a competitive strategy in Scenario 3. Both scenarios were actually the same though the students were unaware of this fact (the facilities of the supply chain were organized differently on the map). Consequently, the potential performance (overall profit) of each exercise was the same.

In Class II, the teams in the groups were always assigned the same strategy. Teams in Group A were assigned the competitive strategy and teams in Group B were assigned the cooperative strategy.

Scenario 4: An individual task similar to the first one. The scenario had an advanced level of difficulty, requiring each student first to design an efficient supply chain using predetermined facilities and then to manage it. The goal was the same as in Scenarios 1 – 3, i.e. to maximize the overall profit over twelve time periods. The goal of the experiment was to measure each student's individual ability after they had learned and gained experience. In addition, this scenario enabled us to compare the two groups' performances. Moreover, Scenario 4 was exactly the same for the two classes, thus enabling us to compare the two classes' performances after handling Scenarios 1 – 3.

3 Experiment Results and Analysis

For Class I we had 66 teams in Scenarios 2 and 3, 32 teams in Group A and 34 teams in Group B. In addition, we collected 120 results of individual students in Scenario 1 and 127 results of individual students in Scenario 4. For Class II we collected the results of 61 teams in Scenarios 2 and 3, 30 teams in the 'Comp-Comp' group and 31 teams in the 'Coop-Coop' group. In addition, we collected 111 results of individual students in Scenario 1 and 112 results of individual students in Scenario 4. The reduction in the number of students participating in the various scenarios was caused by students dropping the course. Moreover, we believe that their reasons for not continuing in the course were unrelated to the simulator. We note that the number of students dropping the course was no greater than normal. In addition, in each class there were 2-3 outliers observations that were removed. These outliers were students that achieved very law score in one of the scenarios, usually that occurred when they started the scenario but abandoned it in the middle.

Whereas one may feel that a simple t-test is suitable to check our hypotheses, we found this not to be the case. The main reason is that the within-group variance masks the differences between groups. This can be understood by the bivariate fit analysis of the performances of both classes. When analyzing Class I and II results, a strong correlation between the teams and their performance was revealed (Class I p.value < 0.002, Class II p.value < 0.001). Fig. 1 present the bivariate fit test results of the correlation between the teams and their performance in Scenarios 1 and 4 in Class I. Class II demonstrates a similar behavior. The teams tended to show either high or low performance regardless of strategy. Due to the correlation findings and in order to reduce the within-group variance, in all our statistical tests below we used ANCOVA to test the significance of differences between the group means of the students' performance in Scenario 4 (dependent variable) using students' performance Scenario 1 as a covariate.

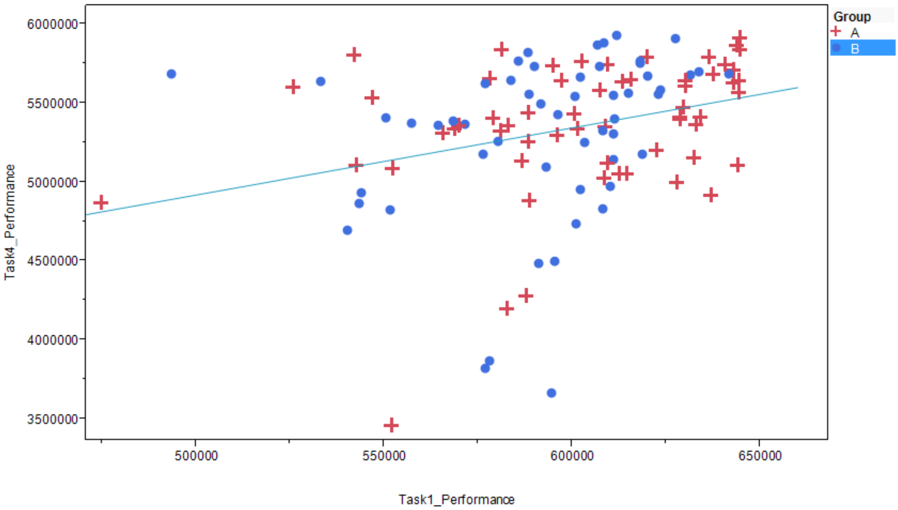

Fig. 1. Bivariate fit graph of Class I Scenarios 1 vs. 4

3.1 Hypothesis 1

In order to test whether a mixed strategy achieves better learning outcomes than using a pure strategy, we checked whether there is a significance difference in the performance of Class I vs. Class II in Scenario 4. We used ANCOVA to test the significance of differences between the means of the students' performance in Scenario 4 (dependent variable). Due to the correlation findings and in order to reduce the within-group variance, we used students' performance in Scenario 1 as a covariate. The results indicate that the performance in Scenario 4 is dependent on the Class. The significance of the model has a p value < 0.001 and the significance of the independent variable (class) has also a p value < 0.001.

3.2 Hypothesis 2

In order to test whether the order of the two strategies is significant when using a mixed strategy, we checked whether there is a significant difference in the performances in Scenario 4 between the groups of Class I. We used ANCOVA to test the significance of differences between the mean performances of the two students groups in Scenario 4 (dependent variable). Due to the correlation findings and in order to reduce the within-group variance, we again used the students' performance in Scenario 1 as a covariate. The results indicate that the performance in Scenario 4 is dependent on the Group when correcting for the groups' performance in Scenario 1. The significance of the model has a p value < 0.001 and the significance of the independent variable (Group) has a p value of 0.007.

4 Discussion and Conclusions

This research focused on team learning using SBT techniques in the business management education domain. We utilized a simulator to manage a supply chain. Two different strategies in were investigated—cooperative and competitive—trying to determine whether a pure strategy or a mixed one is the most effective when using SBT. This study, adopting statistical models to assess the effect of the variables on the students' performance, showed significant results. These results indicate that it is better to teach with mixed strategies when using SBT by teams, than to teach only one (pure) strategy. Moreover, if both strategies are used, then the order of teaching is significant. It is better to start with a competitive strategy and then move to a cooperative strategy rather than the reverse.

The students from Class I in Scenario 4 outperformed the students from Class II in this scenario, thus it supports our first hypothesis that it is better to teach both strategies than only one. A possible explanation to the observed phenomena is that teaching both strategies when using SBT by teams, exposes the students to a broader experience than students who are being taught by only one strategy. This experience enriches the learning process thus it is more efficient.

It seems that teams of Class I that started with a competitive strategy and then used a cooperative strategy learned from this process. The learning was expressed by their better performance of the teams when using a cooperative strategy than a competitive one; i.e., the second round performance was better than the first one. In contrast, teams that started with a cooperative strategy and then used a competitive one did not learn enough from the first round in order to improve their performance in the second round. This observation is supported by the zero difference in the performance of the first and second rounds for the teams using a cooperative and then a competitive strategy. That being the case, allegedly learning from Scenario 2 to Scenario 3 in Class I did not occur (on average) for a team that started with a cooperative strategy.

An additional finding that strengthens the assertion that it is better to start with competitive strategy and then move to cooperative is the students' performance in Scenario 4, which enabled us to compare all the participants' performance. In Scenario 4 the students of Class I that started with the competitive task significantly outperformed the students who started with the cooperative task.

A potential explanation to the differences in the performances of the two groups in Class I is that a competitive exercise causes the team to experience the negative effects of competition and thus during the next session, the team members will appreciate the opportunity to cooperate. Accordingly, one may conclude that learning occurs when the student starts from the "negative example" (competitive), and not the other way around. That is to say that a "negative example" is a better way to induce learning.

Another possible explanation is that a team that started with a cooperative strategy has already internalized the benefits of cooperation. Thus when the team faced a competitive strategy (scenario 3), its members did not act according to the competitive instructions, but continued to act as if they were in a cooperative exercise. It is possible that trying to teach a competitive strategy after a cooperative strategy has already been taught is not effective, as the participants do not follow the competitive strategy instructions but prefer to act as if using a cooperative strategy. The effect here was intensified because the competitive teams were not motivated to act competitively—there was no penalty for them if they did not do so.

A technical explanation for the above findings may perhaps be that a competitive exercise could be more effectively handled from the simulator point of view. It forces each member of the team to deal with the exercise (each team member must take care of himself if he wants to succeed, whereas in a cooperative exercise, each team member knows he can count on his partner).

After considering the above explanations, we propose some guidelines on how to use SBT for team training:

- Teach using both cooperative and competitive strategies (and not just one of them) when using SBT by teams.
- When training teams and trying to encourage a certain behavior and eliminate another behavior considered to be negative, it is better for trainees to first gain experience with the negative behavior and its repercussions; only afterwards should they be exposed to the desired behavior and its benefits because in the latter situation the differences are more obvious and the learning process is intensified.
- Even if teams are being trained in the reverse order (i.e., first the desired behavior and only afterwards the negative one), then make sure that the teams follow the instructions and actually act upon the negative behavior, they should be given motivation to do so.
- Even though the team acts as one unit, in order to ensure that each member participates fully in the exercise and personally gains from it, each should be given personal responsibility and a separate grade. This minimizes the free rider phenomenon.

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Performance Analysis of Reverse Supply Chain Systems by Using Simulation

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Abstract. This paper proposes methodologies of simulation modeling and analysis of supply chain systems with reverse logistics flows. This paper discusses two types of reverse supply chain: PUSH-type reverse logistics and PULL-type reverse logistics. Generic models are introduced and analysis examples of individual features will be provided.

Keywords: Reverse supply chain, Simulation, Performance evaluation, Reverse logistics.

1 Introduction

A supply chain system is a chain of processes from the initial raw materials to the ultimate consumption of the finished product spanning across multiple supplier-customer links. It provides functions within and outside a company that enable the value chain to make products and provide services to the customers. There are many discussions on supply chain operations.

In the last decade, due to environmental and ecological responsibility, enterprises are trying to reuse, remanufacture and recycle the used products to reduce the negative impact on environment, especially the manufacturers of the electrical consumer products. Requirements for corporate responsibility and sustainability are getting more urgent.

Reverse supply chain problems have been discussed from various viewpoints. Gupta at al. reviewed sustainable supply chain systems from management view [1]. Chouinarda at al. discussed reverse logistics activities, and proposed information support system, which covers recovery, processing of unused products, and redistribution of reusable materials [2]. Chung and Wee developed an integrated deteriorating inventory model with green-component lifecycle value design and remanufacturing [3]. Fuente et al. proposed an integrated model for the forward and reverse supply chain management (IMSCM) and demonstrated an application to a metal-mechanic company. This model covers demand management, order management, manufacturing management Procedures, Procurement Management Procedures, Distribution Management Procedures, Client Management Procedures, etc.[4]. Emilianni discussed the use of online reverse auctions to source engineered components in global aerospace supply chains using online reverse auctions [5]. Gou et al. discussed an optimal delivery policy of delivery and showed the formulas for optimal policies of

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delivery by using modifications of the EOQ model [6]. Minner combined the problem of safety stock planning in a general supply chain with the integration of external and internal product return and reuse [7]. Nagumey and Toyasaki developed an integrated framework for the modeling of reverse supply chain management of electronic waste, which includes recycling [8]. They described the behavior of the various decision-makers, and constructed the multitiered e-cycling network equilibrium models.

Performance analysis of supply chain systems is a critical issue in its design stage. Simulation is such a generic approach that gives solutions of performance analysis of supply chain systems. Chan et al. applied simulation to analysis of impact of collaborative transportations in supply chain systems [9]. Chatfield et al. developed a supply chain simulation system by using an object-oriented modeling method [10]. Labarthe et al. proposed an agent-based modeling and simulation of supply chain systems [11]. Umeda and Lee developed a general purpose supply chain simulator [12].

This paper proposes methodologies of simulation modeling and analysis of supply chain systems with reverse logistics flows, and discusses system performance of two types of reverse supply chains: PUSH-type reverse model and PULL-type reverse model. The characteristics of each model will be analyzed by using discrete-event simulation. Section 2 describes scenarios and models for the reverse supply chain system. Section 3 represents simulation-based performances evaluations. And, the final section summarizes the characteristics in each model.

2 Models of Reverse Logistics Supply Chains

2.1 Reverse Logistics Scenarios

Reverse logistics systems require taking back products from customers and the repairing, remanufacturing (value-added recovery), or recycling (material recovery) the returned products. The reverse logistics in supply chains is strongly related to all stages of a product development and is also a critical problem to all level of the industry.

There are many types of reverse logistics [1]. We, here, consider a virtual supply chain system, which is composed of the following components: Chain manager, Supplier, Manufacturer, Retailer, Customers, Collector, and Remanufacturer (Fig.1). This model supposes home electric appliances such as PCs, TVs, and refrigerators

Chain manager receives demand order from Customer. The manager predicts demand in next ordering duration by using Customer's order. The manager also gives production orders production orders to Manufacturer and Supplier by using the predicted demands. Customer uses products, and sends the used products to Collector.

Supplier, Manufacturer, and Retailer are members that form arterial flows (production generation flows) in a chain. Supplier provides parts or materials to Manufacturer according as supply orders from Chain manager. Manufacturer provides products to Retailer according as production orders from Chain manager. Retailer provides products to Customer according as Demand (Purchase) order from Customer. These chain members use Deliverers to carry materials to its downstream.

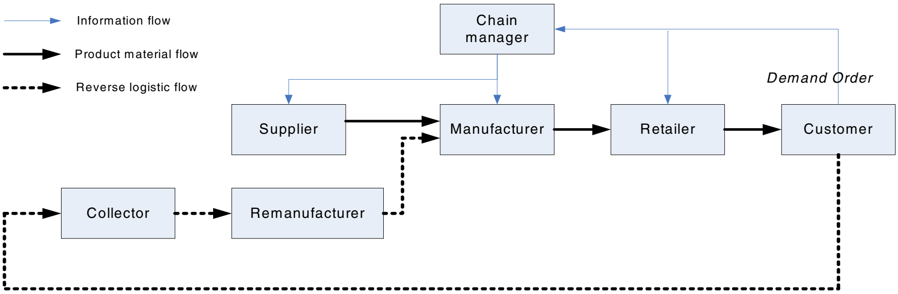


Fig. 1. Configuration the proposed reverse supply chain model

Meanwhile, Collector and Remanufacturer are members that form venous flows (reverse logistic flows) in a chain. The Collector reclaims used products from Customer, when he/she disposes the used product. And, it detaches reusable materials from the disposed product, and sends them to Remanufacturer. Remanufacturer produces remanufactured products by using materials from Collector. It provides the regenerated objects to Manufacturer, such as spare-parts.

2.2 Reverse Logistics Models

These models are based on an analogy between arterial-venous blood flows in a human body and material-flow in a supply chain. Solid lines are production generation flow (arterial-flow), meanwhile, dashed lines are reverse logistics flow (venous-flow) in Figure.2 and 3. Arterial-flows and venous-flow should be synchronized with each other. The system synchronizes venous flows with arterial flows.

The flow from Customer to Remanufacturer by way of Collector is a reverse logistics flow. Customer sends “used-products” to Collector, when Customer disposes them. The role of Collector is to distinguish reusable materials from the disposed products, and stores them. How much volume the Collector gathers reusable material from disposed materials depends on “Collection Rate”. This is a probability variable that the Collector gathers reusable materials from the disposed material by Customers.

We defined two types of this reverse logistics flow: PUSH-type and PULL-type. The PUSH-type is that Collector and Remanufacturer sends reverse products to Manufacturer in an orderly manner. In PUSH-type, remanufactured products are sequentially pushed into Manufacturer, synchronizing with occurrence of reverse. Remanufactured product would be kept as material inventory in Manufacturer. In PUSH-type, remanufactured products are sequentially pushed into Manufacturer, synchronizing with occurrence of reverse. Remanufactured product would be kept as material inventory in Manufacturer.

Meanwhile, the PULL-type is that Collector and Remanufacturer work according as PULL signals from their downs-streams. In PULL-type, reverse products are stocked at Collector. These products stay at there, during no PULL signal from Remanufacturer. And, Remanufacturer does not work until it receives PULL signal.

In Fig. 3, Collector works as “Stock-driven” mode. Collector continuously observes stock volume at Remanufacturer. It starts to produce products when the stock volume is smaller than the stock-replenishment level, and continues to work until the stock volume is equal to or greater than the stock-volume level. This works according to the following operational sequences:

1. Collector periodically observes stock volume data at Remanufacturer.
2. Collector starts producing while stock volume at Remanufacturer goes down below the stock-replenishment level.
3. Collector stops producing when the stock volume reaches the stock-volume level.

This logic is also applicable to the case of between Remanufacturer and Manufacturer.

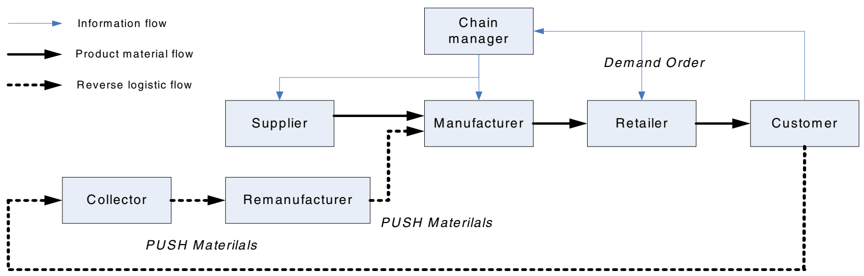


Fig. 2. PUSH-type reverse logistics model

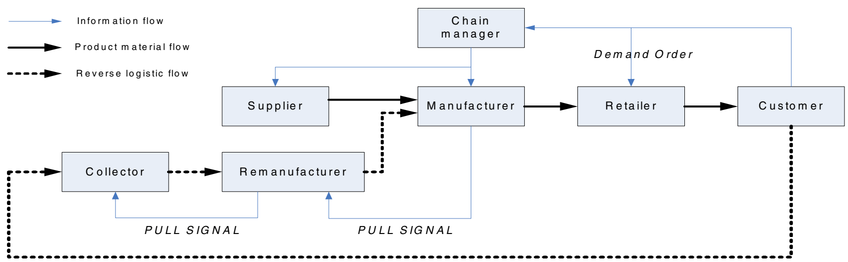


Fig. 3. PULL-type reverse logistics model

3 Simulation Analysis

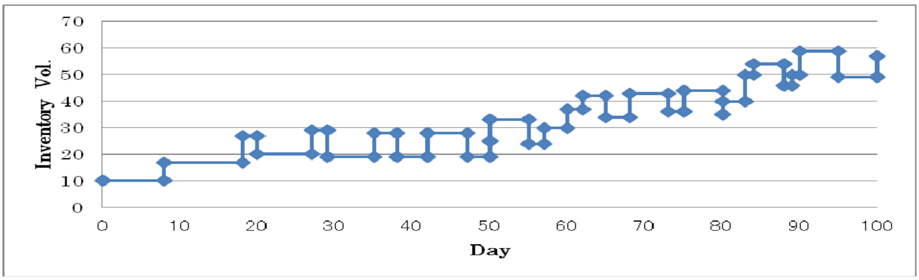
The variable of Customer’s order volume is obedient to a uniform distribution between 6 lots to 10 lots (U(6,10)). And, the order interval of Customer is 5 days. Two levels of “Collection Rate” are defined. This is a probability variable that the Collector gathers reusable materials from the disposed material by Customers. These are 0.6 as high-level reverse and 0.2 as low-level reverse. Simulation duration is set on 100 days.

Table.1 represents the differences between PUSH-type reverse and PULL-type reverse. The PULL system indicates higher utilization of Collector than the PUSH system. In PUSH system, the Collector works only when the materials arrive from it Upstream (Customer). Meanwhile, in PULL system, Collector works to replenish inventories at the downstream (Remanufacturer). This mechanism, accordingly, makes higher resource utilization, when the Collection Rate is at low level.

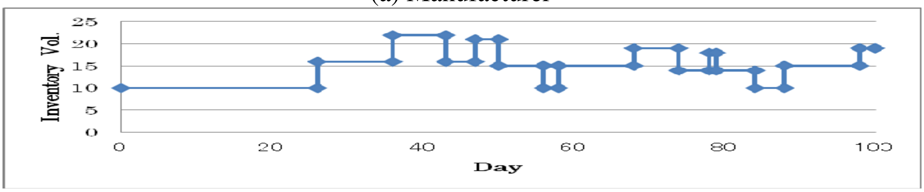
Table 1. Simulation results (Utilizations of each supply chain member)

Model	Collection Rate	Utilization@ Manufacturer	Utilization@ Collector	Utilization@ Re-manufacturer
push	0.6	0.92	0.32	0.30
push	0.2	0.92	0.12	0.10
pull	0.6	0.91	0.36	0.21
pull	0.2	0.90	0.24	0.15

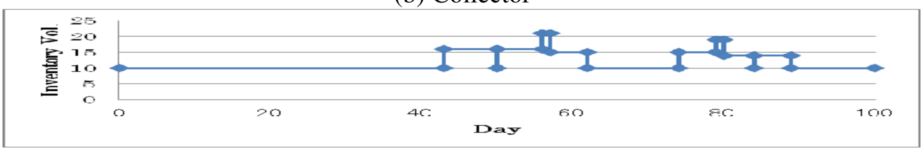
Figure. 4,5,6, and 7 represent material inventories transitions at each supplier in individual simulation run. The material inventory volume at Manufacturer increases as time goes on in PUSH system (Fig.4, Fig.6). Meanwhile, the inventories at both Collector and Remanufacturer do not fluctuate so much. PUSH system processes the collected reusable materials in sequence to produce the regenerated parts, as far as its supply continues. The input material inventory in Manufacture, accordingly, keeps on increasing.



(a) Manufacturer



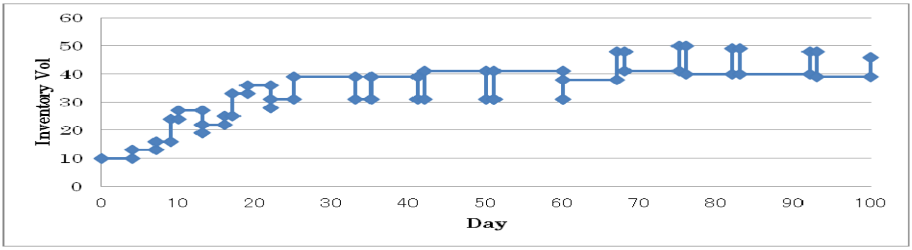
(b) Collector



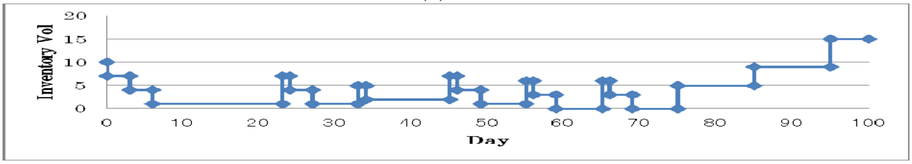
(c) Remanufacturer

Fig. 4. Material inventories transition at each supplier (PUSH model, Collection Rate=0.6)

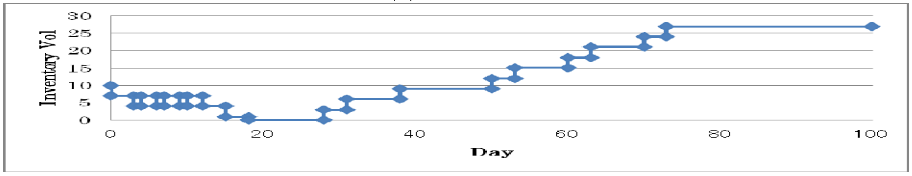
In PULL system, material inventory volume at Manufacture keeps almost constant. Meanwhile, the volume of inventories at Remanufacturer demonstrates an upward trend, and materials at Collector are consumed. In PULL system, the material consumption at Collector synchronizes with material inventory volume at Remanufacturer, and



(a) Manufacturer

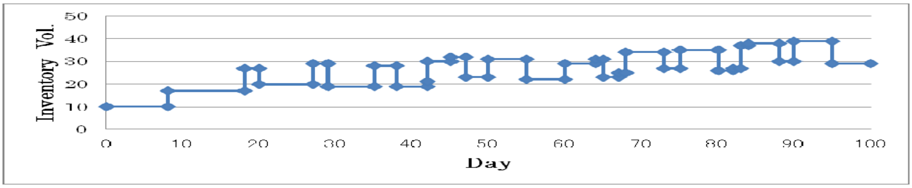


(b) Collector

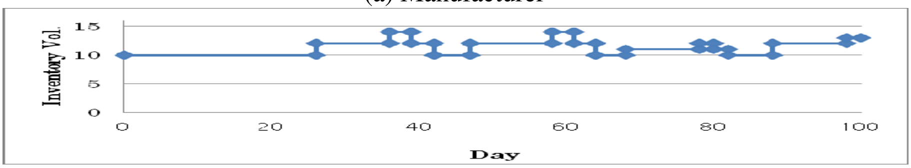


(c) Remanufacturer

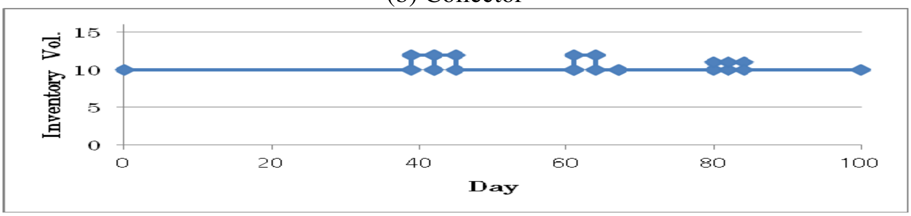
Fig. 5. Material inventories transition at each supplier (PULL model, Collection Rate=0.6)



(a) Manufacturer

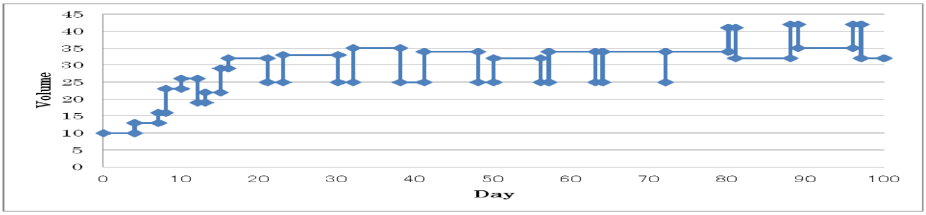


(b) Collector

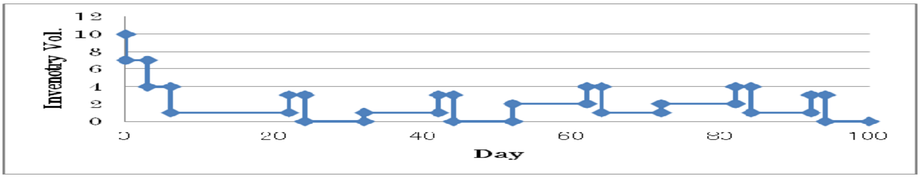


(c) Remanufacturer

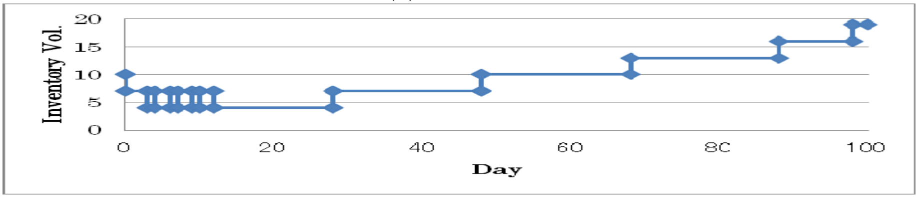
Fig. 6. Material inventories transition at each supplier (PUSH model, Collection Rate=0.2)



(a) Manufacturer



(b) Collector



(c) Remanufacturer

Fig. 7. Material inventories transition at each supplier (PULL model, Collection Rate=0.2)

the material consumption at Remanufacturer synchronizes with material inventory volume at Manufacturer. When the Manufacturer possesses sufficient volume of input material, Remanufacturer does not need to provide Manufacturer with materials any more. (Fig.5, Fig.7)

4 Conclusion

In both PUSH system and PULL system, all of the reusable materials generated at Customer (market) are transferred to Collector. In PUSH system, the gathered materials in Collector are sent to Remanufacturer, which is a re-production process. After this regeneration process, materials accumulate on Manufacturer as its input materials. Meanwhile, in PULL system, the reusable materials staying at Collector would be transferred to Remanufacturer, only when the withdrawal signals from its downstream has been occurred. Therefore, reusable materials stocked in Collector demonstrates an upward trend. This reason suppresses increase of the materials in both Remanufacturer and Manufacturer.

The next stage of this simulation analysis will need to consider processes cost factors at both Collector and Remanufacturer. When the regeneration process at both Collector and Remanufacturer is expensive, the PULL system is the better choice. This is because the PULL system avoids overproductions.

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Business Model Canvas as Tool for SME

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Abstract. SME needs good tools to overcome the "grow or die" situation many of them reaches a few years after start. This paper describes the strategy of two SMEs, based on a short case study, in the context of Osterwalders' Business Model Canvas. The investigation try to map whether SMEs, such as the given case studies, actually follow or can utilize a pattern towards success in line with Osterwalders Business Map Canvas. , The work suggests that the Canvas is suitable for mapping purposes of current activities, but not suitable as a "paradigm" or framework to follow when outlining strategies for the future.

Keywords: Business models, innovation, business model canvas, case studies.

1 Introduction

SME companies tend to be less concerned about strategy and long-term development and more concerned on how to survive today. They seem to come to a stage where they either die or change to improved growth. How fast this stage arrives depends on type of industry and several external and internal factors. There are various business models and strategy tools that aim to map and describe how companies should run and develop their operations.

In general the purpose of creating a model is to help understand, describe, or predict how things work in the real world by exploring a simplified representation. How a business model can be developed and used to explain and communicate strategy for a company has changed a lot during the last 30 years. (Dodgson, Gann, & Salter, 2008; Gertsen, Acur, Sun, & Frick, 2002 ; Laugen & Frick, 2002) And if we can see a trend, it is that start-ups develop such descriptions in their business plans, and larger companies sets these methods into a system when they debate how to proceed and develop into new products, new markets etc.

Morten Lund presented a paper at APMS-2012 where he utilized the canvas developed for Business Models by Osterwalder to tell a story for companies on what could be their strategy.(Lund, 2012)

1.1 Osterwalders' Business Model Canvas

Osterwalder (Osterwalder & Pigneur, 2011) have developed and published a one-page strategy or business plan model. The content of this one is not a new approach as the topics are the same as most entrepreneurship literature suggest as content for a start-up company business plan.

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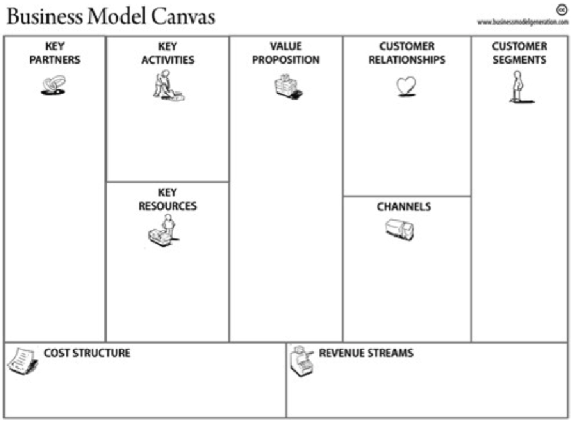

Fig. 1. A simple version of Osterwalders Business Model Canvas

The approach differs from the former issues in terms that it insists on a one-page document. The main reason for this is that a main purpose is to communicate and implement the strategy described by the business model. The other issue is that Osterwalder advise to use as much graphical icons in the one page business plan as possible. This is recommended to get people to think, and also create as much of a visual one-page impression as possible. Morten Lund in his APMS-2012 paper (Lund, 2012) took this even further and emphasized that the canvas should be a storytelling. He even used video clips as pieces in this storytelling context.

The authors of this paper have a similar experience from former projects where we used video-clips, gaming, or system dynamic models to tell a story or parts of a story. In our case this was sometimes done in a strategy context but mostly in an organizational learning context. (J. Frick & Riis, 1991; Jan Frick, 2001; Riis, 1978)

2 Case Companies

These case studies are done to understand the correlation new technology companies might have with Osterwalders' Business model canvas, and its relevance for such entities. Both cases are based on longitudinal, qualitative case study over a period of more than a year of both companies Sekal AS, and 2K Tools AS. The companies were closely followed, from their first commercialization period (to the local market) and then further on towards internationalization of their products and services.

The longitudinal studies of both companies were a part of a commercialization project towards Saudi-Arabia, where researcher(s) followed the companies from start, which involved meetings with clients, and partners, till actual sales in foreign countries, this involved dialogue with the management of the different companies, such as the CEO, CFO, founders and board members, in addition to correspondence and feedback from potential customers and clients in different countries in the Middle East. Both companies have arrived at a stage where they are in need of development.

2.1 Sekal AS

Sekal AS is a technology company based in Stavanger, Norway. The company is a result of a merger between Drilltronics AS and Drill Scene AS. Both of the latter companies were established in 2004. The technology that lays the foundation for these companies has been developed for several years.

The products are classified as drilling technology for offshore and onshore oil sector, and allow users to analyze, detect and solve problems during drilling. Patented, and advanced mathematical models implemented and calculated in real-time, makes this possible. This technology provides a much more efficient and safer drilling process that also gives you more control over the well and the capability to prevent accidents much earlier. The technology is sold in the North Sea area, and Sekal intend to expand to international markets worldwide. Sekal AS has an office in Houston in addition to their office in Stavanger, Norway. They are also in a process of establishing an office in the GCC region to serve the large market in the Middle East.

Sekal AS has several leading oil companies as clients, and has recently signed agreements with Statoil and other major stakeholders on the use of its technology. Other customers of the company include: Schlumberger, BP, Statoil, ConocoPhillips and Dong Energy. They have also received interest from oil companies around the world who are very interested in the technology, including Saudi Aramco.

2.2 2K Tools AS

2K Tools AS is an innovative engineering company that provides new drilling technology to the oil and gas industry. Two engineers with several years experience from other companies founded the company in 2006. They have in the past year focused on the commercialization of new technology in drilling and have as a result of this patented system "Drill String Internal Wiper" or DSIWS.

DSIWS is a tool used in wells during drilling, and drilling companies that provide significant savings due to increased safety on the platforms. The system is based on many years of experience in the oil industry, and has been tested with good results. The company is now in "the tipping point" in relation to the commercialization of its product internationally, and is the first company that can deliver this type of equipment. In 2011 the company commercialized the DSIWS in the North Sea and has started to gain revenue from deliveries of the technology to mainly ConocoPhillips. 2K Tools expects to reach $ 1 million in revenue in 2011, due to new projects both nationally and internationally, and are aiming to triple sales in the coming years. 2K Tools is a small company, with currently only three employees.

2K Tools has attracted investments from external sources of 9 million NOK. Which allow for improvements of DSIWS, development of other technology and the international expansion of the company. The main owners of the company are large Venture Capitalist funds. The company sees oil fields onshore in the Middle East, and then in particular Saudi Arabia, which is ideal in terms of their product.

3 Analysis

How does these two cases fit to the Business Model Canvas? In both cases the companies were established related to a key activity that was drilling for petroleum in the North Sea, and close relations were key partners, which in these cases also partly were customers.

3.1 Key Activities

2K Tools AS has a mechanical and a physical innovation, which needs storage, shipping and logistics. The company has developed innovative tools that reduce mud spills on platform, and increase HMS for the employees. The tool is a cleaning device that is dropped into the drill hole and retracted again. The tool does not need a high degree of expertise, and can be learned easily by personnel on the platforms.

Sekal AS sells and implements software solutions, that are highly sensitive for oil operators. The technology is a real time detection of problems that might occur in wells that are being drilled. This will help drilling operators to cut costs and increase their HMS. The technology is named DrillScene and has been developed for the past twenty years at the IRIS-research center in Stavanger, Norway. This product is highly scalable, and has no costs related to logistics and storage.

3.2 Key Resources

2K Tools is still run by their founders, and is backed up by large Venture Capitalists, that has a interest in commercializing and selling the company in a short period of time. Being a small company, run by their founders, they have flexibility, but it is also restricted to approval from the Venture Capitalists when it comes to larger strategic decisions. Their key resources are their founders and the management that makes most decisions related to the company and its survival.

Sekal AS is in a similar situation but the entrepreneur or founders do not run the company. The owners have hired in a professional management that has long experience in commercializing similar ventures. Their technology has been through the "bleeding" period, and developed and ready to be commercialized into the market. Their Key Resources now are the sales and marketing team, and their IT engineers that improve the product.

3.3 Value Proposition

2K Tools AS value proposition is that the new Wiper Technology that has been developed increases HMS safety on offshore platforms. This is due to the reduction in mud spill once the drill pipe has been retracted to the platform.

Sekal has a similar value proposition. Their technology allows the drilling company to detect and solve problems that might happen in the well during a drilling process. This will also increase HMS for the drilling contractor, but also help them reduce costs, because shut down due to production pauses are very expensive.

3.4 Channels

2K Tools are still in a process where they are evaluating their business model, and channels towards their customers. The company is still quite small, and is in need for agents or operators in foreign countries, in order to serve and deliver the service that they are supposed to do. Their strategy has therefore been to ally with an agent or a partner that can provide the necessary infrastructure to deliver their technology.

Sekal has a technology that requires insight and knowledge about the product. As complex software it needs to be handled by experts from the Sekal team. Therefore the company always works directly with their end-client, which in every case is the drilling operator, such as Statoil and Petrobras. Sekal sets up the infrastructure and the technology, and also leads the operations for the client.

3.5 Cost Structure

The technology that 2K Tools deliver is a physical cleaning device that needs to be produced, and handled by personnel on a platform. The tool is currently being produced in Narvik, Norway and from there shipped abroad to other countries. Later on, it is required that the tool receives maintenance by the agent or operator that has rented the tool.

As a software company, Sekal has a highly scalable product. Once developed, and implemented into the clients portfolio, Sekal can run operations over time with high margins and lower maintenance costs. However there are certain costs involved in adapting each system to specific wells, and also setting up a infrastructure at the clients premises.

3.6 Revenue Stream

2K Tools business model has been based on a rental structure. The company wish to rent out their equipment to agents and operators in the oil industry that wants to use the technology to increase HMS at their platforms. Their margins are high in the North Sea, due to the general level of payment in the region. However, in foreign countries with lower wages and income, they face a challenge in terms of margins on their products. 2K Tools has therefore also evaluated the possibility of starting production of their tools in a foreign, low cost country.

Sekal receives their income from end clients and drilling operators that engage in long term contract with the company. For example, Sekal recently signed a major deal with Statoil, giving them a frame-contract over five years for supplying Statoil with their technology. This frame-contract gives Sekal a reliable source of income for several years while they try to find other clients that would like to use their technology. Since the company has been through the “bleeding” period, one contract with a major client is sufficient to run a sustainable company that makes profit and has enough resources for expansion.

4 Discussion

Osterwalders Business Model Canvas gives us an overview of how the companies operate and how their current strategies are outlined. It therefore is a great tool to be used, for example in internal discussions about maximizing revenues, or improving things such as customer relations. In the cases of both case companies, they operate in a very changing environment where the best strategy for each company needs to be outlined by the management at an ad-hoc basis.

For example, assessing the revenue channels through Osterwalders shows us that 2K Tools have a rental model that is viable in the North Sea due to higher margins and better conditions in terms of payment. But when the company looks at emerging markets, it needs to review its initial penetration strategy in order to be competitive. Lower margins and a different mental mind-set from the customer side in other markets will not allow 2K Tools to implement the same strategy used in the North Sea, in for example the Middle East. We know this because when 2K Tools offered their services to major Arab companies, they were turned down due to their high price asking (which was influenced by the fact that they could receive this amount in the North Sea). The Middle Eastern market did not find the price/ beneficial ratio to be as high as their North Sea counterparts. So in order to penetrate this market, the company and its management decided to revise and totally change their business model for this particular market. Alas, the strategy chosen follows practical need to adapt to new market conditions/ differences.

This is just one of many examples where the company needs to be strategic and flexible when making decisions during international expansion. Using Osterwalders model in this case would be more or less useless, as it would be altered for every market, or every customer/ client differences.

Sekal's income model is different as it is highly scalable, and quite adaptive from market to market. Sekal's income is derived from already developed software, which has low costs when implemented in new markets or at new clients. They usually sign long term agreements with clients, and have business model that has been proven suitable for several markets, despite the differences in payment conditions and margins. This is mostly due to the fact that Sekal has a niche, and a highly advanced technology that only their team, or others that has received sufficient training, can handle the operations. Here, their strategy would suit in a Business Model Canvas, and set as an example to follow.

However, the need for flexible strategy arises at Sekal when you look at the channels for distribution of the technology. The reason for this is because many countries around the world have different rules and regulations for doing business. When Sekal looked at the market in Saudi Arabia, the company needed to partner up with a local firm in order to be able to bid towards Saudi Aramco. The local market conditions also gave them several options, such as choosing to partner with a agent, go into a Joint-Venture or establishing themselves in a so-called "free-zone", with more or less 100% ownership. All of these options had their pros and con's and knowing which one of them that would be perfectly suited for Sekal is quite difficult to assess. In the end the company ended up with an agent option, with the possibility to develop the cooperation into a JV, and then in the long run maybe buy out the local counterpart (if operations were successful). This allowed the company to choose an optimizing strategy specially designed for the Saudi-Arabian market, and some other markets in the Middle East.

This strategy has direct implications into Sekal's revenue streams in the Saudi-Arabian market, since the agent structure obliges the company to pay out a commission of 5-7% of their revenues to the local partner, with a gradual increase if the company forms a JV, then a gradual decrease then Sekal buys into the JV and ultimately acquires the whole operation in Saudi-Arabia. This case shows that Sekal needs to be highly flexible when making decisions related to distribution channels, and might have two totally different strategies in different countries. Putting this into an Osterwalders model would prove to be difficult.

5 Conclusion

From the description and analysis we see that the cases in some ways can fit into the canvas. However, we are not able to make as neat picture for the companies as recommended by Osterwalders. This may be due to missing information or a lack of understanding, but it may just as much be due to a complex daily business and complex relation to partners and customers at the companies. If both 2K Tools and Sekal had been in a starting phase, where management or founders need to have a business plan to stick to, they would have had great use of the Osterwalders Business Canvas Model. It is because the model provides a solid framework, which small start-ups can work from.

However, both 2K Tools and Sekal are companies that have developed into a stage where they already have commercialized their products, and are looking into different ways to increase revenues and improve their infrastructure. This makes them flexible in their strategies when for example penetrating new markets, and increasing their business. This also leaves a large part of the strategy decisions in the hand of the management, and is taken more or less on case-by-case basis, as we have shown in our analysis.

It is impossible for both companies, taken in account that they both wish to operate in international markets, to pursue one strategy either it is revenue stream or source of marketing. The complex nature of this makes the Osterwalders Canvas Tool suitable for both 2K Tools and Sekal when mapping their current structure into a "viewable" and simple story that they can use for example learning purposes. A conclusion would somewhat say that the Osterwalders model, with our two case-studies, is suitable for mapping purposes of current activities, but not suitable as a "paradigm" or framework to follow when outlining strategies for the future.

Seen from outside both companies are doing business in a complex infrastructure with many players, and therefore it is hard to make a good and simple story from what they are doing. And even more, it is our firm belief that they will need to restructure into a "simpler story" of partner relations (Lund, 2012) and activities if they are to succeed when moving abroad.

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Empirical Evidence of an Efficient Formulation for the Multi-period Setup Carryover Lot Sizing Problem

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Abstract. In this paper we present an effective flexible formulation for the capacitated multi-item lot-sizing problem with setup carryovers and setup times. The formulation can accommodate setup times, single or multi-period setup carry-overs, backorders with limits on the number of backorder periods, and shelf-life restrictions without the need for any additional variables and constraints. We provide empirical evidence of the superiority of our model over conventional formulations by comparing LP lower bounds generated on a number of randomly generated test problems. Our flexible formulation dominated the results in 100% of the problem cases.

Keywords: Production Lot Sizing, Setup Times, Setup Carryover, Backorders, Generalized Formulation.

1 Introduction

The single-level capacitated multi-item lot-sizing problem (CMLSP) without setup times is well known. It consists of scheduling N items over a planning horizon of T periods in a single-level production facility. Demands are time varying and are known, and are to be satisfied without backlogging. The objective is to minimize the sum of setup and carrying costs over the planning horizon subject to limited capacity in each time period.

The CMLSP continues to be of importance in batch manufacturing environments. Over the years, formulations of the problem have expanded from earlier versions to incorporate various problem features such as backorders, setup times, and setup carryovers. In order to accommodate these additional features, several of the formulations introduced new variables and constraints that often led to greater model complexity. The added complexity has often meant that the problems became harder to solve optimally, largely because the LP lower bounds were not particularly strong.

In this paper we propose a very flexible formulation that accommodates without the need for any additional variables and constraints, problem features such as setup times, setup carry-overs, backorders, shelf-life restrictions, and preventive maintenance. The formulation is a generalization of a formulation proposed by [1].

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We demonstrate that the model is very effective in providing strong lower bounds from the LP relaxation of the formulation, hence providing the opportunity for reasonable sized problems to be solved to optimality, or for large problems to yield good feasible solutions from heuristic approaches that require good lower bounds.

In the next section we provide a brief literature summary. In section 3 we discuss the various model formulations. Section 4 provides empirical evidence of the dominance of the proposed model over the conventional formulation. The paper concludes in section 5 with discussion and conclusions.

2 Literature Review

The capacitated multi-item lot-sizing problem without setup times is known to be NP-hard [2]. When positive setup times are incorporated in the model the feasibility problem becomes NP-complete [3].

Over the last 20-30 years there have been numerous approaches to the problem and its variants. There are several math programming approaches that use an LP relaxation of the model to generate a lower bound and subsequently employ a solution scheme such as branch and bound or Lagrangian relaxation to close the gap between the lower bound and a feasible primal solution. Lagrangian-based algorithms such as those of [1, 4-10] are all examples of approaches that require an efficient lower bound.

Many of the solution approaches to the capacitated lot-sizing problem that employ a lower bounding scheme often begin with the mathematical formulation found in [11]. However [1,7] presents a formulation that produces superior lower bounds to the formulation found in [11]. The model formulation found in [11] often has to be modified by introducing additional variables and constraints whenever variants of the model must include features such as: backorders, setup times, and setup carryovers. The modifications often make the resulting problem cumbersome and difficult to solve [8, 12, 13].

3 Formulations of the CMLSP and Its Variants

Much of the early work on solving the CMLSP was predicated on the formulation of the model presented in [11] and [2]. The model parameters and variables are as follows:

x_{it} - the quantity of product i produced in period t;

$$y_{it} = \begin{cases} 1 & \text{if } x_{it} > 0 \\ 0 & \text{Otherwise} \end{cases}$$

s_i - setup cost for item i;

h_{it} - the direct variable cost (holding cost) associated with one unit of item i produced in period t;

N - the set of items as well as its cardinality;
a_i - the capacity absorption rate in time per unit for item i;
C_t - the capacity available in period t in time units;
T - the set of periods as well as its cardinality;
d_{it} - the demand in units for item i in period t;
I_{it} - the inventory in units for item i in period t;

3.1 The Capacitated Multi-item Lot Sizing Problem without Backlogging

This model was proposed by Dixon and Silver [2] as a 2-index model. The model is as follows:

$$M1: Min \sum_{i \in \mathrm{N}} \sum_{t \in \mathrm{T}} h_{it} I_{it} + \sum_{i \in \mathrm{N}} \sum_{t \in \mathrm{T}} s_i y_{it} \tag{1}$$

Subject to:

$$\sum_{i \in N} a_i x_{it} \le c_t \qquad \forall_t \tag{2}$$

$$I_{it-1} + x_{it} - I_{it} - d_{it} = 0 \qquad \forall_{it} \tag{3}$$

$$x_{it} - m_{it} y_{it} \le 0 \qquad \forall_{it} \tag{4}$$

$$x_{it}, I_{it} \ge 0 \qquad \forall_{it} \tag{5}$$

$$y_{it} \in \{ 0, 1 \} \qquad \forall_{it} \tag{6}$$

The objective of model M1 is to minimize the sum of set up and holding costs. Constraint (2) limits the capacity consumed in each period. Constraint (3) is the inventory balance constraint. Constraint (4) is a logical constraint that triggers a setup when production of item *i* takes place in period *t*. The constant m_{it} must be $\ge x_{it}$. It is the minimum of the capacity in period *t* or the sum of the demands that can be satisfied by production in that period. The constant m_{it} is computed as follows:

$$m_{it} = \min \left\{ c_t, \sum_{r=t,T} d_{ir} \right\} \qquad \forall_{it} \tag{7}$$

Constraint (5) specifies x_{it} as a continuous variable, while constraint (6) specifies y_{it} as a binary variable.

3.2 The CMLSP with Backlogging: The Conventional Formulation

This model allows unmet demand to be satisfied in the future. It requires the addition of a backorder variable B_{it}, and a unit backorder cost, p_{it}.

$$M2: Min \sum_{i \in N} \sum_{t \in T} s_i y_{it} + \sum_{i \in N} \sum_{t \in T} h_{it} I_{it} + \sum_{i \in N} \sum_{t \in T} p_{it} B_{it} \tag{8}$$

Subject to:
(2), (4), (5), (6)

$$I_{it-1} + x_{it} - I_{it} - B_{it-1} + B_{it} - d_{it} = 0 \qquad \forall_{it} \tag{9}$$

We note that constraint (9) is the inventory balance constraint incorporating backorders. The constant in the logic constraint is computed as follows:

$$m_{it} = \min\left\{ c_{it}, \sum_{r=1,T} d_{ir} \right\} \qquad \forall_{it} \tag{10}$$

We note that for a given problem setting, the constant would be much larger in the backlogging case compared to the case with no backlogging. Consequently, the logical constraint in the LP relaxation of M2 will likely have significant slack in the optimal solution.

3.3 A Three-Index Model

A 3-index model for the production lot-sizing problem was proposed in [1]. The proposed model introduces a 3-index production variable x_{itk}.

x_{itk} - the quantity of product i produced in period t for use in period k;

The model referred to as M3 requires an additional summation over periods k, k=1, T.

$$M3: Min \sum_{i \in N} \sum_{t \in T} \sum_{k \in T} h_{itk} x_{itk} + \sum_{i \in N} \sum_{t \in T} s_i y_{it}$$

Subject to:

$$\sum_{i \in N} \sum_{t \in T} a_i x_{itk} \le c_t \qquad \forall_t$$

$$\sum_{t \in T} x_{itk} \ge d_{ik} \qquad \forall_{ik}$$

$$x_{itk} - d_{ik} y_{it} \le 0 \qquad \forall_{itk} \tag{11}$$

$$y_{it} \in \{0, 1\} \qquad \forall_{it}$$

$$x_{itk} \ge 0 \qquad \forall_{itk}$$

Apart from the difference between the 2-index vs. the 3-index production variable, a key difference between the two models shows up in the logical constraint, constraint (11). In the case of M1, the constant m_{it} can be much larger than the production quantity x_{it}. As such, in an LP relaxation, constraint (4) could have significant levels of slack leading to poor lower bounds. In constraint (11), it is highly likely that the production is equal to the demand, i.e., $x_{itk} = d_{ik}$. Hence in an LP relaxation, many of the logical constraints will have zero slack producing tighter lower bounds and very likely the optimal integer solution to the problem.

3.4 The CMLSP with Backlogging: The 3-Index Model

Accommodating backorders in the Millar-Yang model is rather simple. We allow k to take on values less than t. Values of k < t signal backorders. No additional variables or constraints are needed. This model was tested and presented in [7].

3.5 The Capacitated Multi-item Lot Sizing Problem with Setup Times

To incorporate setup times, the capacity constraint must be modified in both the two-index and three-index models. The modifications are as follows:

$$\sum_{i\in N} a_i x_{it} + \sum_{i\in \mathrm{N}} v_i y_{it} \le c_t \qquad \forall_{t\ge 2} \tag{12}$$

In the case of Millar and Yang's model, the modification is similar.

$$\sum_{i\in \mathrm{N}}\sum_{t\in \mathrm{T}} a_i x_{itk} + \sum_{i\in \mathrm{N}} v_i y_{it} \le c_t \qquad \forall_{t\ge 2} \tag{13}$$

The total of production time plus setup time in any given period must not exceed the capacity of that period.

3.6 The Capacitated Multi-Item Lot Sizing Problem with Setup Carryover: A Two-Index Model

Setup carryovers involve the case where a setup for one of the items in a given period is carried over to the next period. The item with the setup carryover would be produced last in the current period and first in the next. Hasse (1994) and Sox and Gao (1999) proposed two-index formulations that introduced a new variable z_{it}, a binary variable set to 1 if the setup carryover for item I is initiated in period t. Hasse's model [8] will carry a setup for at most one period.

Sox and Gao [13] propose a two-index model that allows setup carryovers over multiple periods. The model modifies the logical constraint and introduces four new constraints (14)-(18) to capture the logic of multi-period setup carryovers.

$$M5: Min \sum_{i \in N} \sum_{t \in T} s_i y_{it} + \sum_{i \in N} \sum_{t \in T} h_{it} I_{it}$$

Subject to:
(2), (3), (5)

$$x_{it} \le m_{it}(y_{it} + z_{it}) \qquad \forall_{t \ge 2} \qquad (14)$$

$$\sum_{i \in I} z_{it} = 1 \qquad \forall_{t \ge 2} \qquad (15)$$

$$z_{it} - y_{it-1} - z_{it-1} \le 0 \qquad \forall_{i,t} \qquad (16)$$

$$z_{it} + z_{it-1} - y_{it-1} + z_{jt-1} \qquad \forall_{t \ge 2} \qquad (17)$$

$$y_{it}, z_{it} \in \{0,1\} \qquad \forall_{i,t} \qquad (18)$$

We note that the models use the form of the logical constraint present in the conventional formulation of the capacitated lot-sizing problem. Given the additional setup carryover constraints, it is highly likely that in the optimal LP relaxations, the logical constraints will possess significant levels of slack.

3.7 A Flexible 3-Index Model

We propose the following mathematical formulation that incorporates backorders, setup times and setup carryovers with two sets of variables (X, Y). The more conventional model of [8] would require a total of four different variables (X, Y, B, Z) to do the same, where B represents the backorder variables. The proposed model considers setup carryovers by converting the set up variable y_{it}, into y_{itq}, a binary variable set to 1 if item i is setup in period t and carried over to period q, where $q \ge t$. Further single or multi-period carryovers are accommodated by simply allowing $q > t+1$. There is no need for additional variables or constraints. The model handles limits on the number of periods of backorders allowed or the number of periods of inventory carried (shelf-life limits) by simply limiting k in the variable x_{itk}. For example, if a maximum of 3 periods of backorders and/or inventory are allowed, then k is allowed to vary such that $t-3 \le k \le t+3$. The proposed model is formulated as follows:

$$\Psi = Min \sum_{i \in N} \sum_{t \in T} \sum_{k \in T} h_{itk} x_{itk} + \sum_{i \in N} \sum_{t \in T} \sum_{q=t,T} s_i y_{itq} + \sum_{j \in J} \sum_{t \in T} g_j r_{jt}$$

subject to:

$$\sum_{i \in N} \sum_{k \in T} a_i x_{itk} + \sum_{i \in N} \sum_{q=t,T} v_i y_{itq} - \sum_{j \in J} r_{jt} = 0 \qquad \forall_t \qquad (19)$$

$$\sum_{t \in T} x_{itk} \ge d_{ik} \qquad \forall_{ik} \qquad (20)$$

$$x_{itk} - d_{ik} \sum_{p=1,} \sum_{tq=t,T} y_{ipq} \leq 0 \qquad \forall_{itk} \qquad (21)$$

$$\sum_{i \in I} \sum_{p=1,} \sum_{tq=t+1,T} y_{ipq} \leq 1 \qquad \forall_{t \leq T-1} \qquad (22)$$

$$\sum_{q=t,T} y_{itq} \leq 1 \qquad \forall_{i,t} \qquad (23)$$

$$\sum_{i \in I} \sum_{p=1,t-1} \sum_{q=t+1,T} y_{ipq} + y_{itt} \leq 1 \qquad \forall_{it} \qquad (24)$$

$$0 \leq r_{jt} \leq c_{jt} \qquad \forall_{jt} \qquad (25)$$

$$y_{itq} \in \{0,1\}$$

$$x_{itk} \geq 0$$

Where

$y_{itq} \in \{0,1\}$ - is a binary variable which is set to 1 if a setup for item i is initiated in period t and carried until period q.

r_{jt} - is the consumption of capacity resource type j in period t

C_{jt} - is the capacity available for resource type j in period t

The variable r_{jt} allows multiple capacity sources to be considered, such as overtime and subcontracting.

Constraints (20) – (22) are standard capacity, demand, and logical constraints modified to reflect the 3-index setup/setup carryover variable. Constraints (23) – (25) address the logic of the carryovers.

4 Computational Results

In this section we present empirical evidence of the effectiveness of the formulation. First we randomly generate 36 small test problems and solve them to optimality using the conventional Dixon-Silver model [2, 11], and the Millar-Yang model [1,7]. No backorders, setup times, or setup carryovers were considered. A branch and bound algorithm in CPLEX was used to solve the problems optimally. Table 1 compares computational effort for the two models. It shows the average number of simplex iterations (SI) and branch and bound (BB) nodes searched during the solution procedure. BAK represents the conventional model [2, 11], and MY the Millar-Yang model [1,7].

Table 1. Comparison of Computational Effort for the 2-index vs. the 3-Index Models

SI-BAK	*BB-BAK*	*SI-MY*	*BB-MY*
463	368	169	27

Table 2. Comparison of LP Gaps (%) for the 2-Index vs. the 3-Index Models

Prob. #	BAK	MY	SG	FLX	Prob. #	BAK	MY	SG	FLX
1	26.4	0.1	63.5	5.2	37	24.79	0.18	62.12	5.22
2	28.4	0.5	64.8	5.1	38	18.52	0.28	60.28	3.70
3	9.5	0.4	65.5	11.8	39	12.58	1.38	68.19	10.91
4	11.2	3.1	60.9	10.0	40	11.28	0.78	59.66	9.84
5	27.1	0.3	62.2	4.7	41	27.47	0.77	59.31	2.19
6	32.0	0.0	67.5	3.6	42	25.94	0.71	57.80	4.67
7	17.3	2.8	65.4	10.8	43	10.65	2.37	67.24	11.81
8	22.2	2.7	67.2	10.2	44	23.68	6.12	66.98	9.33
9	18.4	1.6	64.0	5.0	45	31.73	0.92	60.63	7.93
10	32.5	2.9	63.0	5.3	46	18.20	0.88	56.83	4.45
11	19.0	1.5	68.6	4.7	47	11.85	3.97	60.35	12.00
12	24.6	2.3	69.5	5.9	48	21.45	1.82	67.11	8.92
13	25.3	0.2	65.0	5.0	49	15.25	0.63	61.78	3.82
14	24.5	0.6	62.7	4.5	50	18.14	0.00	62.09	4.92
15	11.7	1.5	62.0	8.6	51	6.67	0.94	66.23	13.49
16	12.0	2.7	69.8	9.5	52	4.27	1.44	62.45	9.55
17	26.0	0.7	58.2	3.2	53	24.02	0.78	54.03	8.04
18	28.2	0.5	64.0	4.7	54	19.24	0.34	59.74	3.69
19	8.4	1.7	69.2	10.0	55	8.28	2.57	72.05	8.60
20	17.5	1.8	64.3	8.4	56	1.43	0.18	61.26	12.82
21	27.3	0.9	59.1	3.8	57	14.54	0.01	53.30	7.53
22	33.6	2.9	59.2	5.3	58	25.58	0.70	56.65	3.83
23	22.6	5.4	68.4	5.6	59	11.41	2.46	72.88	8.76
24	17.3	3.5	68.2	6.4	60	8.07	2.97	65.62	8.44
25	21.33	0.56	57.45	3.31	61	9.31	1.10	67.52	6.27
26	23.11	0.22	61.67	3.85	62	21.89	0.09	52.68	5.75
27	8.30	1.85	62.83	11.94	63	4.44	2.29	74.05	16.11
28	8.96	0.60	55.75	7.16	64	8.83	2.13	67.75	13.73
29	25.68	2.25	66.02	5.88	65	11.66	0.45	60.06	5.95
30	22.79	1.12	57.71	4.83	66	15.10	0.03	52.93	3.36
31	15.15	3.35	62.97	10.51	67	3.45	0.76	64.32	13.34
32	27.32	5.33	70.82	9.58	68	5.59	0.08	69.05	18.22
33	26.53	0.95	60.85	3.34	69	12.98	0.12	64.52	7.15
34	26.93	2.83	60.14	4.58	70	15.49	1.08	59.66	8.22
35	14.10	2.43	71.65	10.13	71	13.76	2.93	66.31	10.31
36	22.29	6.60	66.20	10.12	72	17.55	2.13	77.95	13.24

Tables 2 shows the results for 72 randomly generated test problems of size $i=8$ products and $t=8$ periods. The first 36 problems exclude setup times while the second 36 include setup times. The LP gaps are calculated as follows:

$$Gap(\%) = \frac{(MIP\ optimal - LP)}{MIP\ Optimal}\ x\ 100$$

The table columns are as follows:

BAK Gap – LP gap based on the Baker et al. formulation [11]
MY Gap – LP gap based on the 3-index formulation in Millar and Yang [1,7]
SG Gap – LP gap based on the 2-index formulation of Sox and Gao [8]
FLX Gap – LP gap based on the newly proposed model

5 Conclusion

We have presented a flexible and efficient formulation for the multi-item capacitated lot-sizing problem with several features that include setup times, setup carryover, backorders restrictions, and shelf-life limits. Our model is a 3-index model that allows for the definition of constraints that typically have smaller slack values than their 2-index equivalents. This feature is the principal factor driving the superiority of the LP lower bounds. We provide empirical evidence of the effectiveness of our formulation by solving to optimality 72 randomly generated problems, and obtaining LP relaxations for the 2-index and 3-index variants of the problem.

The results in Table 2 show our 3-index formulation dominated the performance of the 2-index formulations in 100% of all cases. Figure 1 provides a visual of the difference between the results for Sox and Gao [11] and our proposed model. Though not presented in the table, the proposed model required significantly less computational effort in all cases compared to the two-index models.

In conclusion, researchers wishing to explore solution approaches to the lot sizing problem and who are in need of good lower bounds as a starting point now have at their disposal a highly flexible and efficient model.

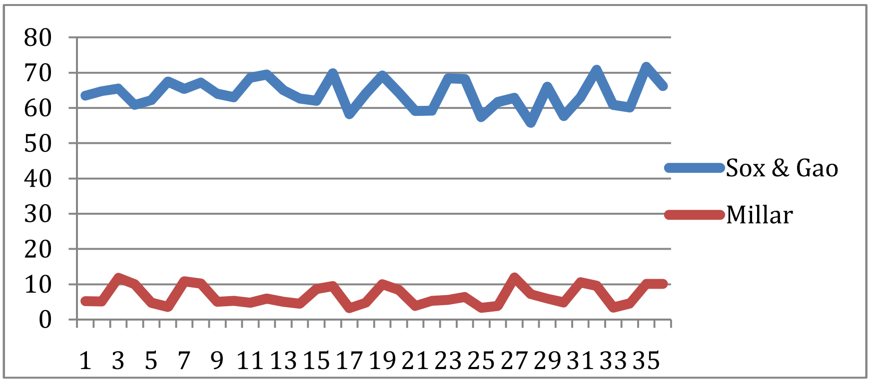

Fig. 1. A graphical comparison of the performance of the proposed formulation with that of Sox and Gao [13]

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Multi-level Service Approach for Flexible Support of Design Processes

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Abstract. The need to answer quickly to new market opportunities and the high variability of consumer demands tend industrial companies to review their adopted organisation, so to improve their reactivity and to facilitate the coupling with the business enactment. Therefore, these companies require agility in their information systems to allow business needs scalability and design process flexibility. We propose in this paper, the business activities as a service based on the service paradigm and whereas a design process is made of agile services orchestrations. We discuss the interest to use a service-oriented approach and propose a layered architecture for design process enactment.

Keywords: Design process, BPM, agility, PLM, SOA, service orchestration, MDA.

1 Introduction

Traditional business process management (BPM) tools with a fixed process' structure are no longer adequate to meet the continuing evolution of the market, enterprises' organization and customers' requirements. These tools tend to be inflexible and time consuming to change. In fact, in a context where organizations are in a constant seek of balance facing up to more and more constraints of the competitive environment, working methods cannot be fixed definitively. Especially in product engineering field; design processes are emergent because of the creativity aspect in engineering and constantly evolving because of the fuzzy and changing expression of customers' needs. Furthermore, unpredictable events may occur during design processes due to external constraints (such as sub-contractor or supplier constraints, etc.) and/or internal constraints (such as delay constraints, staff/resources availability, etc.). Some of these factors, such as satisfying suppliers' constraints, may only cause temporary changes of design processes. While others, such as regulation evolution may cause permanent changes. Reflecting these changes on time represents an ongoing challenge, especially for Product Lifecycle Management (PLM) systems editors since that design processes are mainly supported by these systems. As a result, companies face some obstacles, including the limited implementation of new working methods. Needs in terms of rapid and automated support of business operations are necessary to reflect

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such changes. To address this issue, Service Oriented Architecture (SOA), already used as an enabler of software flexibility, is considered in this study to explore its potential as an enabler of business flexibility. SOA can be seen according different perspectives (business, architecture or implementation) [1]. Our research falls into the first perspective (business) and considers SOA as an approach that supports integrating the business as linked services. Then, services are seen as repeatable business tasks, accessible independently of implementation or transport [1].

Several researches have attempted to solve the problem of BPM tools rigidity by proposing several modeling approaches [2] [3] [4] [5]. Some of them propose to enrich the expression of business processes in order to meet flexibility needs. Some others only address implementation level. Defining an approach for enhancing flexibility at various abstraction levels with a continuum of transformation remains an issue. Based on the findings outlined in literature, we conclude that flexible business processes require specific methods for their design and implementation. Thus, the expected approach is the one in which not only the behavior of activities are not defined a priori but also the relations between activities. Like Boukadi [5], we resort to service based solution in order to map design processes to service-oriented solution. Service-oriented approach, deployed at different abstraction levels (business, functional, software), can promote a flexible support of design processes. The idea is to propose reusable activities as services and evolvable product design processes as services composition. The concept of service defined as providers of reusable functions can be composed and reused to quickly respond to design process changes. That supposes once changes occur we can add to, delete from or replace one service by another one. Indeed, the generalization of SOA to information systems (and thus, the design and requirements analysis layers) would allow the definition of design processes and their implementation by reusing existing services.

The aim of this paper is to propose a methodology specifying and implementing a design process by services composition. This paper is structured as follows. The second section presents the approach we retained, which is based on service paradigm. Then, we present the proposed methodology to identify services (section 3). Section 4 presents the approach for specifying and implementing processes by services' composition. The final chapter concludes this paper.

2 The Proposed Service-Based Approach

The aim of a design process model is to depict interactions between business partners and model their corresponding activities. In past decades, these processes could operate in relatively stable and predictable environments. Now a product design process (named PDP in the following) may not remain steady due to the business environment. That's why we need process flexibility. Process flexibility depends on the easiness to modify design process model and to set up the new business activities. This perception of process flexibility arises from the need to have a method, which allows composing evolvable design process models. In other words, flexibility requires processes made of piece of functionalities that can work together and that can be quickly reconfigurable. The challenge here is to address the mechanisms needed for a solid implementation of dynamic design process change on a real PLM system.

In order to address the problem of design process rigidity in PLM systems, we propose to resort to SOA and to enrich the formalization of design process models and open the way for process modeling by dynamic service composition. Thus, we should have a set of product design services (named PDSs in the following) that expose the business activities of the industrial engineering domain needed to support PDPs. Afterward, we dynamically compose the necessary identified PDS in order to enact the articulations of design process. This process can be materialized by an orchestration of PDS [6]. In fact, we propose to use service as a means for describing the business operations needed to support the design processes. These loosely coupled services may be composed in order to enact in a flexible way the articulations of business. This process is called services orchestration [7]. SOA makes this possible; it allows decomposing processes and business activities into independent business services. Dynamic services orchestration stands for assembling and re-assembling these business services while the process is executing. Thus, service can be composed and reused to quickly respond to design process change and to achieve the new model without needing to replace it completely. Moreover, as services expose operations independently of their real enactment, they can be reused even if the enactment is changing (as consequence, some changes do not affect the services orchestration). This supposes that once a change happens, we can dynamically add to, delete from or replace a service operation with another one. The main characteristic of this service-based approach is that it provides a flexible process structure, which provides the necessary agility to face changing conditions and unpredictable situations.

As we have discussed above, business agility is the fundamental business requirement. So, the entire PLM system, starting by IT level, must support business agility. It's important to remember that design processes are very dependent on the information technology that supports it. So, the business also depends of the IT flexibility. So, we propose the whole system reconsideration and not only a business level reconsideration.

To insure the alignment between technical and business level, there should be a mechanism that allows execution of design process with the same language chosen for the business level. So, we propose a service type for each level of the organization. The different levels that we consider are justified by the reality of enterprise information system. On the one hand, we find the organizational IS. It consists of information (business objects) and actors whose act on this information through their work methods (business activities). On the other hand, there is the system infrastructure or Computerized IS. The computerized IS consists of an organized set of items, machines and applications. It allows the implementation of the working methods of the companies and the organization of their information. Moreover, the actors of the organizational IS use the computerized IS through the interfaces provided by its tools. Therefore, there are three levels in the enterprise IS: the business level associated with organizational IS, the technical level associated with Computerized IS and the functional level associated with the interfaces of the Computerized IS. So, by analogy to this classification, we propose three layers of services. First, we propose a catalog of PDS. A PDS is a collection of PDS operations. A PDS reflect solutions to some business needs of a product design domain. In fact, each PDS operation partly reflects a business activity typically presented in design processes. These PDS operations will be used and composed by the business process designer to build design processes. Secondly, we propose a catalog of Functional PLM Services, which (i) ensures alignment between business and technical levels and (ii) aims to be independent of any PLM system. A Functional PLM service is a collection of Functional PLM services operations. The services operations of this layer represent all functions of the PLM as seen by PLM users independently of any existing PLM tool. A set of functional PLM services operations support a PDS operation. They will be used by process performers and composed to achieve the PDS. In other words, once a new business activity is needed to perform a change at the business level (in a design process), a PDS operation is invoked and added to the orchestration and thus operations of functional PLM services can be solicited from the repository to do it. Finally, we propose a set of technical PLM services that allow the real implementation of functional PLM services. These Technical PLM services cover all technical operations carried out in a PLM system and they will be dynamically orchestrated during the enactment of design processes. They are intended to PLM systems editors. This distinction between functional and technical PLM services allow the reuse of process models, defined only in terms of business and functional PLM services, on different PLM systems. Indeed, once a process deployed on a new PLM system, we have to make correspondence between functional PLM services and technical PLM services.

To make the transition from one level to another one, our conceptual approach is based on a Model-Driven Engineering one (MDE) (Fig. 1). Starting at the top with the business level (Computer Independent Model) it is primarily concerned by the design processes that comprise the day-to-day activities of the enterprise. It contains also the business services (PDS), which allow composing the design process. Moving down a level (Platform independent Model), we see the functional PLM services and orchestration fragments that can be predefined or user-defined. Predefined orchestration fragments define the recommended functional PLM services orchestration, which allows fulfilling a given PDS operation.

Functional PLM services are non-specific to any PLM system. That's why services can be mixed and matched into meaningful combinations without concern for what systems are actually performing the work. Down this, we find the technical level (Platform Specific Model), which contains the technical services. This layer forms the API (core functions) of the PLM system used.

In order to achieve the proposed approach, first we have to propose the services catalogs. Then we have to express design processes as service orchestration. Finally we should propose alignment techniques that allow moving from business to technical level. In the rest of this paper we concentrate on the two first steps of our approach (services identification and design processes definition as service orchestration).

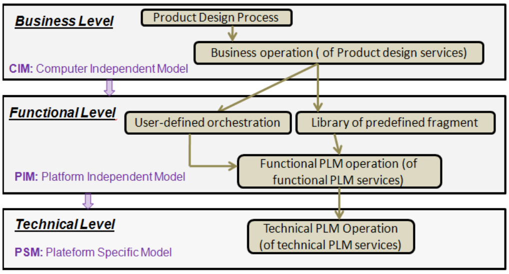

Fig. 1. Conceptual Architecture of the Proposed Approach

3 Service Cartography

As we have discussed above, we aim to offer three services catalogs. A PDS catalog, which expresses the business, needs related to design processes. Functional PLM services catalog enabling the execution of PDS through a functional PLM services orchestration. Finally, technical PLM services catalog enabling the implementation of functional PLM services. The third catalog is dependent on which PLM system we use, so we concentrate only on the business and functional service catalogs. In a previous work the proposed service identification approach is described [8]. Thanks to this approach, fifteen PDS and nine functional PLM services are identified (Fig. 2 and 3).

PrototypeRealisation
CreatePrototype
LaunchPrototypeCreation
DistributePrototype
AskForThePrototype

DesignDepartementDysfonctionnalAnalysis
ElaborateDysfonctionnalAnalysis
DistributeDysfonctionnalAnalysis
EvaluateDysfonctionnalAnalysis
Val;idateDysfonctionnalAnalysis
DysfonctionnalAnalysisElaborationRequest
ConsultDysfonctionnalAnalysis
DysfonctionnalAnalysisEvaluationRequest
DysfonctionnalAnalysisValidationRequest

TestDefinition
ElaborateTestPlan
DistributeTestPlan
EvaluateTestPlan
ValidateTestPlan
TestPlanElaborationRequest
ConsultTestPlan
TestPlanEvaluationRequest
TestPlanValidationRequest

BomManagement
CreateBOM
DistributeBOM
EvaluateBOM
ValidateBOM
BOMElaborationRequest
ConsultBOM
BOMEvaluationRequest
BOMValidationRequest

Fig. 2. An expert from product design service catalog

BOM Management
LinkComponentToProduct
LinkDocumentToProduct
LinkDocumentToComponent
UpdateLinkCPQuantity
UpdateLinkDPQuantity
UpdateLinkDCQuantity
BrowsingUpDocument
CompareProductStructure
CompareComponentStructure
CopyProductStructure
CopyComponentstructure
GetComponentTopParent

Compenent Management
DefineComponent
DefineComponentData
CreateFromComponent
UpdateComponentData
NewComponentVersion
NewComponentRevision
DisplayComponentEditor
DisplayComponentHistoric
DeleteComponent
GetComponentVersion
LockComponent
UnlockComponent

Product Management
DefineNewProduct
DefinePartData
CreateFromProduct
UpdateProductData
NewProductVersion
ChangeProductStatus
DisplayProductAtachment
DisplayProductEditor
DisplayProductHistoric
DeleteProduct
GetProductVersion
LockProduct
UnlockProduct

Document Management
NewDocument (type)
DefineDocumentData
AddDocumentAttachment
NewDocumentFromModel
EditDocumentAttachement
CompleteDocumentData
ExportDocumentToModel
SearchDocument
PrintAttachment
PrintAttachmentToPDF
ExportDocumentToModel
DisplayDocumentEditor
DeleteDocument
GetDocumentVersion

CAD Management
RetreiveASMStructure
RetreivePartQuantity
VisualizeCAO

Fig. 3. Expert from Functional PLM service catalog

4 Design Process as a Service Orchestration

Specifying and implementing one design process consists of:

- Discovering, from PDS catalog, the set of business processes and services' operations that meet the various process modeling requirements. Services are selected based on services' operations labels which allow expressing the business process aims. A business process is seen as a set of steps that contribute to the achievement of the process' aim. Each of these steps has an elementary aim. Selection of services' operations is made regarding these steps' aims. Then, in order to identify the suitable services' operations for each step aim, ontology of product design actions and business objects (product design objects) is proposed to the user. By matching the selected design action with the selected design object, one or more service' operations are proposed to support each process' step. This assumes that user translates each step' aim in pairs "design action/design object". We should highlight that sub-processes which are already defined as orchestrations (i.e. orchestration fragments) can participate in defining the global process. More details on design actions / design objects ontology are given in [9].
- Composing the business orchestration fragments and/or the selected business services'operations, by specifying the set of control flows which link these elements. Control flows allow expressing chaining between operations.

The design process is seen as a composition of orchestrations and services' operations from the design field (PDS). The service orchestration is used to assemble services to achieve a particular goal, through primitive controls (loops, test, exception handling, etc.) [10] or control flow. Regarding the specificities of product design field, service composition approach adopted in this work should:

- be simple at conceptual level, to facilitate the use of various concepts for the process manager and provide a process description which is independent of any platform and understandable to the design actors.
- rely on a manual service composition so that the process manager retain control over the process (decide what services and routines are best suited to the business context).
- allow the dynamic evolution of the services' composition in order to automate the process but also to make changes at the structural level of the process.

The central element of the design process modeling is process decomposition unit, namely service' operations or sub-processes defined by service composition and exposed as full services full (orchestration fragments). Other concepts are needed for the modeling and implementation of the design process. Figure 4 illustrates the concepts that we use for composition approach, using a class diagram described in UML and called orchestration meta-model. This generic orchestration meta-model provides a comprehensive overview of the necessary concepts to express the services composition but also the structural relationships that may exist between these concepts. We define in the following the various concepts included the metamodel and show how this generic metamodel can be used at all levels of our approach.

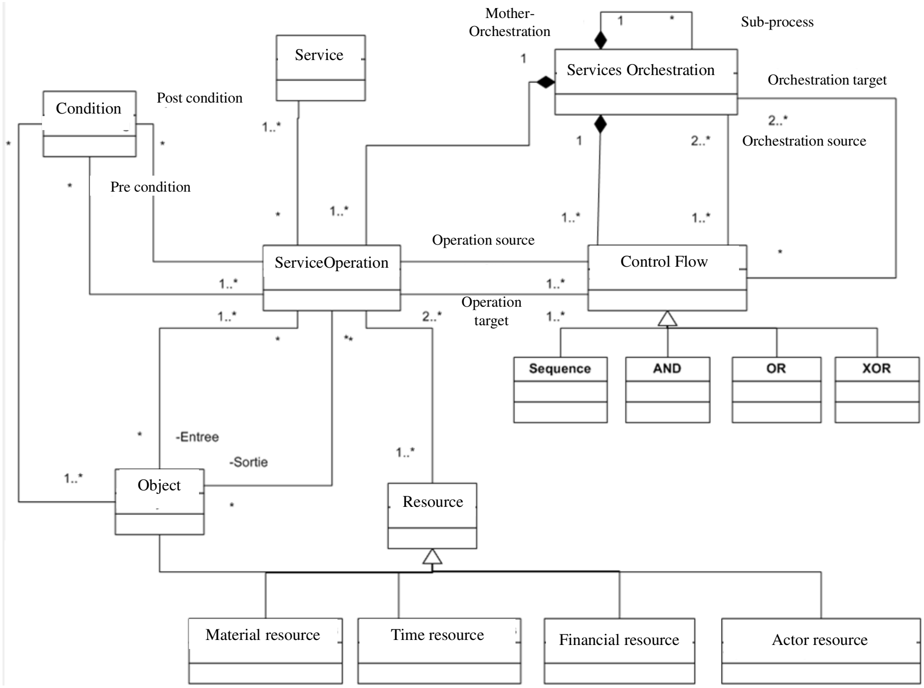

Fig. 4. Generic orchestration meta-model

The central element of this meta-model is the "Services Orchestration" class. This concept corresponds, at the business level of our approach, to the design process model expressed as a composition of services. At the functional level of our approach, it corresponds to the composition of functional PLM services which allow implementing the business level services.

As we can see in Figure 4, the concept of orchestration can be composed by other orchestrations or by instances of the "ServiceOperation" class. This means that the orchestration can call other orchestration fragments already defined. For example, at business level, the design process (i.e. Services Orchestration) may involve sub-processes which are already defined. The orchestration can also be composed by service operations belonging to the services we proposed previously. Structural relationships that we defined between instances of the "Services Orchestration" class and the "ServiceOperation" class facilitate the task of the process manager and simplify the final model. This proposal will allow defining processes (Services Orchestration) which are complex but unambiguous, because the complexity of the sub-processes is masked by the orchestration fragments composing the overall orchestration. Resources element includes resources family that may have an instance of the "ServiceOperation" class. In fact, so they can be executed, instances of the "ServiceOperation" class may need some resources. For example, at the functional level of our approach, the PLM functional operation related to the design of a 2D model will need an instance of the "Actor resource" class who can make CAD models. Another kind of resource necessary for our approach is the "Object" class. Instances of this class represent material or information objects handled or generated by design actors during the execution of the "ServiceOperation". Instances of this class are characterized by their states (created, modified, validated, archived, etc.) which express pre / post conditions on instances of the "ServiceOperation" class in terms of input and output objects. These structural relationships between ServiceOperation, Object and Condition classes can provide flexibility in the design process. The design process ongoing can be altered by changing the states on the objects related to the service operations participating in the orchestration.

Finally, the order for executing the service operations and orchestrations involved in the composite orchestrating is controlled using a set of Control Flow. There are many kinds of control flows in the literature [11] [12] where each connection type has a distinct semantics. We consider the commonly used connections types : sequence flow (to represent the execution order of services participating in the composition of services), AND (to create and synchronize parallel flows linking service operations, business orchestrations of business or service operations with business orchestrations), XOR and OR (to specify the possibility of multiple choice between several alternatives, exclusive or not). The use of control flows allow to express the sequence of service operations and orchestration fragments. The source and target of each flow control can be instances of two classes: ServiceOperations or Services Orchestration. The structural relationships between "ServiceOperation", "Services Orchestartion" and "Control Flow" classes allow providing flexibility at the structural level of orchestration (i.e. the process). Indeed, by changing the source and target of control flows which define the process structure (i.e. orchestration), service operations or orchestrations fragments can be replaced by other service operations or orchestration fragments.

As we can see through Figure 4 and the explanations that follow, the composition approach is generic and independent of any platform or execution system. We also specializing the generic orchestration meta-model at every level of our approach.

5 Discussion and Conclusion

In this paper we discussed the problem of design processes flexibility in PLM system. Product Design processes are emergent and design actors cannot deal with existing technical solutions. Current modeling approaches dealing with business process flexibility were discussed and analyzed. The assumption made is that flexible design processes require specific methods for their design. Our contributions respond to the limitations and problems described above by providing a methodological approach that aims to provide design process flexibility by adhering to service orientation. A service-based approach was introduced to address dynamic design process changes. This approach presents the design process model as a PDS orchestration. In this case the process refers to business behavior in which all steps are PDS operations. Thus, a PDS can be invoked to perform a given step of a design process. The challenge here is to react quickly to changes either by replacing some services by other ones or by adding new services to the orchestration. In order to deal with alignment issues between technical and business level, we first proposed a service type for each level. Then, we proposed an orchestration model in each level (business, functional and technical) and a mean that allows transforming the business orchestration model to a functional orchestration model by adhering to MDE techniques. Finally, according to the used PLM system, a mapping between the functional services of the functional orchestration model and the technical services of the PLM system should be done using the same deployment techniques. In this paper we presented the business and functional services catalog. We also defined the meta-model needed to orchestrate PDS. Then, the proposed service-based approach supports changes at both levels: process model (process model is changed by composing reusable PDS and orchestrations' fragments) and process instance (process instance is changed by composing reusable PLM technical services obtained through transformation of business services into technical services). Support of emergent process evolution has not been addressed in this paper. To allow managing "on the fly" emergent or ad-hoc processes, the composition approach should include mechanisms to allow deferred services selection. Techniques that allow moving from one level to another one have not been addressed either. To do so, we proposed a conceptual architecture based on a Model-Driven-Engineering approach [13]. We defined a mapping meta-model between business and functional levels, which we named business deployment meta-model. According to the business deployment meta-model and the business orchestration model, executing a set of mappings rules can generate the functional orchestration model. As far as, we defined a mapping meta-model between functional and technical levels that we named functional deployment meta-model. Using the same deployment techniques, the technical orchestration model can be generated based on the functional orchestration model and the functional deployment meta-model. The distinction between functional and technical PLM services shows the genericity of the proposed approach. In fact, an enterprise can change her PLM system or even have multiple PLM systems. The advantage of our approach is that the company can uses the same business orchestration model (and the same business deployment model), but execute many functional deployments model according to the used PLM systems. Indeed, once a process model deployed on a new PLM system we have just to execute the right functional deployment. In contrast, the limitation of our approach is that we define the deployment only on a top-down manner and we consider that all functional PLM services operations have a corresponding list of technical PLM service operations.

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Simulated Annealing for a Vehicle Routing Problem with Simultaneous Pickup-Delivery and Time Windows

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Abstract. A variant of vehicle routing problem in which customers require simultaneous pickup and delivery goods during specific individual time windows (VRPSPDTW) is addressed. A general mixed integer programming model focused on minimizing the number of vehicles is proposed. A simulated annealing (SA) algorithm is developed and applied to solve this NP-hard optimization problem. Computational results are reported for a set of 15 test problems from Wang and Chen's benchmark and compared with the results from a genetic algorithm (GA). It is shown that SA is an effective metaheuristic to solve the VRPSPDTW.

Keywords: simulated annealing, simultaneous delivery and pickup, vehicle routing problem, time windows.

1 Introduction

The Vehicle Routing Problem with Simultaneous Pickup-Delivery and Time Windows (VRPSPDTW) is the important subclass of Vehicle Routing Problem with Simultaneous Pickup and Delivery (VRPSPD) where a fleet of homogenous or non-homogenous vehicles stationed at a depot are not only required to deliver from the depot to customers but also simultaneously to pickup goods at the customer location for return to the depot without violating vehicle capacity constraints and time windows constraints. Time windows define the earliest and latest service time allowed for each customer.

From a practical point of view, VRPSPDTW falls within the field of logistics resource integration and supply chain integration which incorporates reverse logistics into the forward channel and has attracted more and more attention recently because of the increasing focus on environmental protection and sustainable supply chains. For example, Hewlett-Packard (HP) was reported to distribute the products in logistics network and pick up the used IT hardware such as used original toner cartridges and supplies from the retail location [1]. From a mathematical point of view, VRPSPDTW is a NP-hard combinatorial optimization problem which means that exact algorithms can only be used to find solutions for small-and-medium scale instances. The commercial linear programming software CPLEX has been reported to

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solve the VRPSPDTW problem executed on an Intel Core2 Quad 2.4G computer with 1G memory, and was only able to solve a 10 customer instance, and a portion of 25 and 50 customer scenarios [2]. For the solved instance RCdp 1004 (10 customers instance) and RCdp5001 (50 customers instance), the computation time was 1503 seconds and 327,404 seconds respectively. To solve the computational challenge associated with applied problem that involve more customers, researchers and practitioners have to develop heuristic or metaheuristic approaches to produce high-quality solutions (but not necessarily optimal solutions) with reasonable computational times.

The technical literature on VRPSPDTW problem is somewhat limited. Angelelli and Mansini [3] was the first researchers to solve VRPSPDTW with a comprehensive exact algorithm which combined a branch-and-price and branch-and-bound approach. Lai and Cao [4] proposed an Improved Differential Evolution (IDE) algorithm for solving this problem and did numerical experiments with their own instances. Boubahri et al. [5] constructed a multi-agent colonies algorithm for this problem, but did not test with the instances. Wang and Chen [2] proposed a co-evolution genetic algorithm with variants of the cheapest insertion method for VRPSPDTW. They also developed 65 instances revised from the well-known Solomon benchmark [6] for VRPTW.

However the literature on the VRPSPD problem is better studied than the more specific class of problem noted above, i.e., research that does not consider time windows. For good reviews on the VRPSPDTW, the reader is referred to Subramanian et al. [7]. Min [8] was the first to study this problem. He solved the book distribution problem in a public library system which involved 22 customers and two vehicles. Some exact methods have been developed for the VRPSPD, including the branch-and-price technique [9] [10] and the branch-and-cut technique [11]. However, due to the problem difficulty, the design of efficient heuristics or metaheuristics which are capable of solving this problem in large scale instances has attracted many research efforts in the past few years. Some example heuristics are: Residual Capacity and Radical Surcharge (RCRS) algorithm [12], Large Neighborhood Search (LNS) [13], and GENEVNS-TS-CL-PR algorithm [14]. Some example metaheuristics are: pure or hybrid Tabu Search (TS) [15] [16], Ant Colony Optimization (ACO) [17] [18], Genetic Algorithm (GA) [19], Particle Swarm Optimization (PSO) [20], and Iterated Local Search (ILS) algorithm [7] [21].

The purpose of the present study is to develop an efficient metaheuristic to solve the VRPSPDTW problem by using simulated annealing algorithm. The paper is organized as follows. Section 2 gives a detailed description of how the proposed simulated annealing algorithm is implemented on the VRPSPDTW problem. Section 3 provides comparisons to the VRPSPDTW benchmark. Finally, conclusions are drawn in Section 4.

2 Simulated Annealing (SA) Applied to VRPSPDTW

The problem-solving methodology based on the SA algorithm is presented in this section. SA implements a Metropolis sampling strategy with probability mutability, randomizes the local search procedure, and obtains the global optimum with a slow cooling schedule. The most important feature of SA compared with other local search algorithms is that SA always accepts a better or unchanged solution as a new current solution, and accepts a worse solution with a certain probability, which allows the search to escape from local minima and become a global optimum algorithm in theory.

The text below describes the steps in the simulated annealing algorithm applied to solve the VRPSPDTW problem.

Step 1 Initialization of the solution and temperature

(1) Generate an initial heuristic solution. In order to improve the convergence speed of SA, it is better to introduce a small-size heuristic algorithm and find a high quality feasible solution as the initial solution. VRPSPDTW considers a simultaneous pickup and delivery, therefore the Push-Forward Insertion Heuristic (PFIH) and Genetic Sectoring Heuristic (GSH), which are used for solving VRPTW, are no longer applicable because the vehicles are assumed to be at full load when leaving the central depot in their algorithms. In this paper, the initial solution is constructed using the RSRC algorithm [12] proposed by Dethloff for the VRPSPD problem, where it is noted that the load of vehicle when leaving is depot is not equal to vehicle capacity, but rather, calculated in the algorithm.

(2) Set initial annealing temperature. The setting of an initial temperature determines whether the initial stage of the annealing process can accept poorer solutions with high probability. Based on the characteristics of VRPSPDTW, and combined with the relevant literature [22] about simulated annealing theory, the following method can be used to choose the initial temperature.

The cost and cooling temperature of the VRPSPDTW solution is computed as follows:

$$\cos t(s_k) = d + \sigma(c \times n + e_{\min}) \tag{1}$$

$$T_k = \gamma \times \cos t(s_k) \tag{2}$$

where s_k is the feasible solution, d is the total travel distance of the routes, σ is a constant， c is the number of routes in solution s_k (equal to the number of vehicles needed), n is the number of customers, $e_{\min}$ is the number of customers in the shortest route, and $\gamma < 1$ is a constant.

Van Laarhoven and Aarts [23] proposed a method of decreasing temperature which appears to be the most widely used method reported in the literature:

$$T_{k+1} = \beta * T_k \tag{3}$$

where β is the coefficient controlling the cooling schedule, and a constant less than 1.

When $k = 0$, the initial temperature is:

$$T_0 = \gamma \times \cos t(s_0) \tag{4}$$

Step 2 Repeat the following operation under the current temperature T_k until it reaches the equilibrium state at T_k.

(1) Local search in the neighborhood of the current solution s_k to generate a new feasible solution s_k'. We use a standard SA procedure with a random neighborhood structure which imposes three types of improvement methods, including insertion move, swap move, and 2-opt move, to solve VRPSPDTW. These moves are commonly embedded in SA heuristics, and other meta-heuristics. We define the set $N(s_k)$ to be the set of solutions neighboring of solution s_k. At each iteration, the next solution s_k' is selected from $N(s_k)$ either by insertion move, 2-opt move, or swap/shift move. The probabilities of choosing the insertion move, 2-opt move, or swap/shift move are set to be 1/3, 1/3 and 1/3, respectively.

Insertion move is a random improvement method, which is carried out by randomly selecting the ith number of s_k and inserting it into the position immediately before another randomly selected jth number of s_k. 2-opt move is a intra-route exchange, which tries to lower the route distance by altering the sequence of customers within a single route. It switches the route direction between two consecutive nodes. If the cost function of the route has been reduced, then the modified route is kept; other-wise, the route returns to the last condition. Swap/shift move is a inter-route exchange proposed. It either shifts a customer from one route to another, or exchanges a customer on one route with a customer on another route.

(2) Determine whether to accept the new solution

The SA process proceeds by comparison of the cost of the newly generated feasible solution s_k' and the current solution s_k. If $s_k' \le s_k$, the newly generated solution s_k' becomes the current solution. If $s_k' > s_k$, s_k' is accepted with the probability

$$p = \begin{cases} 1 & \cos t(s_k) > \cos t(s_k') \\ \exp(\dfrac{\cos t(s_k) - \cos t(s_k')}{T_k}) & \cos t(s_k) < \cos t(s_k') \end{cases} \qquad (5)$$

where T_k $(k = 0,1,..,k_{\max})$ is a parameter called temperature of annealing. This temporary deterioration of the objective function value is an uphill move process, which avoids the metaheuristic to trap into a local optimum.

(3) Determine whether to terminate the inner loop

Metropolis sampling stability criterion is used to determine the number of candidate solutions produced at the respective temperatures. Here we set L steps as the maximum number of iterations at temperature T. If the iterations counter for temperature T is not exceed L, return to **Step 2** (1) and continue the procedure of generating and accepting new feasible solution, otherwise, the inner loop is terminated, the temperature is decreased according to Equation (3) and transferred to **Step 3**.

Step 3 End the procedure if the stopping criterion is met

The common stopping criteria are: (i) specify a determined maximum number of total iterations the search proceeds; (ii) set the final temperature T_F, below T_F the

SA procedure is terminated; (iii) specify a maximum number of successive iterations $\omega_{\max}$ which remains the non-improving best solution found so far for a consecutive temperature reduction stages. This paper uses the third stop criterion, which determines whether to stop the outer loop based on whether the gradually lowered temperature during the search procedure is able to continue to improve the current optimal solution or not.

Step 4 Output the optimal solution.

Output the optimal solution, and terminate the algorithm.

3 Computation and Evaluation

In this section, we demonstrate the effectiveness of our SA metaheuristic by testing it on the benchmark datasets, namely Wang and Chen's instances [2]. All experiments are executed on a 32 core Redhat Linux server (8 $\times$ quad core 2.3 Mhz, Opteron 8346) with 64G of RAM.

In the proposed SA, parameters must be specified and appropriately adjusted: parameter σ in Equation (1), parameter γ represents relations between cost and temperature, the constant of decreasing temperature β, Δ which represents the probability of accepting worse solutions, parameter L which is the maximum number of iterations for temperature T, parameter $\omega_{\max}$ which is the maximum number of iterations of non-improving the current best solution, parameters *lamda* and *alpha* in RCRS insertion criterion proposed by Dethloff [12]. The above parameter values were obtained through fine tuning and are listed in Table 1. In general the performance of the SA algorithms is sensitive to the above cooling schedule.

Table 1. Parameters used in the SA

SA paramater	σ	γ	β	L	$\omega_{\max}$	Δ	*lamda*	*alpha*
Value	1	1	0.97	30	200	0.6	0.8	0.8

Wang and Chen's instances[1] about VRPSPDTW were revised from Solomon's VRPTW benchmarks[2]. Six different sets of problems were generated. The geographical data are randomly generated in problem sets R1 and R2, clustered in problem sets C1 and C2, and a mix of random and clustered structures in problem sets by RC1 and RC2. Problem sets R1, C1 and RC1 have a narrow scheduling horizon, and the sets R2, C2 and RC2 have a large scheduling horizon. Three 10-customer instances, three 25-customer instance, three 50-customer instances and six 100-customer distances are tested for proposed SA.

[1] Download of Wang and Chen's benchmark instances from Y. Y. Chen: `http://oz.nthu.edu.tw/~d933810/test.htm`

[2] Download of Solomon's benchmark instances from M. M. Solomon: `http://w.cba.neu.edu/~msolomon/problems.htm`

Table 2 compares the best resulted obtained by Wang and Chen [2] (GA metaheuristic) with the results obtained by the simulated annealing we developed for part of 65 Wang and Chen benchmark. The last column of this table shows the gaps between GA and proposed SA. These results are summarized at the bottom of the table. The mean and maximum percentage gaps are -0.22% and 1.61% respectively.

Table 2. Comparasion between GA and the proposed SA to the VRPSPDTW

Problem/Instance	GA		Proposed SA		Gap	
	NV	TD	NV	TD	NV	TD
Rcdp1001/10	3	348.98	3	348.98	0	0.00%
Rcdp1004/10	2	216.69	2	216.69	0	0.00%
Rcdp1007/10	2	310.81	2	310.81	0	0.00%
Rcdp2501/25	5	551.05	5	554.33	0	0.60%
Rcdp2504/25	4	473.46	4	473.46	0	0.00%
Rcdp2507/25	5	540.87	5	540.87	0	0.00%
Rcdp5001/50	9	994.18	9	994.7	0	0.05%
Rcdp5004/50	6	725.59	6	725.9	0	0.04%
Rcdp5007/50	7	809.72	7	810.04	0	0.04%
Rdp101/100	19	1653.53	19	1660.98	0	0.45%
Cdp101/100	11	1001.97	11	992.88	0	-0.91%
RCdp101/100	15	1652.9	15	1679.46	0	1.61%
Rdp201/100	4	1280.44	4	1286.55	0	0.48%
Cdp201/100	3	591.56	3	591.56	0	0.00%
RCdp201/100	4	1587.92	4	1497.8	0	-5.68%
				Minimum		-5.68%
				Mean		-0.22%
				Maximum		1.61%

Take RCdp1001 instance as an example, a run of SA shows that the best operational plan is: vehicle 1 (route 1): 1-31-51-92-1, the delivery and pickup amount is 53 and 23 respectively, the route distance is 104.85 and need 189.04 to finish this service; vehicle 2 (route 2): 1-83-72-95-101-1, the delivery and pickup amount is 49 and 90 respectively, the route distance is 116.68 and need 209.24 to finish this service; vehicle 3 (route 3): 1-60-88-49-1, the delivery and pickup amount is 52 and 83 respectively, the route distance is 127.45 and need 206.04 to finish this service; the total distance and total travel time traveled by the three vehicles is 348.98 and 604.32 respectively.

4 Summary and Conclusion

The vehicle routing problem with simultaneous pickup-delivery and time windows is a very application-intensive but notoriously NP-hard problem, so the complexity of medium-and-large instances in practice does not allow an exact solution of the problem, making it necessary to implement heuristic or metaheuristic approaches to provide the approximated solutions within reasonable computational time. This paper has presented a simulated annealing metaheuristic for the VRPSPDTW problem. To the best of our knowledge, this is the first simulated annealing approach proposed to solve this problem. Comparisons from the results of the GA algorithm and the proposed SA show that the proposed method is effective for solving VRPSPDTW problem.

High-quality solutions are guaranteed by the tight cooling schedule, particularly when a sufficiently high initial temperature, slow annealing speed, a large number of iterations, and holding time at the same temperature are utilized. This is usually at the price of a high computation resources and times. Therefore, further work will concentrate on parallelization of SA to accelerate the proposed algorithm.

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Development of a Decision Support System to Facilitate Multi-criteria Decision Making during Humanitarian Operation within a Project Life Cycle

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Abstract. The use of decision support systems is an important part of supply chain management. Quick and adequate decision making is sometimes difficult to achieve. Three issues arise: how to gather relevant data and use past experiences, how to make the decision when many criteria have to be taken into account and how can we ensure that the decision making process is quick. Those three issues are currently faced by many companies and some solutions have already been proposed in the literature. Yet, in some cases, it is difficult, if not possible to apply those solutions. Humanitarian organizations, for example, have difficulties to build on past experiences. Quick decision making in this sector is vital. The purpose of this paper is to design and develop decision-making tool to support the performance of humanitarian logistics. A case study at the French Red Cross will validate this proposal.

Keywords: Decision support system, supply chain management, humanitarian logistics, multi-criteria decision making.

1 Introduction

Crises happen. Earthquakes, floods, conflicts, chemical leaks are but a few examples of disasters, which affect organizations. We are unable to know for certain when a disaster will occur or how violent it will be. To assist the population affected by disasters, to send relief items and supplies, but also doctors and other human resources, a supply chain is set up. Moreover, the decision need to be quick. Resources need to be sent within five days after the disaster to enable an effective disaster relief. They are usually pre-positioned in strategic places to reduce the lead time during those crucial days. Usually, the choice regarding the usage of one warehouse instead of another and the choice regarding the mean of transportation used are overlooked because quickness has precedence over any other indicator such as costs or environmental impact. Yet, nowadays, humanitarian organizations undergo an increased pressure to improve their processes.

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Humanitarian organizations differ from private companies in many ways. Among others, this sector is historically focused only on its currents action, on the day to day work needed to attend affected people. The funding of operations comes before any long term project, such as the development of Computer Based Information System (CBIS). In addition, the high turnover of staff reduces the possibilities to build knowledge on past experience, especially since few or no data are recorded from past operations. The inconsistent and uncertain environments in which organizations operate also complicate the situation, as data is difficult to collect and analyze. Last, but not least, the decision making process needs to be quick due to the lives at stake.

Currently, many organizations are becoming more interested and aware of the importance of supply chains and try to find ways to make humanitarian logistics [10] more efficient and suitable. The scope of supply chain management being broad, for the purpose of this study, we focus on humanitarian logistics, and especially on transportation. Most of the existing research in humanitarian field are focusing on the efficient understanding of the core capabilities of humanitarian logistics and the understanding of processes of disaster relief. Our proposal is to go beyond this theoretical approach and propose a simulation tool to facilitate.

2 Research Background

To describe the current situation on decision-making of humanitarian sector concern in academic research, we have reviewed the articles related on project life cycle management, performance indicators in this sector, Multi-criteria via decision making and Decision Support System (DSS). In this part, the literature is analyzed and synthesized according to the main research areas needed to design and develop a multi-criteria decision support system for humanitarian sectors.

2.1 Project Life Cycle Management (PLM)

Another element contributing significantly to the originality and innovative nature of our project is our intention to build our study with a project life cycle management (PLM). Indeed, up until now, many stakeholders, from donors to researchers focus on one specific phase of disaster relief operations, usually one of the two first phases (preparedness or immediate response). According to Zhou et al.[11], “it is clear that the existing literatures mostly deal with a specific activity in the emergency response process. Researchers care more about emergency logistics”. Our intention with this proposal is to fill this gap, and take a project life cycle approach to map out the steps needed to complete humanitarian operations with specific targeted results.

In our study, we can map all the processes in one project life cycle, from the initiation until the closing or operations. This PLM approach fits to the humanitarian sector and their way of operating. Indeed, they set up operations in a specific country, were a crisis occurred, and they proceed step by step to send to assist disasters victims, until operations are closed, usually a few months after. Humanitarian operation life cycle and some factors that humanitarian workers must consider are illustrated in Fig.1. Indeed, during operations, the quantity and quality of available data changes, and so does the priorities of each performance factor (Fig.1.)[2].

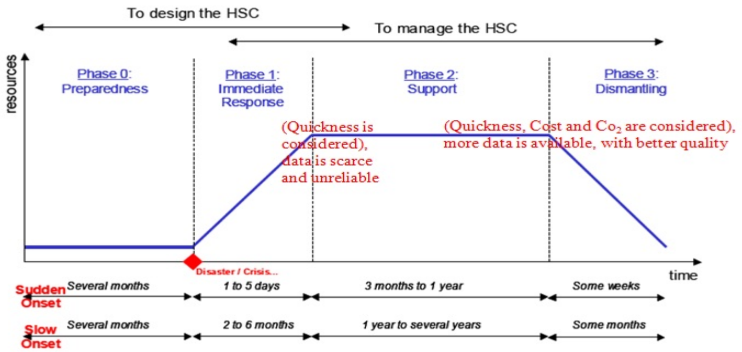


Fig. 1. Humanitarian Operation life cycle

2.2 Multi-criteria via Decision Making

There are several critical success factor in the context of humanitarian and supply chains. According to [9] there are ten critical success factors consisting in strategic planning, resource management, transport planning, capacity planning, information management, technology utilization, human resources management, continuous improvement, supplier relations and supply chain strategy.

If we consider one of the most important factor, transportation planning, then both long-term and short-term decisions are made. For those decisions, many factors or criteria have to be taken into account. Which one should we focus on?

Quickness or rapid response time of delivery is one of many key performance indicators (KPI) for humanitarians supply chains [1]. Indeed, the timely delivery of critical goods has always been a crucial element of an effective disaster response[3]. The transportation costs are also needed because of the characteristic of non-profit organizations. As the major income comes from donations, it is uncertain. We should consider this issue because recently there has been an increased pressure on non-profit humanitarian organizations to held them accountable of spending their donors' money wisely. This is a universal indicator which should be included [1]. Nowadays, the environmental impact is also emerging as a key performance indicator. The CO_2 emission, also called carbon footprint, is the main factor affecting transportation. The value of Carbon Footprint is one of many factors which can show how much of equivalent tons of carbon dioxide (CO_2) is emitted [5]. As a result, quickness, cost and CO_2 are the main criteria (KPI) of humanitarian logistics for our model.

When we consider these criteria in each phase of the humanitarian operation life cycle in Fig.1, the importance of each criteria evolves. Whereas quickness has precedence during the first two weeks, costs and CO_2 are also important later on. During each phase of the cycle, the weight of each criteria is changed. To choose transportation means and suppliers locations in each phase, we have to consider those three criteria, but with different weights. One approach for decision maker such as multi-criteria decision analysis (MCDA) and Analytic hierarchy process (AHP) decision model should be considered.

2.3 Decision Support System (DSS) and Management Information System (MIS)

To face the lack of available information, we propose to build a system to facilitate planning, preparing and managing operations. The system collects raw data and transforms it into information, as information is a crucial part to support the decision making process. This is the purpose of the following section.

In our study we aim to develop a multi-criteria decision support system within a project life cycle. We will analyze the factors which should and can be used to support the decision making process. We will work on available internal and external data, but also propose a solution to better take into account the knowledge of past operations. Then we will design and apply a multi-criteria decision support system for one specific organization: the French Red Cross. This study designed to address a need in a specific sector, can then be generalized to fit with other organizations, or private companies. The third and fourth section provide some inputs with regards to the system we are designing and its expected results.

3 Humanitarian Logistics Management Application

As we mentioned earlier in introduction, due to the limitation of time in during international disaster relief operations, it is hard to manage operations and make a good decision, especially in terms of logistics. For example, at a humanitarian organization, when a crisis happen, a project is planned and the decision maker tries to find the best way to make decision regarding the choice of adequate transportation means, material, medicines, food and supporting staff. What should they do to ensure that their decision will be correct and proper for rescuing people in a limited time?

Problem in the determination of performance in Humanitarian Logistics is quite complex. Both quantitative and qualitative data have to be taken into account, they are unclear, scarce, and often uncertain. Although we can measure the amount of delivery time, cost, and CO_2 from a calculation tool but quantitative data such as criteria weight may have changed overnight (Fig.1.) that must be considered. It is a complex decision making problem.

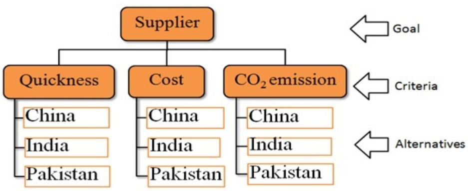
The second problem is how to combine quantitative data and qualitative data in one output value? The value should be quantitative data because it is easy to compare and make decision. One of the possible approaches is AHP model. Indeed, according to [7] AHP was designed for complex problems in situations which involve a number of conflicting criteria, alternatives and defined attributes. It also can reduces the complexity of decision making in reliable way. For these reasons we choose AHP to implement our decision model.

According to AHP decision steps so we need to decompose our model into the following steps.

1. Structure the decision hierarchy of humanitarian logistics.

The goal composed of "Which supplier, warehouse and vehicles should be selected in each project?" are the goal. For supplier is illustrated in Fig.2. The criteria of case study in our scope are time response (quickness), Cost, CO_2. The alternative, The supplier composed of China, India and Pakistan. These preliminary data have already been gathered thanks to interviews at the French Red Cross offices.

2. Construct a set of pairwise comparison matrix for supplier goal with three main criteria. The priority of weights (W_1,W_2 and W_3) will be given by FRC logistics specialist. There is illustrated on Fig.2



Criterion	Quickness	Cost	CO_2
Quickness	1	W_1	W_2
Cost	$1/W_1$	1	W_3
CO_2	$1/W_2$	$1/W_3$	1
Eigenvector	EQn	ECost	ECO_2

Fig. 2. Supplier AHP decision model and a pairwise comparison matrix of supplier

All elements in the matrix is normalized and consistency ratio checked, then get three eigenvectors consist of EQn, ECost and ECO_2.

3. Construct a set of pairwise comparison matrices pairwise comparison matrix for alternative (Supplier : S_1,S_2 and S_3) with each main criteria. The priority of weights (w_1,w_2 and w_3) will be given by our information system automatically which will be discussed next. All elements in the matrix is normalized and consistency ratio checked, then get three eigenvectors consist of $EQnS_1$, $EQnS_2$ and $EQnS_3$.

4. Repeat step 3 with remaining criteria (Cost and CO_2)then we will get parameters in following : $ECostS_1$, $ECostS_2$, $ECostS_3$, ECO_2S_1, ECO_2S_2 and ECO_2S_3.

Our formulas are

- $S1 = (EQnxEQnS_1)+(ECostxECostS_1) + (ECO_2xECO_2S_1)$
- $S2 = (EQnxEQnS_2)+(ECostxECostS_2) + (ECO_2xECO_2S_2)$
- $S3 = (EQnxEQnS_3)+(ECostxECostS_3) + (ECO_2xECO_2S_3)$

We can make comparison and get optimize supplier from this simple model.

5. Repeat step 2, 3 and 4 with the other goal ("Which warehouse and vehicles?")

then we will also get the optimize of warehouse and vehicles.

From these model we can simulate and get the ideal optimize results that we should select but in fact we have to think in advance and plan to manage uncertain situations or the riskiness that may occur. For our study we are undergoing in this issue.

Due to their characteristics, non-profit organizations may not collect data in a proper way to enable their analysis and usage directly for decision making. Our aim is to provide a DSS which will facilitate data collection and management, and store information that we can use in a complex decision model for our DSS. This DSS will quickly provide possible alternative decisions to users, with their main advantages. The components of our application for the French Red Cross decision support system are inspired from [8]. The decision support methodology and knowledge management activities come from [4]. Both are illustrated in Fig.3.

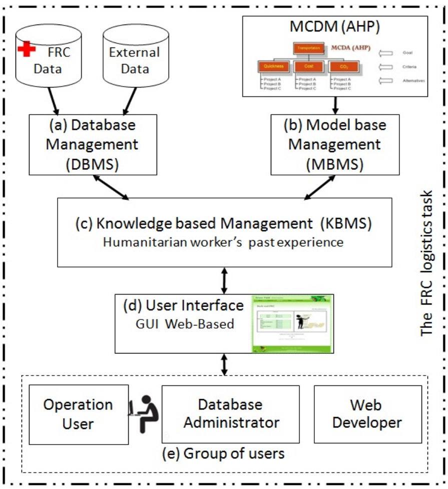


Fig. 3. A framework of decision support system

The framework of the DSS we propose the consists of five main components

(a) DBMS: We design and develop fundamental database by using relational database. Logistics data is provided by the FRC directly, such as disaster relief, departure location (supplier, warehouse) and destination location, vehicle type, fuel, selected item (first aid kit, food, medicine). External data has been selected the necessary data such as the value of emission factor from existing data in reliable sources.

(b) MBMS: We construct a decision model by using AHP approach. Mapping of elementary criterion and alternatives, In case of supplier choosing. It is illustrated in Fig.2.

(c) KBMS: We will combines information from DBMS and MBMS, including past experiences of logistics worker. This phase is undergoing.

(d) UI: We choose to develop a GUI web-based application to manage and simulate information flows of our DSS.

(e) Group of Users : We divide users into three groups : operation user, database administrator and web developer.

We already developed the first version of web-based application for the logistics department of FRC. It is working on client-server model. The DBMS and MBMS are embedded on server-site and scoped in supporting the decision-making process in the tactical level and the operation levels.

4 The First Result and Expected Results

This first tool has been chosen to show the value added of our proposal, with a simple and straightforward application. It corresponds to the specifications required at the FRC. Some web pages are already done as illustrated in Fig.4. Further work is undergoing to include the other performance dimensions and enable an agile response according to the life cycle phase.

Fig. 4. FRC logistic management application

5 Conclusion

Presently, The work of humanitarian organizations is an increasingly important mission, especially during disaster relief operations. The main issue faced by humanitarian workers is the lack of decision support systems to improve, facilitate and accelerate the process of decision making.

In the near future, we will model the specific AHP decision model. We also plan to design and apply a case study approach to gain some crucial knowledge from involved logistics experts. Then we will continue to develop the DSS application in every needed function and make it fit to user requirements as defined by our case study.

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Interactive Business Models to Deliver Product-Services to Global Markets

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Abstract. The main aim of this paper is to propose a collaborative solution platform to design, assess and deploy technology-based business models, supporting the analysis and evaluation of business ecosystems for the manufacturing and delivery of customised product-services in global markets. The proposed platform will guarantee a common thread for the execution of a multi-stage gate reference process for the generation and consolidation of a technology-based business model, providing a consistent path from the idea generation to the production, delivery and commercialisation of a solution.

Keywords: Business Models, Value Propositions, Emerging Technologies, Global Markets, Product-Service Systems.

1 Introduction

To create new sources of value, several industrial sectors are striving to provide integrated product-service solutions, which would contribute to tighten and foster the relationship with the customer. Regardless of the business context, either B2B or B2C, customers ask for products with a high degree of personalisation and with better quality, faster delivery times, and shorter times between successive generations of products. The distinction between products and services, tangible and intangible, is blurring in favour of the elaboration of a more customer-oriented strategy. Breaking down the traditional barriers between products and services, the concept of *Product-Service System (PSS)* prevails as a systemic approach enabling a strategic and managerial transition from selling a mere artefact to providing the user with a unique and positive experience throughout the journey with a customised and result-oriented solution.

In response to this, manufacturing industry has to change its approach from cost-cutting to customer-centric knowledge-based value adding through the adoption of innovative business models, aiming at increasing the product variability, customisability, and production robustness.

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The combination of these trends, summarised in Figure 1, is pushing companies to rethink their value creation mechanisms by shifting from a broad global standpoint to a responsive local perspective in order to be perceived by the final customer as a "good and reliable neighbour". These factories of the future need to be collaborative, reconfigurable, adaptive and evolving, capable of small-scale production to create new customised products and services, environmental friendly and able to respond promptly to the uncertain market evolution.

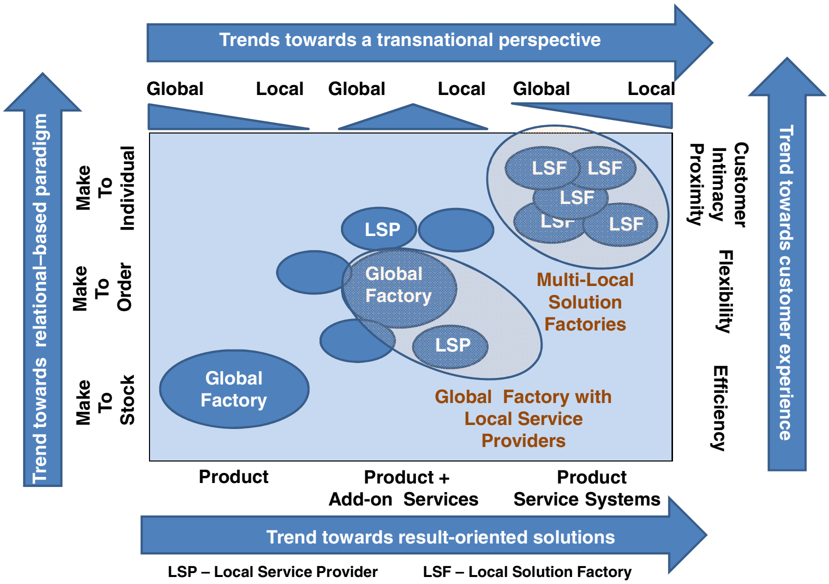

Fig. 1. The Evolutionary Path towards Multiple-Local Solution Factories

Consequently, enterprises are moving from an international business approach, with large and highly specialised global factories, to a transnational strategic positioning, by relying on a multitude of *local solution factories (LSF),* proximate to the demand and able to provide customised PSS. Such a strategic changeover requires also the dynamic reconfiguration of a constellation of manufacturing companies and solution providers capable to operate at multiple locations around the globe.

To tackle all these challenges and maintain the competitive leadership in different markets, the European Strategy 2020 Agenda stresses the role of technology as the key enabler of flexible and innovation-driven networks. Technology plays an important enabling role in developing value for the society by providing innovative ideas to be turned into new customer-oriented *product-service systems* and in restructuring industrial processes. However, even if the mastering and deployment of *key enabling technologies* are expected to provide significant economic benefits, their actual application is still limited and in many cases their commercialisation has not been as successful as expected. According to the *EC Working Team on Advanced Manufacturing Systems,* it is fundamental to find a consistent way to link innovation policies for key enabling technologies to an industrial policy, which will underpin the deployment and further development of advanced manufacturing technologies.

In such a context, the main motivation of this paper resides in the need to rely on a reference process for technology-based business models generation. This would enhance and exploit the opportunities and the potential derived from the introduction and proper hybridisation of emerging technologies in the global production and service contexts.

2 Business Model Frameworks for Product-Service Systems

Since the 90s, companies operating in the western mature markets have progressively realised the importance of complementing industrial goods with the provision of value added services, shifting the business focus from selling a physical product to offering functions, services and performance [1]. In exploring this phenomenon, a relevant stream of the literature has assigned an increasing emphasis to the role of Product–Service Systems (PSS) as a concrete response to these emerging pressures. The main idea behind the PSS concept is that it ensues from an innovation strategy, moving the business focus from the design and sales of physical products to the design and sales of a system consisting of products, services, supporting networks and infrastructures, which are jointly capable of fulfilling specific client demands [2].

However, although services are thought to deliver higher margins, most organisations find it quite problematic to master this transformation. To properly provide services, they must radically change the way they operate and mature the capability to design and deliver services rather than products and develop new knowledge, organisational principles, metrics and incentives.

In order to ensure a successful implementation of a PSS into the market, proper business models must be identified. A business model is a logical description of how a firm does its business with its products and services [3]. It provides a basis for creation of tools and frameworks to assist business managers and engineers in investigating business models and value propositions. These tools serve a number of potential functions: from capturing and understanding the relevant elements and interactions of a business model to assisting in the design, planning and management of value creation logic, as well as in prospecting business models through structured design and simulation [4]. Along the literature in the last decade, it is possible to find several business model generation processes and reference models. Among them, the most famous one is the business model canvas proposed by Osterwalder and Pigneur [5]. Most of the contributions attempt to establish the taxonomy, architecture, or constituent elements of business models, mostly focusing on the question: *"What elements are needed to establish a firm's business model?"*, whilst neglecting the question: *"How is an innovative business model to be designed?"*

Among the many factors that support business model innovation, emerging or new technologies have always played a key role, because they can provide a relevant contribution in designing new products and services, in improving product and service quality, and in making a production process more flexible, configurable and economic. Innovation and new initiatives require business model changes at the enterprise level, because if new and emerging technologies are poured into old business models, innovation will not be successful for companies and it will not lead to customer orders and new revenues.

However, the success or failure of a company's business model depends on how it interacts with the business models of other players in the industry, that are all fighting to create and capture value too. In fact, if analysed in isolation one business model can appear successful, but the interactions with other companies' business models can lead to a failure. Thus, it is important, when developing a business model, to consider the dynamic interactions with all the other players (e.g. suppliers, distributors, customers and even competitors) operating in the business ecosystem[1] involved in the delivery of a specific product or service that could also lead to turn a rival into a partner in value creation [6].

For this reason, it becomes important to foster collaboration with other partners inside the same industry in order to identify new business opportunities leveraging on cooperation and on the exploitation of new technologies. Besides the lack of external collaboration, one of the main barriers companies have to cope with to provide successful *product-service systems* is the lack of experience and know-how to design product-service solutions and the related management systems [7].

Compared to physical products, services are still under-designed and inefficiently developed, even if service design and development issues are increasingly being recognised as important to managers [8]. There is the need to design and develop an integrated offering that is valuable to customers in order to contribute to a continuous positive change throughout the journey of experience.

In addition, the creation and successful implementation of PSS business models requires a rethinking of managerial and organisational practices, new capabilities and competencies, as well as an assessment of supply chain relationships, in order to define the level of collaboration among firms, and the intensity and density of interaction and coordination modalities. These elements are crucial for identifying business models tailored to specific contexts. It does not only facilitate market-led initiatives, but also plays a major role in initiating the process of capability building and coordinating the actions of a large number of interested actors.

Furthermore, a fundamental key success factor, especially for manufacturers operating in sectors where market turbulence is higher, is the aptitude to rapidly adapt to unexpected market fluctuations in order to keep customers satisfied. This goal can be achieved by exploiting manufacturing technologies, and ensuring the proper flexibility and reconfigurability levels, that can allow such rapid changes in volumes and features of the produced parts [9].

In such a context, what is needed is a reference process for a technology-based business model generation which could enhance and exploit at best the opportunities and the potential deriving from the introduction and proper hybridisation of emerging technologies in the global production and service contexts. In other words, a structured methodology to translate customer needs into a product-service solution and to provide companies with a product-service oriented reference process supporting its design and development with a systematic perspective and a seamless integration of product and service contents, as well as supply and service chains configurations, and new manufacturing systems engineering.

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[1] A business ecosystem is a network of organisations - including suppliers, distributors, customers, competitors, and so on - involved in the delivery of a specific product or service through both competition and cooperation.

3 An Interactive Business Model Framework for PSS

The main goal of this paper is to propose a collaborative solution platform to design, assess and deploy technology-based business models, supporting the analysis and evaluation of a business ecosystem for the manufacturing and delivering of customised product-services in global markets.
In order to pursue this objective, three are the main assisting means or tools, as highlighted in Figure 2.

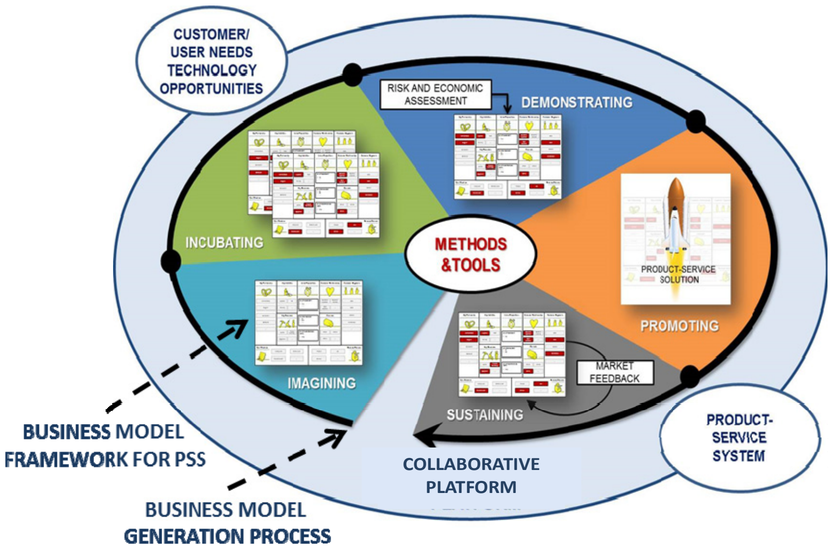

Fig. 2. An Interactive Business Model Framework for PSS

In particular:

- *The Business Model Framework*: founded on the Business Model Canvas, it contains the main elements of a business model and can be used to describe, analyse and design business models to guarantee a successful implementation of a *product-service system* in the market.
- *The Business Model Generation Process*: it is a multi-stage gate reference process for the generation and consolidation of technology-based business models, providing a consistent path from the idea generation to the commercialisation and provision of a product-service solution, particularly addressing the technological contents of the product-service solution and of the manufacturing and assembly systems.
- *The Collaborative Platform* provides the collaborative IT environment involving the focal actor and the different stakeholders in the creation of a customised business model and in simulating its affordability, robustness and durability throughout the whole lifecycle.

3.1 The Business Model Framework for PSS

The proposed Business Model Framework is based on the Business Model Canvas developed by Osterwalder and Pigneur (2010) [5]. This canvas contains the main elements of a business model and can be used to describe, analyse and design business models. As depicted in Figure 3, it is composed by nine elements: value proposition, customer segments, customer relationships, channels, key activities, key resources, key partners, cost structures, and revenue streams.

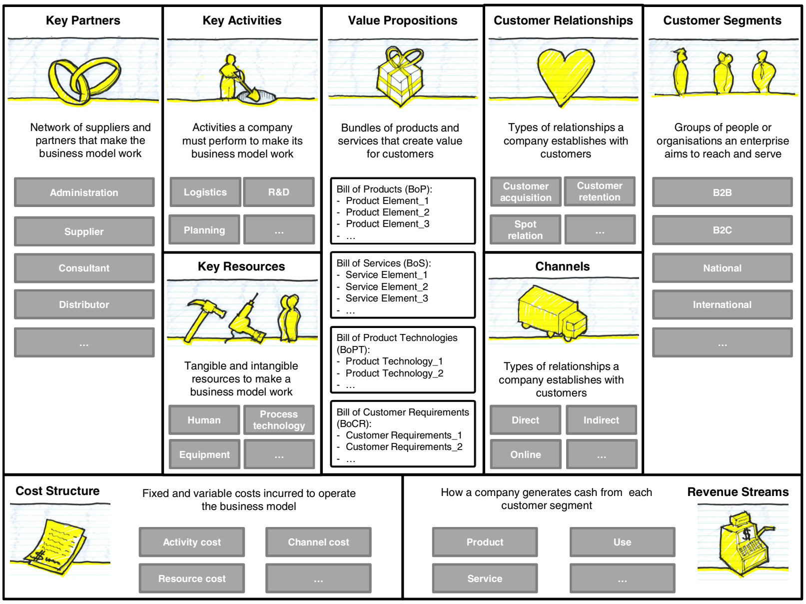

Fig. 3. The Business Model Framework for PSS [Adapted from 5]

This structured business model framework acts as a template/canvas where each element (except the value proposition) consists of predefined building blocks that represent strategic and tactical patterns. An example of a business model framework with the predefined building blocks is depicted in the same Figure 3. The building blocks in the Business Model Framework are devised in such a way that they can represent any PSS business model case (e.g. B2B, B2C). They are generic enough to be combined across the boundaries of various industries so that proven ideas in one business model could be transplanted into another, which is often the case in the real world. By mixing & matching various building blocks, this Business Model Framework could provide one or more alternative business models that will be then assessed.

An exception is represented by the value proposition element: it would not be composed of building blocks, but designed and defined as the combination of a Bill of Products (BoP), Bill of Services (BoS), Bill of Product Technologies (BoPT), and Bill of Customer Requirements (BoCR). These bills are specific to the company/industry context under analysis, and they will contain all the elementary products, service elements, product technologies and customer requirements that will be the constituent parts and design-drivers of the product-service solution.

3.2 The Business Model Generation Process for PSS

The Business Model (BM) Generation Process proposed is based on the experience of companies implementing successfully PSS Business Models into the market. This BM Generation Process is divided in the following five phases [Adapted from 10]:

1. *Imagining:* starting from the BoP, BoS, BoPT, and BoCR, the objective of this phase is to create the value proposition based on a user-centric approach. The Business Model Framework represents a guideline to support, and to design a PSS business model as a selection of a set of predefined building blocks.
2. *Incubating*: this phase deals with the product-service engineering, the supply and service chain configuration, and the manufacturing and assembly system configuration.
3. *Demonstrating*: this phase consists in the definition of economic and risk models to assess alternative *product-service systems,* in terms of product-service solution, supply and service chain, provision process, manufacturing and assembly system.
4. *Promoting*: the objective of this phase is to define the most effective marketing strategy to launch the product-service solution into the market and to start its commercialisation.
5. *Sustaining*: this phase deals with the commercialisation of the product-service solution and with the undertaking of the product-service lifecycle operations.

3.3 The Collaborative Platform

The implementation of the Collaborative Platform is crucial for gaining concrete results of this vision. It provides the collaborative environment involving the focal actors and the different stakeholders in the emerging creation of a customised business model and in simulating its affordability, robustness and durability throughout the whole lifecycle. The main distinctive design features of this platform are:

- Supporting a stage-gate process, where “gates” or decision points are placed at specific phases of the business model generation process;
- Acting as a repository of data and information (e.g. searching the best available technologies, the most qualified partners for a specific competence required, etc.), where all the documentation is archived and can be easily retrieved through a knowledge inference engine in order to favour team working and information sharing among cross functional teams;
- Acting as an open technology marketplace in order to encourage collaboration among companies working in different but complementary industries with the aim of creating innovation and providing product-service solutions tailored to customer needs;
- Supporting the elaboration of simulation scenarios and what-if analysis for proactively evaluating the expected technical, risk and economic implications derived from a specific configuration of the business model;
- Embedding a dashboard in its functionality for monitoring the main technical and financial KPIs (Key Performance Indicators) throughout a contract lifecycle in order to enable a prompt understanding of any deviations from expected SLAs (Service Level Agreements) and highlight eventual counter-measures.

4 Conclusions and Future Work

The proposed collaborative platform will enable the adoption of novel value proposition concepts to global markets leading to user-oriented higher value-added solutions, by integrating a service perspective into new or existing products from their conception on; methodologies and tools for the interactive design of alternative technology-based business models, with particular emphasis on the co-evolution from the early design stage of product-services and their production systems and delivery processes based on global partner networks for worldwide markets; and methodologies and tools for the assessment of the key economic and risk factors involved in the designed product-service ecosystem, in particular for the integration of new complex production technologies and global partner networks.

This assessment will be based on interactive and model-based decision-making processes, able to evaluate the impact derived from the introduction of emerging technologies and the performance of alternative configurations of the actors involved in the global partner network providing product-services into the worldwide market.

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Word of Mouth in Hospitality Management: The Case of Luxury Hotels in China

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Abstract. As the most important emerging market and the second biggest luxury goods consumer, China has been receiving a growing amount of foreign investment in luxury hotels. This paper studies China's luxury hotel industry in terms of its customers' word-of-mouth (WOM) on hotel staying experiences in five-star hotels of Western and Chinese origins in Beijing and Shanghai. Analyses on the WOM are made from three perspectives: online booking site vs. online meta-search site; Western and Hong Kong/ Macau/ Taiwan/ Singapore (HMTS) hotels vs. Chinese hotels; and hotels in Beijing vs. hotels in Shanghai. These three perspectives respectively draw on the incentive, cultural, and geopolitical factors in evaluating luxury hotels in China. Results of this study are useful for companies in the hospitality industry operating in emerging markets by providing the most updated insights from the most vivid case of the emerging economies.

Keywords: internationalization, China, luxury hotels, word-of-mouth.

1 Introduction

Luxury goods include both luxury products and services. This original study deals with an important type of luxury service—luxury hotels—by assessing the word-of-mouth (WOM) among customers. The paper uses the case of the most important and fast-growing emerging market—China, to analyze luxury hotel staying experiences. This is a market of growing importance, as nowadays virtually all Western hotel chains and brands have entered China and are facing fierce competition from local hotels. How to adapt their service and products to local customers, and how would local customers rate the staying experience compared with local hotels, are key issues to understand in the process of Western hotels' internationalization.

In this study, analyses were done from various perspectives using online reviews of hotel guests, and the online reviews have been analyzed based on three groups of comparisons: Western and Hong Kong/ Macau/ Taiwan/ Singapore (HMTS) hotels vs. Chinese hotels; hotels in Beijing vs. hotels in Shanghai; and most notably, online booking site vs. online meta-search site, which are the two major types of websites people use to get informed and make reservations for travels. Important issues such as information asymmetry, incentive level, cultural and geopolitical influences are

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discussed. It is concluded that online booking sites tend to report better customer reviews compared with meta-search sites, and according to customers' reviews, Chinese luxury hotels somewhat underperform their foreign counterparts operating in China. Implications of this study provide valuable insights and recommendations for luxury hotels operating in China and other emerging markets.

The rest of the paper is organized as follows. Part 2 and 3 give the background knowledge of the luxury hotel industry in China and the WOM used to evaluate the hotels' service. Part 4 reviews the literature and proposes the hypotheses. Part 5 and 6 draw on the data and methodology used in this study as well as the main results. Conclusion, recommendations, limitations and areas for further research are provided in part 7.

2 Growth of Hotel Industry in China

The development of the hospitality industry in China has been dramatic since the last two decades. According to China National Tourism Administration (CNTA), the hotel industry of China has been growing rapidly from only 137 star-rated hotels in early 1980s to 14,237 in 2009. In 2010, the country received 55.7 million international tourists, ranking third in the world (after United States and France), which generated $45.8 billion USD income, ranking it fourth in the world (CNTA). The domestic tourism market of China is even larger; it is estimated to be at least 10 times larger than the international inbound tourism (CNTA).

On the other hand, Internet using in China is also growing at a rapid rate. China already has the greatest number of "netizens" in the world. According to Internet World Stats, as of December 2010, China has 460 million Internet users, which represents 23% of the whole world's Internet users. Along with the increasing number of both hotel and Internet users, the way that people reserve or purchase travel services and products is undergoing profound changes. The growing importance of the Internet as an electronic medium has led to the emergence of various forms of online travel distribution channels (Law et al. 2007). The rapid growth of Internet applications on the hospitality industry in turn leads to an enormous and ever-growing amount of consumer-generated online reviews on travel products and services. According to Gretzel and Yoo (2008), more than three-quarters of travelers have considered online consumer reviews as an important information source when planning their trips.

3 Word-of-Mouth (WOM)

Word-of-mouth (WOM) refers to the interpersonal communications among consumers concerning their personal experiences and evaluations of a product or a brand (Richins, 1983). While electronic word-of-mouth (eWOM) refers to those same interpersonal communications but taken place via an electronic platform, usually via the Internet. Since WOM is a consumer-made channel of information communications where the author of the evaluation is independent of the product or service provider, it is therefore perceived to be more credible and reliable by consumers than firm-generated information

(Schiffman & Kanuk, 1995). Moreover, through multiple exchanges among consumers, a single WOM message can reach and potentially influence a huge number of consumers (Lau & Ng, 2001).

The influence of eWOM can be directly applied to the hospitality industry as online user-generated reviews have become an important source of information for travelers. Since consumers may not fully know about a hotel before consumption, they might seek WOM information from an experienced and trusted source. Therefore, the eWOM offers consumers an efficient solution to the "intangibility" of such products (Klein, 1998). Moreover, as Gretzel and Yoo (2008) stated, online travel reviews are often perceived as more likely to provide up-to-date and reliable information than reviews posted by travel service suppliers. And since negative consumer opinions can substantially influence customers' perception of a company's image, online WOM exchange platforms may be used by consumers as an important instrument of power.

4 Hypotheses Proposing

Due to the perishable nature, hospitality products are particularly suitable for online distribution channels (Rong et al., 2009). Among all online channels, there are two major types of online travel sites: online travel-booking sites, and online travel meta-search sites. Online travel-booking sites are traditional online travel intermediaries that sell hotel rooms from a number of different hotels to offer a full range of products and services to potential hotel guests. Examples of online travel-booking sites include Expedia, Travelocity, Orbitz, Pricelines, ctrip, etc. Travel meta-search engines differ from traditional online booking sites in that they do not directly process booking transactions. Instead, they link consumers to the travel supplier where the actual booking transaction will take place. The meta-search sites are then compensated for the role they play in the booking process. Examples of travel meta-search sites include Kayak, Side Step, daodao, etc.

Based on the different transaction schemes of the two types of websites, the issue of independence and incentives of the information provider can be discussed. Incentive misalignments can arise from the inverse relationship between rewards and the quality of the report from the information provider: Travel-booking sites, which earn commission from the intermediary role they play in the transaction, may have incentives to cheat on the ratings; while meta-search sites, which do not earn compensation through guests' bookings, may not have incentives to do so.

Hypothesis 1: Online travel-booking websites are reporting better customers' WOM on luxury hotels than meta-search websites.

Chinese hotels, many of them state-owned ones, are growing at a rapid rate especially since the past two decades. With the ongoing economic reforms, Chinese hotels have been gradually transformed from government-orientated to market-orientated. However, gaps still exist when compared with their international competitors. Externally, Chinese hotels are generally considered to be hindered from multiform ownership, fierce competition, and a sophisticated legal system. Internally, Chinese hotels often lack skillful personnel and the know-how.

On the other hand, international hotel groups are developing upscale and luxury hotels in forms of wholly owning, joint ventures, or management contracts to take advantage of the enormous business opportunities in China (Pine, 2002). Despite the barriers preventing international hotels' development, which can be foreign currency control, local government interference, and in particular, lack of personal relationships and networking known as "guanxi" (Heung et al., 2008), international luxury hotels tend to have more competitive advantages resulted from economy of scale, brand prestige, management expertise and IT platforms. Indeed, as found by Pine and Phillips (2005), international hotels in China have achieved higher occupancy, profit, and brand awareness compared with their Chinese counterparts.

Hypothesis 2: Western and Hong Kong/ Macau/ Taiwan/ Singapore luxury hotels are receiving better WOM than Chinese luxury hotels.

Another perspective of the research is the geopolitical differences of the cities in which hotels are located. The two most important Chinese cities—Beijing and Shanghai—are compared here. The two cities are overall quite similar in terms of dimension, population, level of development, as well as hospitality products and services provided. However, differences exist in their function, orientation, and level of control. Beijing, the Chinese capital, is the political and cultural center of the country. On one hand, it enjoys the most direct governmental and political preferences and advantages. On the other hand, it is also more directly controlled by the central government. Shanghai, the economic and financial center of China, has somewhat less direct governmental control compared with the capital.

An important constraint of state-owned hotels, which are more common in Beijing, is the non-commercial objectives which somehow prevent their reform and affect their competitiveness. Moreover, business objectives are often unclear in state-owned hotels of China (Heung et al., 2008), as the development of luxury hotels is often related to the status and aspirations of local entrepreneurs and politicians, with somewhat less concerns over the real market needs (Dai, 2006).

Hypothesis 3: Luxury hotels in Shanghai are receiving better WOM than luxury hotels in Beijing.

5 Data and Methodology

For this study, Beijing and Shanghai are chosen because they are the most important Chinese cities receiving most visits from either domestic or international, business or leisure travelers. Moreover, these two cities represent the latest and most vivid image of modern China and are therefore, updated with the latest trend and standard of hospitality products and services. Two Chinese travel websites are chosen for this study: ctrip.com, the country's most important travel-booking site with over 40 million members and a network of over 32,000 hotels worldwide, and daodao.com, one of the most popular meta-search sites among the Chinese, with more than 20 million members and over 40 million online ratings by real travelers. Both websites are nationwide considered as most popular and reliable sites. These sites are often identified as opinion leaders and help accelerate the information diffusion.

In total, data from 202 five-star hotels in Beijing and Shanghai (of which 109 in Beijing and 93 in Shanghai) are used, and hotels used on both websites are exactly the same ones. All ratings are on a scale of 1 to 5. Rating providers are predominantly Chinese. The ratings were manually collected during July and August of 2011. A demographic summary is provided in Table 1.

Table 1. Sample demographics

City	Origin	N	Percentage
Beijing	Chinese	63	57.8%
	Western	35	32.1%
	HMTS	11	10.1%
	Subtotal	109	100%
Shanghai	Chinese	32	34.4%
	Western	53	57.0%
	HMTS	8	8.6%
	Subtotal	93	100%
Combined	Chinese	95	47.0%
	Western	88	43.6%
	HMTS	19	9.4%
	Total	202	100%

To compare the ratings between websites, cities, and types of hotels, mean difference and two-sample t-test were conducted. As presented in the following tables, the types of hotels are classified into Chinese, Western, and HMTS (Hong Kong/ Macau/ Taiwan/ Singapore). Note here that non-Chinese hotels are divided into two groups: Western and HMTS, that is because HMTS hotels are culturally Chinese though they are closer to Western style when it comes to managerial issues. By dividing them into a separate group, more insights are expected to be provided.

Apart from the overall ratings used to test the hypotheses, categorized ratings (e.g., service, location, cleanliness) were also obtained from the websites. The average value for Chinese and Western luxury hotels in Beijing, Shanghai, and both cities were obtained. These rating, as the overall ratings, are also in the 1 to 5 Likert scale. Results of the categorized ratings are expected to help Chinese and Western luxury hotels to gain better knowledge of their strengths and weaknesses.

6 Results

To test Hypothesis 1, comparisons in terms of rating differences between ctrip.com and daodao.com (ctrip ratings minus daodao ratings) were done on each type of the hotels plus the combined types. As Table 2 demonstrates, results are surprisingly similar among the four groups. That is to say, ctrip provides significantly better ratings than daodao for luxury hotels in Beijing and Shanghai regardless of the origin of the hotels. These results give evidence to what has been argued previously on the incentive issue and thus supports Hypothesis 1.

Table 2. Mean Difference (t-test) between websites (*ctrip – daodao*)

	Chinese	Western	HMTS	combined
BJ + SH	.2494737 (6.2157***)	.2772727 (8.3055***)	.2263158 (2.8939**)	.2594059 (9.8734***)
BJ	.2380953 (4.5979***)	.2599999 (4.6856***)	.2272727 (2.6236**)	.2440367 (6.1907***)
SH	.271875 (4.4526***)	.2886792 (7.0545***)	.2250001 (1.6550*)	.2774193 (8.2535***)

For Hypothesis 2, analyses were done on both websites, and mean difference and two-sample t-test were obtained. As can be seen in Table 3, hotels in Beijing and hotels in Shanghai were treated separately and combined. Comparing Chinese hotels and Western hotels, negative mean differences were obtained, and the t-test demonstrates that all those differences are significant. Similar results were obtained when comparing Chinese hotels and HMTS hotels. For the comparison between Western and HMTS hotels, no significant results were obtained. For DaoDao (Table 4), similar results were obtained. Thus Hypothesis 2 is supported.

Table 3. Mean difference (t-test) among hotels types (*ctrip*)

Ctrip	Chinese – Western	Chinese – HMTS	Western - HMTS
BJ + SH	-.1764115 (-4.3165***)	-.1957895 (-2.5539**)	-.019378 (-0.3226)
BJ	-.2425397 (-3.8859***)	-.2916306 (-2.8460**)	-.0490909 (-0.6420)
SH	-.0949882 (-1.7018*)	-.046875 (-0.4172)	.0481132 (0.5157)

Table 4. Mean difference (t-test) among hotels types (*daodao*)

daodao	Chinese – Western	Chinese – HMTS	Western - HMTS
BJ + SH	-.1486125 (-4.4779***)	-.2189474 (-3.7472***)	-.0703349 (-1.3137*)
BJ	-.220635 (-4.2863***)	-.3024531 (-3.8233***)	-.0818181 (-1.0272)
SH	-.078184 (-1.7915*)	-.0937499 (-1.1335)	-.015566 (-0.2186)

Finally, to compare hotels in Beijing and hotels in Shanghai for Hypothesis 3, similar analyses were conducted. As Table 5 shows, comparisons based on different websites as well as different types of hotels were done. Results in this table are the differences between Beijing and Shanghai in each of the hotel types and websites. For ctrip.com, no statistically significant results were found, and for daodao.com, the only significant result is that Western and HMTS hotels are slightly doing better in Beijing than in Shanghai. But overall, no significant results were obtained. Therefore, Hypothesis 3 cannot be supported.

Table 5. Mean difference (t-test) between cities (Beijing-Shanghai)

	ctrip.com	**daodao.com**
Chinese	-.0856647 (-1.2685)	-.0518849 (-1.0135)
Western	.0618868 (1.2321)	.0905661 (2.0032*)
HMTS	.1590909 (1.3169)	.1568182 (1.6498*)
Combined	-.0365197 (-0.8968)	-.003137 (-0.0934)

In terms of the categorized ratings, as can be seen in Table 6, among all the six categories included in the study. Western hotels have obtained better results than their Chinese counterparts in both cities. However, rating difference exists among the six categories with Cleanliness rated highest and Value rated lowest. This difference, especially the lowly rated Value, deserves additional attention, as it implies that consumers would pay less for the service and product they got or, demand something more for the money they paid.

Table 6. Categorized ratings (average value)

Western	Cleanliness	Service	Location	Facilities	Comfort	Value
Beijing	4.67	4.40	4.35	4.45	4.26	3.90
Shanghai	4.63	4.27	4.30	4.38	4.19	3.84
BJ+SH	4.64	4.32	4.32	4.41	4.22	3.86

Chinese	Cleanliness	Service	Location	Facilities	Comfort	Value
Beijing	4.44	4.10	4.21	4.13	4.02	3.85
Shanghai	4.54	4.14	4.23	4.28	4.11	3.84
BJ+SH	4.48	4.11	4.22	4.18	4.05	3.85

7 Conclusion and Recommendations

This study draws on the issue of WOM differences in terms of reservation website, hotel origin, and location. It has been found that the traditional online booking site (ctrip.com) in China provides significantly better WOM than the novel meta-search site (daodao.com), and that, overall, Chinese luxury hotels underperform their Western and HMTS counterparts in China, giving space for further improvements and reforms towards a more customer-oriented business model. As to location difference, no significant WOM difference was found between Beijing and Shanghai, which implies that difference in political and functional orientations does not necessarily lead to difference in service providing in hospitality industry.

There are several novelties and contributions of this study. The two types of the above mentioned travel websites are studied in conjunction, which is few, if not none, in the literature. And studies of this combination were especially scarce for emerging markets. Moreover, cultural factors in this study are drawn from the opposite direction of the majority of the literature where cultural diversity lies in service receivers, while here the cultural diversity arises from service providers. Finally, managerial implications and recommendations for luxury hotels of China are provided, which is a valuable knowledge asset for strategic and operational improvements for both Chinese and non-Chinese players in this sector.

As to limitations and further research, since WOM behavior is likely to change over the customer life cycle, long-term effects of WOM communication and effects on the Internet can be studied using longitudinal data. Meanwhile, similar studies on other sectors of the tourism industry such as airlines and catering sectors can be carried out. Furthermore, the scope of this study can be extended beyond China by studying and comparing cases in other emerging markets.

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Application of Design by Customer in Tile Decoration Business

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Abstract. The new concept of Design By Customer (DBC) has been introduced recently to increase customers' satisfaction by providing maximum involvement channels to the customers so that the customers do not reduce their requirements to meet with the specifications of available products. It is foreseen that if DBC concept is applicable for tile business, it will encourage customers to involve actively in pursuing their own decorative designs. Thus, this research has investigated the potential to apply Design By Customer concept in tile decoration business which requires the following two main issues to be answered. The first issue is on the readiness of technologies at this moment to support the production of different decorative tiles quickly. The second one is on customers' interest in tile decorative design.

Keywords: design by customer, tile decoration, conjoint analysis.

1 Introduction

Tile has been used for surface covering since ancient time. Not only can it provide good surface protection but also allows aesthetic value to be created on the surface from arrangement of its different colors, shapes and sizes. However, in today tile business, manufacturers only allow customers to select or create their decorative designs from the available on shelf tiles. The manufacturers typically offer tiles with various designs, and may display a few tile decorations to attract customers. The customers who like these decorations can resemble by purchasing similar tiles while others are required to mix and match available tiles to create their own designs. Customized decorative design may be available, but at high cost and long waiting time. Therefore, what has happened is the opportunity for the customers to involve in designing their decoration is limited. Moreover, most of them unavoidably relax their requirements to select only available choices that manufacturers offer instead of pursuing their designs.

Recently, Design By Customer concept (DBC) has been introduced in order to encourage manufacturers to increase customers' satisfaction by letting customers engage in a value creation as many channels as possible [1]. The customers are encouraged to

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select the products that best match with their requirements, costs and waiting time. The level of involvement (CIDP) then, varies from mass production to individual personalization as illustrated in Fig. 1, depended upon the capability and readiness of manufacturers, customers' interest, and engineering constraint [2].

Therefore, applying DBC in tile decoration business might be applicable to increase customers' satisfaction level. As illustrated in Fig. 1, if the customers do not have specific requirement, they can involve in a value creation chain by selecting typical standard products. Furthermore, the customers are able to mix and match some components before assembling and/or manufacturing phase. Lastly, they can participate in designing the products by using the tools that manufacturers provide such as google sketch up, adobe illustrator, also photos and sketches as initial designs. In order to allow customers to participate in various channels with fast response, tile production technologies must support DBC concept. In addition, the product attributes must not violate the manufacturers' capability and crowdscreening can be implemented in order to extract the top rank components and products. Furthermore, the customers themselves should express their interests to participate in designing the products; otherwise, providing these channels will not bring success to the business. Therefore, this paper presents the investigation of two key elements: available tile production technologies and customers' interest.

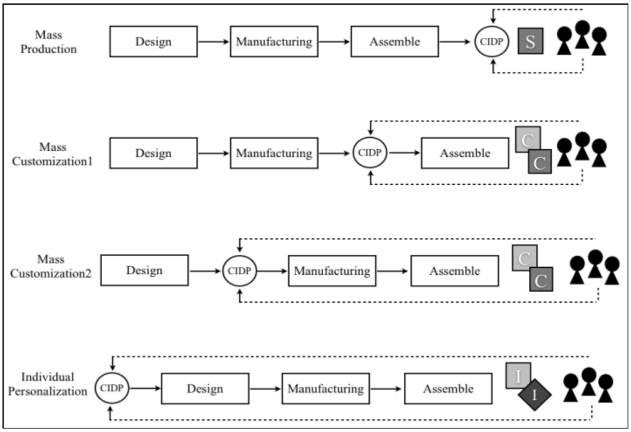


Fig. 1. Channels for customers' involvement in Design By Customer (DBC)

2 Review of Tiling Technologies

Tile production typically consists of eight steps as illustrated in Fig.2 [3], Raw materials including clay, water, minerals and chemical substances are prepared. These materials are weighted according to the types of tiles before being mixed and grinned together in a mixer until the mixture looks smooth. The fine clay is sent to spray drying process in order to remove the excess water. Once the condition of the fine clay is appropriate, the forming process is started. Various methods i.e. dry pressing, extrusion and punching and pressure glazing are available for making tiles in different sizes and shapes. These tiles are dried in the next step which needs several days to remove the humidity slowly to avoid cracks and shrinkage. Lastly, the dried tiles are glazed before sending to the furnace to increase the strength which also takes several days.

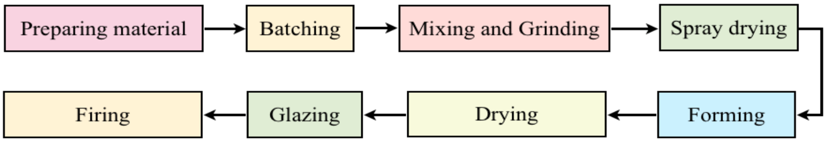


Fig. 2. Tile production process (reprinted from http://www.madehow.com/Volume-1/Ceramic-Tile.html)

The value of tiles increases when they are assembled to express a design. Tiling of a customized decorative design can be done by using ready-made tiles or by fabricating new tiles and their capabilities to support DBC are reviewed in the following subsections.

2.1 Decoration from Ready-Made Tiles

For this group, a pattern similar to the design is created by modifying and arranging the ready-made tiles. Mosaic and profile-cut tiles are in this group.

Mosaic Tile

Mosaic is the arrangement of small pieces of tile to form the pattern. Recently, the automation tiling system has been developed to support the mosaic tile industry [4][5]. The process starts from rendering an input image to a mosaic-like image that its pixels are matched with available color tiles. The identified tiles are released from storages and sorted automatically before assembling in the final step. According to [5], a 1m x1.5m custom mosaic can be produced in approximately two hours.

Profile-Cut Tile

This type of decoration involves cutting and assembling the ready-made tiles. Recently, researchers have introduced rapid cutting for tile pattern creation [6]. The process starts from tracing the contours on the image of a design. The tile colors are selected next by matching the colors on the image with the colors available in a stock. These pieces of tiles are cut rapidly on a waterjet machine that toolpaths are generated directly from the obtained contour without writing a single G-code [7]. The decorative area is formed by assembling these cut tiles. In case that the contour is larger than the tile, the system will calculate the new toolpath and identify the number of tiles before the cutting process starts [8]. Since the toolpaths can be generated quickly, tiles for the decorative area of 1m x 1.5m can be cut within one to two hours.

2.2 Decoration by Fabricating New Tiles

Another group of the customized tiles is related to the creation of a design on tiles in the production process. Additional steps are introduced into the process. This group consists of molding and printed tiles.

Molding Tile

Molding tile includes an embossed design on ceramic and sandstone tiles. For molding ceramic tiles, moulds are made at the beginning before preparing the materials and moving to the other steps as in Fig.2. However, for sandstone tiles, the process is more complicate. The design is created and drawn on a paper that is used to form the clay to a pattern. Once the clay is set, the craftsman will construct a prototype by casting plaster and curving the details by hand. The mold is then constructed from the fine prototype [9]. According to local manufacturers, making a standard molding tile in any size takes at least three weeks. Therefore, the waiting time will be much longer for the custom decorative design.

Printed Tile

Tile printing is the screening of pictures on the ceramic tile surface. This extra step is done before the glazing step. Furthermore, printing on glass tiles has been developed and recently introduced to the market. The production process is divided into three main steps. First, the image is customized according to the customer preference. Next, the input image will be printed on the glass surface and lastly dried to ensure that the screen is stacked tightly on the surface. The resolution of the image was about 300 dpi [10] and the largest tile size is limited to 24” x 36”. According to the local manufacturers, making a customized product takes about three weeks.

3 Survey of Customers’ Interest

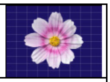
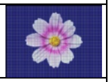
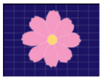
Regarding to the current technologies, the manufacturers are able to offer various tile decoration methods but at different response times. Therefore, the survey of the customers’ interest has been conducted by using one-to-one interview and conjoint analysis. In the first part of the survey, the participants were asked about their interest on tile decoration and on designing the tile patterns by themselves. They were also asked to rank tile decoration methods from most to least preferable (most =4, least =1) for different types of pictures as showed in Fig.3 and to support their ranking with rationale.

(a) (b) (c)

Fig. 3. Pictures for tiling method survey (a) http://www.umarin.com (b)www.renders-graphiques.fr (c) http://justbeingmysel.blogspot.com

Since molding tile has long processing time, it is not suitable for DBC. Therefore, only the other three types were used in the survey. Four options created from the other three types as shown in Table 1 were presented to participants.

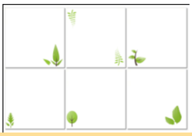
Table 1. Tile decoration methods

1) Printed tile decoration1: The picture is formed by assembling 8”x12” printed tiles with the gap of 3 mm.	
2) Printed tile decoration2: The picture is printed on one 24”x36” large tile that is cut along the picture profile. It is assembled with 8”x12” background tiles with the gap of 3 mm.	
3) Mosaic tile decoration: The picture is displayed by arranging small pieces of tile (1.5-2.5 cm^2) with the gap approximate 2-3 mm.	
4) Profile-cut tile decoration: 24”x36” solid color tiles are cut and are assembled with 8”x12” background tiles to form a picture. The gap is 3 mm.	

Furthermore, conjoint analysis was used to identify the customer preference and key attributes by letting the participants take every combination of attributes in consideration rather than a single factor [11]. The important attributes are classified into five groups and three levels each as followings:

1. Surface: Glossy, Matt, Rough
2. Design: Picture, Tracy, Plain
3. Material: Ceramic, Glass, Stone or Sand
4. Size: Small (2x2cm.), Medium (20x20cm.), Large (60x60cm.)
5. Waiting time: Within three days, Within two weeks, More than two weeks

These attributes can be combined into 243 profiles; however, the combinations were reduced to eighteen profiles by using orthogonal design in SPSS in order to avoid confusion when the participants rank the cards [12]. The examples of conjoint cards are showed in Fig. 4.



(a) Card No.2

Surface: Glossy Design: Tracy

Size: Medium Material: Ceramic

Waiting time: Within 2 weeks

(b) Card No.7

Surface: Rough Design: Picture

Size: Large Material: Glass

Waiting time: More than 2 weeks

Fig. 4. Example of cards (a) http://freevectorsb.wordpress.com (b) www.cotto.co.th

4 Result and Discussion

From the interview of thirty-two participants who have planned for tiling or experienced in tiling, thirty people were interested in tile decoration of which twenty-six participants preferred to engage in designing tile decoration by themselves. The ranking score in Table 2 reveals that the participants preferred the printed tile decoration 2 most for all three pictures. Most of the participants claimed that this decoration method has only a few tile grouts on the picture which make it looks dominant and realistic. The printed tile decoration 1 came second. Some participants preferred this method because it looked smooth like a printed picture on a paper. The profile-cut tile decoration came last since they felt that it does not provide realistic pictures.

From processing scores in SPSS program, the card number2 as shown in Fig. 4(a) had the highest utility score of 11.227 ($Y_2 = 10.2+0.261+1.133+0.694+0.139-0.7-0.5$). The utility score is referred to the preference of each attributes. Thus, higher utility result refers to higher preference from the view point of the participants [12]. Furthermore, as illustrated in Table 3, design is the most important among five attributes from the customers' point of view. Therefore, the customers tend to take design in consideration as the key factor before making a decision.

Table 2. Survey result on tiling method preferences

Decoration method				Average score
Printed tile decoration 1	23.67%	25.33%	26.67%	25.22%
Printed tile decoration 2	32.33%	35.00%	33.67%	33.67%
Mosaic tile decoration	22.67%	20.00%	22.33%	21.67%
Profile-cut tile decoration	21.33%	19.67%	17.33%	19.44%

Table 3. Importance Values

Importance Values

Surface	17.778
Design	33.759
Size	23.972
materials	16.178
Waiting_time	8.313

Regarding to the manufacturers' capabilities and the customers' interests in Table 4, DBC has the potential to be applied in tile decoration business. However, the levels of customer involvement will be varied depending on the manufacturers' capabilities which are discussed as followings.

4.1 Printed Tile

According to the survey, printed tile is the most preferable to customer as it provides a realistic picture but the printed tile decoration 2 will not be available for large decorative area due to the available size of tile. The attractiveness of the printed tile decoration 1 is lower and is not much higher than mosaic decoration. Furthermore, due to the long lead time, approximately three weeks, the design from customers at the beginning phase is not recommended. The offering channels should be limited to only mass production and mass customization1. The customers are allowed to choose the standard products from the stores or customize each design of tiles by themselves rather than design the new one.

4.2 Mosaic Tile

Some groups of the customers are interested in this decoration method. The smaller the tile size and the gap size are, the more attractive, this method will be. Regarding to assembling the ready-made tiles group, the lead time is shortened to only a few hours. Therefore, the manufacturers can open all four channels to the customers to involve. As a result, the customers can participate from selecting the final products to design the new one themselves. However, the technology is not ready to allow the variation of the size and shape of tile.

4.3 Profile-Cut Tile

The fast response of the available technologies allows manufacturers to open all four channels to the customers even though the limited number of the customers has interest in this decoration method. This method might be an attractive choice for abstract picture and the picture of cartoon character that display by solid colors.

4.4 Molding Tile

According to the slow response, the customers can hardly involve in the designing process. Therefore, the manufacturers are suggested to open only two channels, letting the customers participate in selecting standard products, and mixing and matching components.

Table 4. Assessment of manufacturers' capability and customers' interest

Category	Decoration method	Customers' interest	Mass production	Mass customization1	Mass customization2	Individual personalization
Using the ready-made tiles in a pattern	Mosaic tiles	21.67%	x	x	x	x
	Profile-cut tiles	19.44%	x	x	x	x
Fabricating new tiles	Molding tiles	-	x	x		
	Printed tiles	25.22%	x	x		

5 Conclusion

This paper presents the potential to apply DBC in tile decoration business. From the study, customers are interested in custom decorative design, but their involvement will be varied depending on the manufacturers' capabilities. The manufactures will be able to offer four channels from mass production to individual personalization for tile decoration methods that use the ready-made tiles, but for printed tile decoration that the customers prefer most they will be able to offer only two levels; mass production and mass customization1 due to the slow response time. If the manufacturers can turn customers' interest to mosaic, both sides will benefit most from DBC. Therefore, future research will focus on applying choice architecture to direct customers' interest to the decoration methods that use the ready-made tiles.

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Monitoring and Controlling in an Industrial Service Ecosystem

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Abstract. Industrial companies usually have a defined product development process, but they lack a sufficiently defined service development process as found in traditional service companies [1]. Many firms recognize that the existing corporate structures and processes do not allow for efficient development and market positioning of innovative services. In addition, they are faced with the problem of being poorly equipped with appropriate approaches, methodologies and tools for an efficient development of services. Other problems can include the high complexity of services, missing organizational structures, lack of innovative climate and inadequate qualifications [1], [2]. It should be emphasized at this point that the lack of service performance assessment and monitoring is the cause of errors, redundancy and duplication of work between the main actors of industrial service ecosystem [3].

In this respect, the purpose of this paper is therefore to lay the foundations for a monitoring and controlling framework related to an industrial service ecosystem. These foundations are based on establishing methods and tools to select, identify and use proper KPIs within an industrial service ecosystem. Accordingly, monitoring framework will support enterprises to control their goals and decision-making processes within the industrial service ecosystem while providing them a monitoring cockpit.

Keywords: Monitoring Framework, Industrial Service Ecosystem & Key Performance Indicators.

1 Introduction

In the present economic climate, the service sector is becoming increasingly important for developed economies generally. In the European Union the service sector creates about three quarters of the overall Gross Domestic Product (GDP) [4] and has high impact on the European labor market, as almost three-quarters of all European jobs are allocated here [4]. Moreover, firms - industrial companies in particular - are striving to become more service-oriented in order to meet users' expectations and customer's requirements [2].

As far as the creation of high value services in industrial ecosystem context through methods for monitoring and controlling the service ecosystem is concerned, all actors in the industrial service ecosystem need to learn how to combine their complementary core competencies across sectors, and how to share highly specialized

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knowledge about new functions, features, and processing procedures [5]. Also problems like bureaucracy, inefficiency or missing process quality are tackled by functional modules that are encapsulated by business as well as IT services. Therefore, ecosystem monitoring and governance can be used as a set of guidelines to adapt, coordinate and safeguard autonomous action performed by different actors, collectively working on a joint plan determined by collaboration, where risks, resources, responsibilities and rewards are shared to achieve a common goal.

Furthermore, Service management needs to be able to measure and control the service system in order to ensure maximum productivity. By using monitoring and controlling framework we will be able to elaborate the framework as a useful method to help the ecosystem to evaluate their service systems. Apart from analyzing the service system, the framework will provide, collect and share the results of the controlling activities among service ecosystem members.

Monitoring and controlling framework will allow regular observation and recording of activities, controlling and measuring actual performances and presenting a visualization system which can guide the industrial service ecosystem on taking corrective actions. The results of the monitoring framework, then, can be fundamental for decision making. Likewise, monitoring and controlling framework will be able to give a method of assessment to optimize the resources and support decision making. This will be useful to provide the partners with effective solutions for governance.

Finally, we will propose the monitoring framework by means of visualization method to visualize the data as a guiding strategic tool. This framework will be integrated into the service ecosystem platform to support service management, exchange and evaluation within the manufacturing networks.

The next section will discuss and analyze different methods and frameworks. Relevant connections between monitoring and service activities will also be highlighted and finally, a conceptual schema for monitoring framework will be proposed.

2 Relevant Monitoring and Controlling Methods

In this section some relevant existing control systems which support the decision making within the industrial service ecosystem will be analyzed. A few tools (recommendations, models, methods, systems and frameworks), proposed by various researchers and practitioners to control and monitor performances, are going to be studied. This paper, then, will focus on defining the specific components and elements necessary to control and monitor. Each methodology has its own criteria, so in order to align with the objectives of the paper, we will try to select and extract just the components and elements which are important to monitor and evaluate the industrial service ecosystem within its internal departments and the ecosystem network by integrating them with ICT tools.

As mentioned in the last section the purpose of this paper is to lay down the foundations of monitoring framework, by using the world of frameworks, methodologies and tool boxes which can support various levels of performance indicators in the industrial service ecosystem. So, according to aforementioned importance we will focus on the three extracted models for the classification of industrial service ecosystem activities.

2.1 GRAI (Graph with Results and Activities Interrelated) Model

The GRAI method is an enterprise modeling method that can represent and analyze the operations of all or part of a production activity. The strength of the GRAI method lies in its ability to enable modelers to effectively model the decision-making system of the company, i.e. organizational processes that generate decisions [6].

Meanwhile, the GRAI model describes the control of a variety of organizations using a combination of system theory, control theory and particularly hierarchical theory. Indeed, even if each project task is clearly defined, the main difficulty concerns its management: what are the required decisions to take periodically to manage tasks? The GRAI decisional Grid aims to define the "set of decisions" from the strategic level (where the horizon is longer than the project duration in order to take into account the dissemination) to the tactical and operational levels [7]. This model defines a reference model of decisions for project management. It defines also periods in a horizon: the periods determine the timing to check the results.

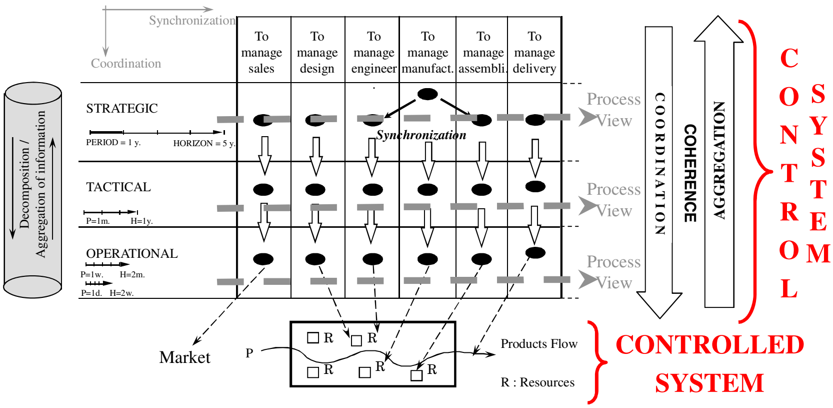

Fig. 1. GRAI conceptual model [8]

The Method is composed of three main building blocks. The first one is the reference model, called GRAI model, which is a consistent set of concepts that models any production system. Therefore it is clearly independent of the case upon which the method is applied. The second building block is concerned by graphical modeling languages that enable to instantiate the concepts of the GRAI model to build the specific model of the studied case. Finally, the third is a structured and participative approach in which actors and steps are defined. The purpose of such an approach is to act as effectively as possible and to save time. The interest of a conceptual model is to relate the various concepts in order to show their coherence, to avoid redundancies and to have a complete model. Generally, in the GRAI model for typical enterprise, six functions are taken into account: to manage production, to manage sales, to manage design, to manage development, to manage production, to manage assembling, and to manage delivery.

By synthesizing the GRAI model with the next two methods which will be explained in next sections, we will try to make a hierarchical decomposition to facilitate the integration between decisional levels and between functions.

2.2 The Model Driven Service Engineering Architecture (MDSEA)

The proposed MDSEA framework defines KPIs for the monitoring of the service ecosystem and analyses the KPIs in terms of implementation. KPIs can be separated into three components: IT, Organization and Human resources. The criteria of these performance indicators will be related to traditional performances such as cost, quality, lead time and efficiency, as well as other kinds of performances such as interoperability, flexibility, environment, etc.

By defining the framework for service ecosystem modeling around three abstraction levels which will be defined below, we will aim to accomplish this framework by dividing the KPIs into three separate components: Business Service Modeling (BSM), Technology Independent Modeling (TIM), and Technology Specific Modeling (TSM) [9]. The mentioned components are important for forming the foundation to monitoring the performance indicators within the ecosystem. In the section below, a brief definition of mentioned components are considered:

- Business Service Modeling (BSM): specifies the models at the global level, describing the running of the enterprise or set of enterprises as well as the links between these enterprises.
- Technology Independent Modeling (TIM): is the model at a second level of abstraction, independent from the technology used to implement the system.
- Technology Specific Modeling (TSM): combines the specification in the TIM model with details that specify how the system uses a particular type of technology (such as, for example, IT platform, Machine technology organization structure or human profile).

So, based on the decomposition above (BSM, TIM & TSM) it is necessary to ensure that at each level of decomposition, performance evaluation is possible. The framework of the performance indicators is shown in figure 2, below.

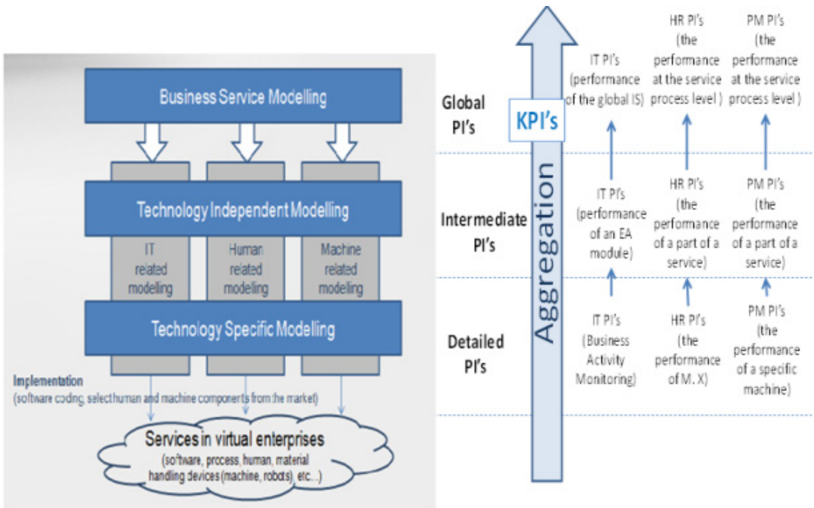

Fig. 2. Performance Indicator in the frame of MDSEA

MDSE Architecture and GRAI Model have been chosen on the basis of the decomposition by level of decision and decomposition by abstraction level. On the other hand the next section will explain Unified Governance Framework (UGF), which will focus on aiding enterprises in implementing consistent governance with a certain focus on the use of ICT and ICT-based services.

2.3 Unified Governance Framework

This section aims to explain Unified Governance Framework (UGF) model and its related components by highlighting their advantages and synthesizing the main issues with previously mentioned methods.

IBMs Unified Governance Framework (UGF) [10] is intended to cover the entire field of enterprise governance, with a focus on how IT-related services and components can support governance. The main purpose and novelty of UGF is to serve as a framework also for the governance-enabling technology for the overall enterprise governance field. In the diagram of the UGF below, the inner three layers are those of an enterprise, while the outer (red) layers represent the environment.

The core of UGF is the highest-level components, which are shown in figure below. A component model is a grouping of related functions and capabilities into components that communicate through relatively well-defined interfaces. A component can contain organizational, structures, processes, people, and technology. The specific purpose of UGF is to focus on enterprise governance, i.e., to distinguish and describe governance components in more depth than the rest of the enterprise. Three specific layers are described on the following figure and they may be referred to in the service management sector as well as in the organization as a whole.

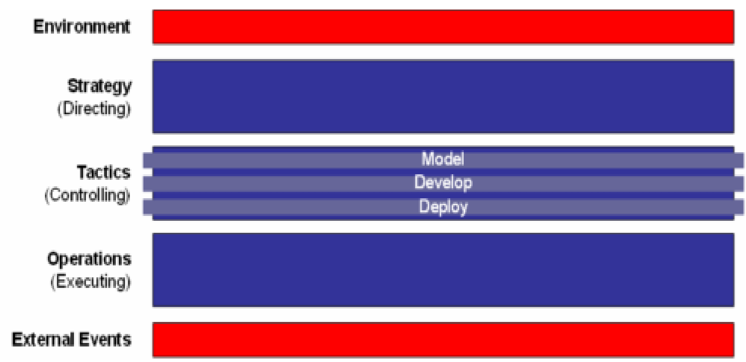

Fig. 3. – UGF layers

In the strategy layer, the normal enterprise capabilities are summarized. Governance deals with three main aspects: business performance goals, legal issues, and risk. In the strategy layer, aspects involve overall analysis, goal setting, and establishment of appropriate organizational structures, such as service performance goals and measurements.

In the tactical layer, the normal enterprise capabilities are defined in terms of process and information management, and resource management. The former corresponds to business parts organized by lines of business and business processes, the latter to functional units like IT, HR (human resources), and facilities. Each of the component's performance management, controls management and risk management, correspond to the strategy component above it. In the operation layer, the normal enterprise capabilities are evaluated in a similar way and they are based on day-to-day tasks.

Finally, with reference to the UGF model's core components, GRAI decomposition model by level of decisions, and MDSE Architecture by level of abstraction; we aim to generate a new service monitoring framework by synthesizing the three models mentioned above.

3 Conceptual Schema for Monitoring Framework (Proposition)

In this section, we present a proposition of a conceptual schema of monitoring framework in which GRAI and MDSEA models have been synthetized with UGF model in order to create a conceptual monitoring framework. Conceptual monitoring framework will be developed to support service ecosystem in order to achieve the following goals:

- To support the service performance assessment to monitor performances and prevent errors causing and redundancy or duplication of work among the main actors of service ecosystem;
- Facilitate the integration between decisional levels & functions.

Relevant methods, which are useful to generate and control service monitoring, have been studied in this research. All the requirements need to be separated into the three levels of decomposition (strategic, tactical and operational) on the basis of the MDSE Architecture in order to classify quantity and quality KPIs inside one unique model.

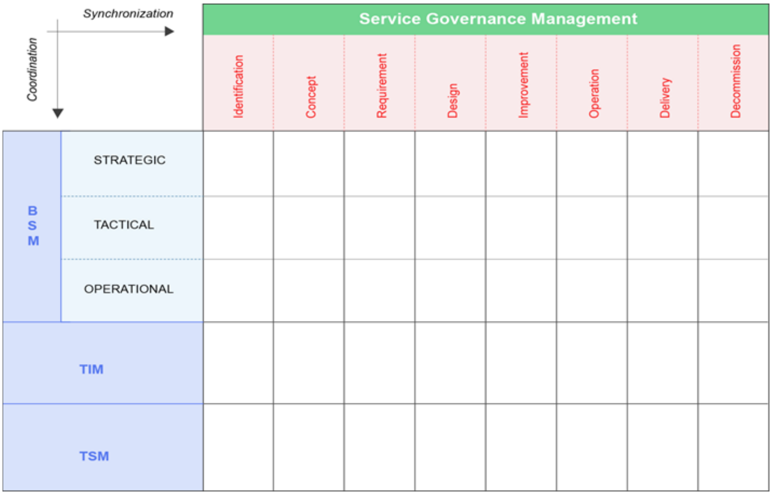

Fig. 4. Conceptual schema for monitoring framework (proposition)

Relevant PIs and KPIs can be then generated on the basis of the requirements identified inside the monitoring framework. They can be presented in three levels, as following the decomposition of BSM level (i.e. Strategic, Tactical and Operational). The remaining KPIs which are collected in TIM and TSM levels specify the parameters which can be used as a supporting means with reference to technology implementation. The MDSE Architecture has been used, therefore, as a filter for KPIs, in order to define in detail which parameter is affecting which functions inside the SLM (Service Lifecycle Management) of a service system and at which level within the enterprise environment.

As it is possible to notice from our proposition of the Conceptual schema for monitoring framework, several phases have been identified inside the Service monitoring management axis. These phases have to be considered like the "functions" which have been identified and used in the GRAI method. These functions have been identified following the service life cycle phases. Service engineering components can cover the whole service lifecycle phases from early stages, where both intrinsic and extrinsic parameters and requirements should be defined and measured, to the final decommissioning steps, which could give rise to further business opportunities (recycling, refurbishing, different use, etc.).

As it has been discussed above, the functions can be simplified in order to set the assessment just during particular phases. As far as the SLM is concerned, we can consider upper phases related to Service ecosystem (identification, concept, requirement) and lower phases to manufacturing enterprises (design, implementation, operation, decommission). The conceptual schema for monitoring framework tries to synthesize MDSE Architecture with the modeling of a service system along the SLM lifecycle. BSM aims at elaborating high abstraction level model from business users' point of view. TIM gives service system specifications independent of technology for implementation. TSM adds necessary technology specific information related to implementation options. The aim of this framework is to help end users represent and describe the intended service and its system from various points of view, and give structure in order to help the decision making and the controlling activities.

4 Conclusion

In this paper a monitoring methodology has been proposed in order to support and define a clear monitoring framework to be used by industrial service ecosystem. Several methods have been studied and synthesized in order to create a monitoring framework for service: GRAI method, UGF and MDSEA.

It should be emphasized that the proposed conceptual framework can represent a clear and open structure to share knowledge and resources among the partners inside the industrial service ecosystem. Therefore, the framework needs to integrate within the service ecosystem platform so as to support service management, exchange and evaluation within the manufacturing networks. The framework can also be used as a supporting toolset to generate specific KPIs related to end users' core activities.

Further steps are needed in order to validate the mentioned framework within a real condition in an industrial service ecosystem.

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Engineering Product-Service Solutions: An Application in the Power and Automation Industry

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Abstract. Manufacturing companies are heavily competing for the identification of new sources of value for the market, moving from a traditional transaction-based and product-centric orientation towards the provision of integrated solutions to their customers. In this context, Service Engineering, the discipline concerned with the systematic development and design of service and product-services, is gaining particular relevance for mastering the service lifecycle management of a product-service solution. This paper provides a contribution in this field with the description of a Service Engineering Framework platform to support the reengineering of the service offering in a multinational company operating in the power and automation industry, with the aim to provide a customized solution able to fulfill the specific customer requirements and at the same time to gain a better efficiency in the delivery of the service processes.

Keywords: Service Engineering, Discrete-Event Simulation, Customer value.

1 Introduction

The recent macro-economic events have contributed to increase awareness of the strategic relevance deriving from the provision of services related to products, as an economic anti-cyclical remedy for tackling the dramatic contraction of the markets. This strategic evolutionary path followed by most manufacturing companies, usually termed as *servitization*, is mainly motivated by a continuous search of new sources of value, by either reactively fulfilling explicit requirements or proactively providing new integrated product-service solutions to the customer [1], evolving from a "pure product" orientation towards a more integrated product-service perspective [2].

One of the major managerial challenges is related to the need of companies to redesign their organisational principles, structures and processes [3], capabilities [4], relationships with customers [5] and suppliers [6]. In this sense, the design and development of a product-service solution and of its lifecycle raise new issues, since the service component introduces further requirements that in a traditional product-based business model are not relevant. In particular, the cultural shift from a transaction-based approach

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to a long-term relationship with a customer needs to be thoroughly understood by companies along with the acquisition of suitable models, methods and tools for collecting, engineering and embedding in a solution all the knowledge that meets or exceeds people's emotional needs and expectations. However, as reported by [1], even though a significant part of the literature has provided contributions on methods and tools, only a small number of approaches have been developed specifically for service and product-service design and engineering.

In such a context, Service Engineering (SE), calling for the design and the development of an integrated product-service offering valuable to customers and contributing to a continuous positive change of customer satisfaction and experience [7] [8], becomes a predominant field. The relevant aspect of SE as a new discipline is that it investigates product-service design and development considering both customer and company internal perspectives.

In spite of the SE advantages underlined by theory, only few authors have proposed methodologies and tools which can be easily adopted by industrial companies, that continue to maintain a product-centric focus during the design of a solution. In addition, the existing tools in SE are mainly focused on design solutions able to satisfy customer needs, without balancing the search for an excellent value provided to final customers with the achievement of better efficiency in the delivery of the service processes. Moreover, a Service Lifecycle Management (SLM) perspective is missed, reducing service to a mere delivery execution process. This could lead to the emergence of what has been defined as *service paradox* [9] as an evidence of the counter-effects on the company's organization and its cost profile that could derive from venturing in these new markets due to a combination of hazard and opportunities.

In order to fill this gap, purpose of this paper is to discuss a real case application of the Service Engineering Framework which has been developed with the aim of integrating the design capabilities of the Service CAD, a modeling methodology for Service Design, with a simulation platform, enabling the comparison of several product-service configurations and the evaluation of technical and financial performances.

Using this framework, the service offering - in particular, the preventive maintenance service delivered by a multinational company operating on a global scale in the power and automation industry - has been investigated, with the purpose of providing re-engineering proposals of the current way it provides its services to the market. To illustrate the framework and its application, the paper is structured as follows. Section 2 is devoted to a literature review on SE with a brief state of the art of design and simulation methods and tools, focusing in particular on the Service CAD methodology and Discrete Event Simulation (DES). By making use of the case study, Section 3 provides an in-depth description of the single modules of the framework. Conclusions and further developments of the research are reported in the last section.

2 Service Engineering

The profit generation and the commercial success of a product-service solution critically depend on its conceptualisation, design and development, even if this notion has been largely ignored [7]. According to [10], the plethora of available tools and methodologies are typically a rearrangement of conventional processes, thus lacking a critical and in-depth evaluation of their performance in practice. Compared to physical products, services are generally under-designed and inefficiently developed [11]. Service Engineering (SE) is an emerging discipline aiming at filling this gap between product and service design. Sharing the definitions provided by [7] and [8], SE can be termed as a technical discipline concerned with a systematic development and design of services aiming at increasing the value of artefacts.

So far, a significant part of the SE literature has provided contributions on "HOW" a SE process must be carried out through the adoption of appropriate practices [7] [1], as well as methods and tools required to perform the single activities and phases. However, a small number of methods have been developed specifically for service design, development and engineering [1].

Among the different academic schools approaching the SE, Tokyo Metropolitan University has been working in this area since the beginning of the last decade developing the Service CAD methodology [12] [13] [14]. Service CAD is a modeling methodology created to describe and develop a customer value and its ground, the relationship between customer value and service contents, the service contents delivered by products and/or services [13]. The following paragraph better explains the main features of the Service CAD and the Service Explorer, a computerized design tool thought to describe and improve the quality of services.

2.1 Basics of the Service CAD Methodology

In accordance with the Service CAD methodology, a service is defined as an activity that changes the state of a service receiver by make him/her satisfied. More in detail, the receiver is described by a set of Receiver State Parameters (RSPs) representing the customer value [12].

The Service CAD provides some models which have to support a designer in the service design [12] [13], as briefly described in the following:

(1) the *Flow model* represents the flow among the various agents of a value chain.
(2) the *View model* describes, through a functional tree structure, the mutual relationships between the customer value, represented by a RSP, and the related functionalities. In the lower level of a View model the entities (hardware and humanware resources) and their attributes are introduced. Using a View model, designers perform a static evaluation of customer satisfaction based on these entities and their attributes.
(3) the *Scope model* describes the real activities taking place between two agents, i.e. between a receiver and a service provider. It deals with the RSPs of both the provider and the receiver, and handles multiple view models (namely, multiple RSPs).
(4) the *Extended Service Blueprinting* represents the service delivery process, and how the entities are connected with sub-processes and functions. The details of the relationships between functions and entities are here depicted. A Business Process Modeling Notation (BPMN) [18] is used in the extended service blueprint.

Therefore, by connecting the service functionalities defined through the View model and the service delivery process defined by the Extended Service Blueprinting, designers can clarify the relationship between the service process and the customer expected value through the explication of its functionalities.

Based on the aforementioned modeling method, a computer-aided design system called Service Explorer has been under development since 2002 [14]. Aim of the Service Explorer is to describe the customer needs and their mutual relationships as well as to provide a design environment that can support designers from individual customer analyses up to entities construction.

2.2 Discrete Event Simulation Models

Simulation can be defined as "a technique of constructing a model that describes the behavior of a real world system, and the resulting model can then be used to test how the performance of a proposed system alters over differing operating conditions" [16]. Business process simulations have been extensively studied in the past, and many techniques and tools currently exist. In particular, Life Cycle simulation [17] and Discrete-Event Simulation (DES) modeling have been investigated in the area of product-service. The adoption of simulation in the service field is becoming relevant due to the increasing scale of operations, and to the complexity and the nature of operations connected. In this sense, simulation can be really supportive in the design of the service delivery process and in the evaluation of different systems created under multiple 'what-if' scenarios. Several existing projects aiming at modeling and simulating product-service systems are reported in literature [15].

In this research field, authors have mainly stressed the need to design solutions able to satisfy customer needs. However, in order to make service provision profitable in the long term, it is of utmost relevance to balance the excellence in the value channel to the customer with a high efficiency and productivity of the service processes, through the achievement of standardization and modularization of the underlying activities and resources. In this sense, the integration of Service CAD and simulation, and in particular DES, can really support managers to reach this equilibrium. The main advantage of DES is that the development of simulation models requires less assumptions, data and is more robust than analytical models.

3 The Service Engineering Framework and Its Application

The aim of the Service Engineering Framework is to support the engineering of a new product-related service and the reengineering of already available solutions. Further, it aims at allowing the definition of the most suitable and complete service and/or solution for a customer in terms of content and provision processes. As depicted in Fig. 1, the framework is based on five different modules, each one referring to a specific phase of the Product-Service Engineering process. The simulation model has been developed using the ARENA® simulation software by Rockwell Automation.

Each phase is briefly presented hereafter. The description includes a general presentation of the main steps and the results obtained in the real case study application. The case refers to the application of the framework in a multinational company operating in the power and automation industry which is currently reengineering its service offering. The entire service portfolio has been analyzed and in particular the provision of industrial services based on preventive maintenance, identified as the most relevant service for the final customer, has been investigated.

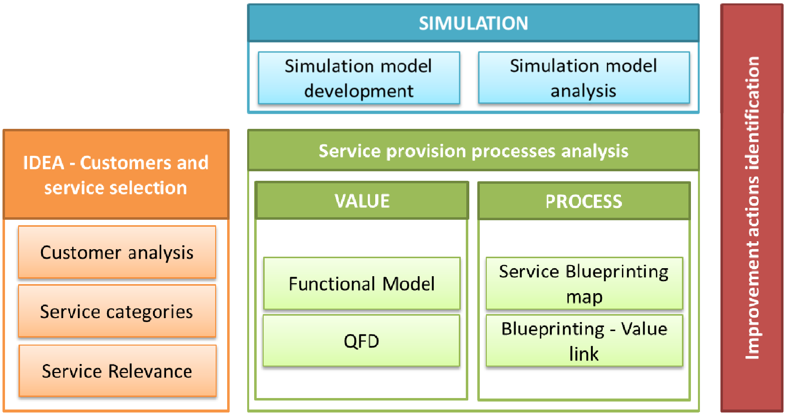

Fig. 1. The main modules of the proposed framework

IDEA

- *Analysis of the customer segments based on their needs*: by using the marketing data available (two surveys, one analyzing the customer needs and one the service preferences) two customer segments were identified: Seg.1) customers that rely on the producer's capability to maintain their equipment in good shapes; they want to be granted of an effective service execution; Seg.2) customers that would perform service activities autonomously, with the remote support of provider's technicians.
- *Analysis of the service offering and needs satisfied through service provision*: thanks to direct interviews to different Service Managers, a relationship between customer needs and services preferences was established; by matching customer needs with the needs fulfilled by services, the service offering that mostly suits the requirements of the two customer segments was identified.
- *Identification of the most relevant services*: four services were identified as relevant for both the customer segments; in particular, preventive maintenance was considered as the most strategic one; the aim is to satisfy customer's needs by providing a proper preventive maintenance service able to "maximize the customer's equipment availability".

VALUE

- *Development of the functional tree*: the functional tree of the need "*maximize the customer equipment availability*" was developed using the View model; this need was qualitatively decomposed into six functionalities at the first level; each of them was further drilled down until the definition of four detailed sub-levels of functionalities. At the last level, tangible entities and their attributes enabling to carry out the different functionalities were identified. This tree represents all the functionalities the service offer has to provide to the customer in order to satisfy his need. At the first level of the tree, among the six functionalities identified, the functionality "*ensure failure prevention*" was identified (Fig. 2). This functionality and the ones deriving from it represent the functional branch strictly related to the Preventive Maintenance service.

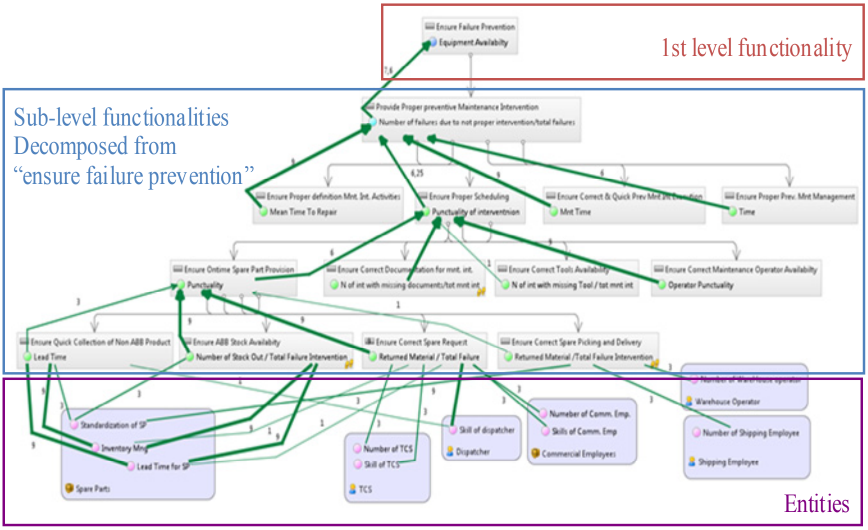

Fig. 2. The functional tree resulting from "ensure a proper failure prevention" functionality

- *Analysis of the functionalities and entities relevance by use of QFD*: Quality Function Deployment was adopted with the aim to identify the most relevant functionalities and entities of the preventive maintenance service the company can leverage on to optimize its provision process and satisfy customer needs. All the functionalities directly connected with the onsite execution of the maintenance and the human entities that have a direct relationship with the customer (e.g. maintenance operators and dispatcher) are the most critical ones to properly satisfy customer's needs.

PROCESSS

- *Definition of the process blueprinting*: the onsite and offsite preventive maintenance processes were modeled by use of the service blueprinting methodology. A detailed model of the processes was defined, and for each humanware entity a swimming lane in the process maps was reserved with the aim to better explain the process flow.
- *Link of the blueprinting and the functionalities*: in order to verify whether the current processes are able to satisfy the customer's need, it is fundamental to ascertain whether the functionalities identified in the previous phases are delivered along the

process and which part of the process is the most critical in terms of customer satisfaction. The processes under analysis were able to provide the functionalities characterizing a good preventive maintenance service. Moreover, it was observed that the company reserves a lot of attention to the front-line activities.

SIMULATION

- *Development of the simulation model*: The static models developed in the Value and Process phases were transposed in the DES simulation tool environment. The transposition has been done manually by the translation of the BPMN model in the ARENA® nomenclature. In particular, both the customer process and the service delivery processes (as detailed in the blueprinting) have been simulated by using real field data, and different scenarios were tested.
- *What-if analysis of the simulation model*: The scenarios were defined and evaluated based on the functional tree and the QFD analysis by a modification of: i) the saturation of the most relevant entities (maintenance operators and dispatcher) and ii) the priority assigned to the different functionalities and therefore to the different part of the process. Moreover, tests connected to a variation of the number of maintenance interventions were also carried out. In this way it was possible to identify the best solution which maximizes the expected performance, in terms of both company's revenues and customer satisfaction.

4 Conclusions

This paper presents the application of the Service Engineering Framework to support the re-engineering of a product-related service in a real company. Built around five different phases, the framework extends the logic of the Service CAD methodology through the introduction of a Discrete Event Simulation phase to support the economical and risk assessment of the most suitable product-service solution and the best performing provision process. Many are the advantages achievable through the introduction of this framework in the investigated company: (i) the adoption of a systematic procedure to analyse the existing services, (ii) an improvement of the process performance by the identification of the elements affecting customer values, (iii) a reduction of the costs and (iv) a better definition of the process changes in order to properly manage an increase of demand and revenues.

The output resulting from the simulation gave the company a lot of insights to improve its processes and to define a more customer-oriented structure. Due to confidentiality reasons, it was not possible to report in this paper more detailed data.

In order to better understand the appropriateness and robustness of the framework, further applications should be carried out either in engineering new services or in the reengineering of existing solutions enlarging also the perspective to non-industrial service systems, such as healthcare or touristic services.

As it was experienced along the case study, the main requirement for a fruitful adoption of the framework resides on the need of a massive quantity of field data which normally are not systematically collected and easily retrievable.

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Service Delivery Process Based on Service Composition Mechanisms

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Abstract. Service engineering has merged to boost the development of services required by users to satisfy Quality of Service requirements. As there is a shift towards a service based economy planned to increase profit, more and more complex services are proposed by companies. At the same time customer needs due to numerous offers are ill-defined, change rapidly over the time and even does not exit on the market. The combination of existing services to build a new one is a possibility that is time consuming for the service consumer and necessitates expertise to make the combination successful. In IT, service brokers are used to provide services satisfying QoS requirements. In that paper we propose to use concepts from service engineering to define a service composition mechanism enabling the development of complex services regardless its type as well as a service delivery process modeling to support service production.

Keywords: service modeling, service composition, service engineering, service delivery.

1 Introduction

As the service sector expands into the global economy, service engineering develops as a field enabling service efficient innovation by applying scientific understanding and management practices to designing, improving, and scaling service systems. Service Engineering is becoming a hot topic even in manufacturing companies as the shift towards service-based economies is bringing new business concerns to focus.

Service Engineering is a comprehensive solution that delivers everything as a service. Based upon service components (human, machine, etc.) configured to work together in the service framework and deliver a service through a single system, service engineering is supposed to increase company profit, satisfy beneficiary requirements in terms of quality of service with less energy and resource consumption, unlike manufacturing sector. To achieve this goal, some considerations on beneficiary requirements, service added value, service availability, service customization, etc. might be taken into account. These considerations discussed in the next part show the importance of the relationship between the service provider and the service beneficiary to elicit the requirements and the difficulty for the former to

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satisfy the latter with a level of quality that is requirement compliant as the service required is sometimes not available or even does not exist.

Service broker is a solution to decompose a service into sub services in the IT domain, allocate the existing sub-services in the service market and integrate them together to generate a new one, which can help greatly improving beneficiary experience and satisfaction. Here, we propose to use the concepts of service engineering, service composition to define a dynamic delivery process of complex services that can be IT independent.

The relationship between the provider and the beneficiary of the service is depicted in section three, through a service delivery process modeling, in its static and dynamic perspective. Section four details a service composition mechanism based on service engineering aiming to favor complex service delivery. The last section draws conclusions and highlights future works.

2 A Few Considerations to Make Service Engineering Efficient

2.1 Definitions and Service Engineering Insights

Service Engineering approach is global and encompasses the entire service trading process. It provides services to the mass, ranging from the end-users to enterprises. Service Level Agreements (SLAs) [1] including Quality of Service (QoS) requirements are set up between service consumers and service providers. An SLA is a commitment entered by a provider with regard to a customer that specifies the quality of service to be provided for a hardware or software, over a certain period of time, in terms of metrics agreed upon by all parties, and penalties for violating the expectations. SLAs act as a warranty for users.

A requirement is a statement that identifies a capability or function needed by a system in order to satisfy a consumer need [2]. The stakeholders include all the people, organizations, and institutions that are a part of the system environment because the system provides some benefit to them and they have an interest in the system. This includes end users, operators, bill payers, owners, regulatory agencies, victims, sponsors, maintainers, architects, managers, customers, surrogate customers, testers, quality assurance, risk management, purchasing, and the environment. As the relation is bijective, protagonists are subsequently shortly named provider and consumer. To make complex service delivery efficient, attention must be paid to the following assertions:

- Consumers always don't know exactly what they want and their requirements can change rapidly over time.
- Different consumers have their own business logic that cannot be satisfied by the existing services in the market or the existing ones are too expensive to afford.
- Consumers (like small and medium companies, individuals) cannot afford customized services whose price is often expensive and time consuming.
- Providers could not provide specified services to every consumer, as it is not realistic. They focus on facing a large group of population and try to satisfy requests from majority of them.

2.2 Requirements Categorization

Requirements are categorized in several ways [3]. The following are common categorizations of requirements that relate to technical management: Customer Requirements, architectural requirements, structural requirements, behavioral requirements, functional requirements, non-functional requirements, performance requirement, etc. Among them, service requirements are more related to functional and non-functional types.

Functional requirements specify particular results of a system (specific behavior or functions). This should be contrasted with non-functional requirements that specify overall characteristics such as cost and reliability. Often called quality of service requirements, non-functional requirements can be divided into two categories: execution qualities and evolution qualities. Broadly, functional requirements define what a system is supposed to do whereas non-functional requirements define how a system is supposed to be. The knowledge of these two requirements is mandatory to reach the service engineering abovementioned objectives.

2.3 Requirements Elicitation as a Pre Requisite

Service requirements truly represent the business logic and consumer perspective. When a service is desired, a good understanding of the goals, motivations and needs consumers have must be established. The latter are difficult to predict and mostly consumers are not consciously aware of those needs [4].

Services so far are provided by organizations and are thought through and planned (designed) mostly from this provider perspective. The point of difference that the Service Engineering approach offers regarding more traditional IT service design approach is the development of service systems focusing on the consumers as well as on the organization. Consumers are involved in designing the service delivery process; without their participation there can be no service. Over time, they encounter different touch-points. A touch-point is a contact point with one of the elements of the service offering. All touch-points can be considered experience puzzle pieces of a service and can be built out of product and service components. The overall experience a consumer has, is driven by the Service Interface. It is a mental concept in the consumer mind that has consequences on the perceived QoS. Designing this interface means to align all touch-points against the service concept. Furthermore as the consumer is a mandatory stakeholder of the service delivery process, he is an integral part of the service performance. QoS will be dependent of the quality of consumer's participation in the process (requirements elicitation ability) and of the quality of stakeholders' experience/expertise (interaction ability).

It's difficult to build a solution if the requirements are not known. The "elicitation" phase is the phase of the service delivery process during which the requirements are gathered from the client. Many techniques are available in the IT domain for gathering requirements. Each has value in certain circumstances, and in many cases, we need multiple techniques to gain a complete picture from a diverse set of clients and stakeholders like one-on-one interviews, group interviews, joint application development (JAD), questionnaires, prototyping, Use cases, brainstorming, etc.

The concepts borrowed from the computer science and IT domain presented here assumes that everything is a service (XaaS). Previous works dealing with service in manufacturing already mentioned this fact: in 1972, Lewitt claims that "everybody is in service" [5] and later Gronross attempted to quash the division between products (tangibles) and services (intangibles), saying that: "it does not make sense to determine whether customers buy products or services [6]. What they actually buy are the benefits that products and services provide them with. From this perspective, all companies can be said to offer services, even traditional manufacturing firms. Our works pointing in the same direction, the previous concepts are adapted for use in service (more or less tangible) delivery system (i.e. provision of a product or a service in a dual representation).

3 A Conceptual Model of Service and Service Delivery

3.1 Basic Modeling Concepts

Based on section 2, we consider that (Figure 1):

- A service as an action performed by a provider to the benefit of a consumer [7], interaction between both [8]. The provider uses means and has a capability enabling one or more actions. These actions lead to a result or an effect aiming to satisfy consumer requirements against its own actions performed using its own means and capability.

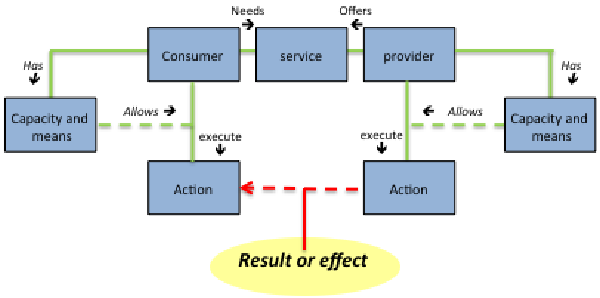

Fig. 1. Service interaction modeling

- A provider is identified with regard to his function and is noted F. A consumer is characterized by his need and is noted B (figure 2, left part). As a provider can be consumer of one or more services and conversely, we assume that it can become a hybrid object (figure 2, right part) [9].

Fig. 2. Basic principle and hybrid object generic representation

- Service delivery relations become then more complex i.e. each relation is defined for a given service. A hybrid object is then part of a service delivery series, linked to another upstream object as consumer and a downstream object as provider.

3.2 Service Delivery Process

A service delivery process is a process enabling the delivery of a service. It requires a coupling between a provider and consumer and sometimes necessitates means. The service is returned as long as the coupling exists. When it stops, the service ends and each stakeholder find back its freedom. When the coupling starts, requirements have to be elicited by the consumer.

The abovementioned description supposes that the service delivery process can only be led during the coupling. Obviously, the interaction between the service provider/consumer is the main part of the service delivery process. However, in more complex cases both actors can require to be prepared in an upstream phase (some sort of pre-process) and to get free in a downstream phase (some sort of post-process) (figure 3). The corresponding phases are the following ones:

Initialization: this phase does not require the coupling to be established but requires to know that the service must be returned. Information on the service needs is necessary to activate the phase. Information refers for the consumer to the identification by his requirements and for the provider to the identification of the requests he can satisfy.

Customization and contextualization: in case the service is not standard, a phase of customization based on information coming from consumers is to be envisaged. The contextualization focuses on the adaptation to the context (consumer, surrounding conditions, etc.) of the service to be returned and of the service delivery process.

Closing and de-contextualization phases exist when both actors require a process to close the activity. This process is similar to the one of the initialization phase but occurs after the service delivery. It can lead for the provider in a change regarding its ability to deliver the same service [10].

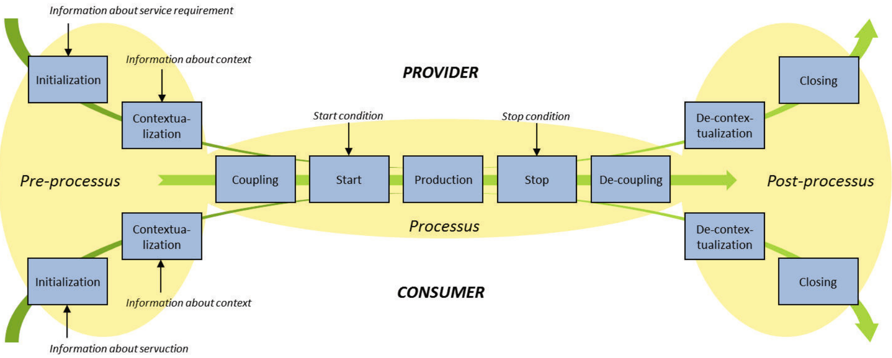

Fig. 3. Cartography of the whole service delivery process

3.3 Global Dynamics of Simple Services

The above-presented model focuses on an elementary service (sub-service) to be delivered. Three items of importance concerning the dynamic of the model and its operationalization need to be addressed: the matching procedure between a function and a need, the definition by the consumer of the function that can fulfill his need (service requirements) and at least, the identification of the provider that can propose the function.

Accordingly, the process is as follows: any provider has to declare publicly the precise nature of the functions he can fulfill in a “service directory”. The statement is build upon a reference frame in order to facilitate the function description, its comparison and ranking regarding functions that can be competitive. The nature of the function is the static part of the statement while the capacity that can be used at a moment corresponds to the dynamic part of the statement (figure 4, left part).

When a consumer has a request, he has to elicit his requirements (needs) using the same frame to make a comparison feasible (figure 4, central part), i.e. at first in term of nature and then in term of load. Expression of QoS is sought during this step.

Once this is done, the matching between providers and consumer can be started. The function offered is compared to expressed needs. In case there is a matching i.e. a provider can provide the consumer with the required function to satisfy the requirement (nature, load and QoS) and a service is delivered. If no, the request cannot be satisfied and then can be updated, or confirmed and put on hold until a provider declare a relevant function. A final opportunity, discussed in the next part, concerning the composition/decomposition of sub-services exists.

The whole process is described on the right part of figure 4: (1) requirement elicitation by the consumer, (2) service discovery according to the frame (request), (3) choice among providers able to fulfill the need and service allocation, (4) service integration and delivery by provider to the consumer.

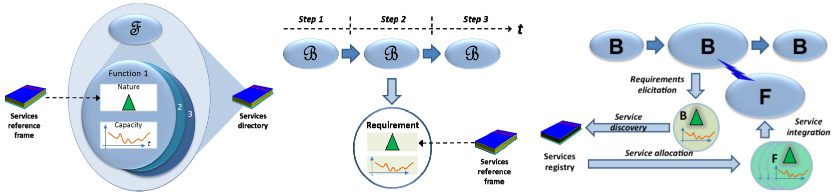

Fig. 4. Service statement, expression of needs and matching sequence

4 Service Composition

Obviously, service requirements are most of the time specific and no existing service in the market is able to satisfy them. A solution is to combine existing services together in order to fulfill the request. This trend known as service composition receives attention from both academia and industry. The selected and finally integrated services should optimize the overall QoS of the composed service while satisfying all the constraints specified by the consumers on individual QoS parameters. Algorithms exist to select services to combine based on global QoS optimization [11], [12]. The implementation of these algorithms can sometimes lead to unfeasible solutions because of the lack of interoperability among providers during integration or between consumers and providers.

The mechanism we propose is first to build the service registry (pre-processus, see figure 3) and then use it (service delivery process). The process is described hereafter:

Step 1-service decomposition: any existing service will be decomposed to collect the service components from user requirements and identifying the important details of each service to reduce the efforts in service integration and allocation.

Step 2- Service registry: any existing service, sub-service and component details will be registered using a registration procedure. When new services enter into service market, its whole description is registered.

Step 3- Consumer requirement discovery: customer requirements are described as explicitly as possible. Consumers are expected to fill out a form that is composed of a host of items on a user interface.

Step 4- Service decomposition: Once customer requirements are elicited, the requested service is to be decomposed to suitable extent, neither too detail nor too specific. The decomposition process is based on the functional requirements. The interrelationship and interoperability conditions of the sub-functions that guide the decomposition are described in a wise way so that decomposed sub services don't have too many interactions between them to reduce errors and interaction.

Step 5- Service selection and integration: Based on QoS requirements and service ranking coming from previous user experiences and former service performances, service integration gives as an output a sorted list of services that can be used to satisfy the need. To rank services based on multiple KPIs, we propose a ranking mechanism based on Analytic Hierarchy Process. There are three phases in the process: problem decomposition, judgment of priorities, and aggregation of these priorities. In the first phase, the ranking of a complex problem is modeled in a hierarchy structure that specifies the interrelation among three kinds of elements, including the overall goal, QoS attributes and their sub-attributes, and alternative services. The second phase consists of two parts: a pairwise comparison of QoS attributes is done to specify their relative priorities; and a pairwise comparison of services based on their QoS attributes to compute their local ranks. In the final phase, for each alternative service, the relative local ranks of all criteria are aggregated to generate the global ranking values for all the services. **Service integration strategy:** in many cases to have a standalone service is not enough. When there is no single service having the ability to satisfy a consumer requirement, service composition is needed to select several correlative services together for the purpose of fulfilling the need. Therefore, the problem is how to effectively and efficiently integrates the services provided by different providers to new services with higher value. After service allocation, one decomposed sub service could have more than one kind of candidates with the ranking of service allocation strategies. However, it doesn't means that integrating the highest ranked sub services together could generate an optimal result. Accordingly, the sets of the services selected by the service allocation mechanism is the preliminary one which provide a plenty sets of services to do a further selection.

5 Conclusion

The existing service market proposes services that are not enough to satisfy all consumer requirements as each one has his proper own logic. Customizing a new one with a specified provider is not a wise choice for service consumers as it costs a lot and is also time consuming. As a consequence, service decomposition and integration mechanisms based on Service Engineering are proposed to solve the above problem focusing on user requirements discovery, service decomposition and integration strategy. There are still some works need to be done in the future. Among them is the need to make more efforts to seek for the non-existing but largely demanded service components published by consumers, in the service market within which to guide the providers' future business work to produce such greatly demanded services. Finally, integrated service or newly generated services should be registered as a new service that can gradually enrich the quantity of services provided in market and will continuously benefic service component providers and future consumers.

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Servitization of the Manufacturer's Value Chain

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Abstract. Servitization, the offering of product-services, is a more and more pervasive concept. When applied correctly, it exploits the product and generates additional added value for the manufacturer as for the customer. Until now, servitization has been applied only onto the usage phase of the product, creating services around it. However the product is not the only valuable and tradable asset in a manufacturing enterprise. Therefore this article scrutinizes the possibility to additionally exploit the manufacturer's value chain, by servitizing its components and hence transforming them into products per se. To test this possibility Thoben's seminal representation of servitization was taken and applied onto the components of the value chain identified by Porter. It was elucidated that the proposed concept is feasible and under certain circumstances, it increases the seller's and buyer's sustainable competitive advantage. The article concludes by questioning the effect of this novel concept onto sustainability.

Keywords: servitization, value chain, manufacturing, competitive advantage.

1 Introduction

Fordism was a time where a mass production represented the core of the benefit. Though, evidently a manufacturing industry as part of the globalisation race with unscrupulous economic, trade and labour policies, indirectly fostering quickly commoditized products, is not a long term solution for developed economies. Hence, out of flexible manufacturing systems, marketing related customer orientations stemmed out the nimble concept of creating product-services from the consumers' products. With this approach manufacturers are trying to achieve and especially sustain their competitive advantage. Strategic management literature is referring to this concept as the sustained competitive advantage, which can lead to sustainability.

Through service oriented approaches, like servitization and Product-Service Systems (PSS), manufacturers tend to create more added value for their customers, as also for themselves in form of higher revenues, prolonged product life cycle, customer loyalty, new customer segments and foremost higher level of competitive advantage. Also due to the increase of services and other fuzzy elements like service level agreements, network collaboration, the imitation and replication of such business models becomes more challenging for competitors. Consequently, not only that servitization increases a manufacturer's competitive advantage, but it also increases

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its retention level, making it more sustainable. Hence, servitization, by increasing the level of exploitation of the product, can be defined as a process that enables the creation of additional substantial added value for the provider as also for the consumer.

However until now the process of servitization has been applied only onto the usage phase of the product (e.g. services for remote machine maintenance, offering an airplane machine per miles, "pay per-view or per-use models" etc. – all services are related to the usage phase). Be that as it may, the end product is not the only valuable and tradable asset in manufacturing enterprises, where each of them has its own personalized value chain [1], with its own strengths and weaknesses, with its own resources, ranging from advanced IT tools to active global collaborative networks. Therefore, this article proposes to apply the concept of servitization to components of the manufacturer's value chain. This means that a manufacturer offers its components, with high added value, to other business entities, as a service. Such offering can be called Value Chain as a Service. Consequently, this article proposes to enable manufacturers to additionally exploit their existing resources along the value chain with the objective to increase its level of competitiveness and leading him one step closer to a more sustainable competitive advantage than its competitors. This article links the pervasive concept of servitization with the concept of the manufacturer's value chain, whereas its components through servitization, become new products or product-services per se.

2 Research Approach

In order to avoid the pervasive "paradigm mentality" simultaneously proliferating and polarizing perspectives, which often inhibits discourse across paradigms, biasing theorists against opposing explanation and fostering development of provincial theories [2], this article applies the concept of metatriangulation. It implies a multi-perspective view, though not across methods within a single theory or paradigm, but across different theories and paradigms [3]. The intent is to identify differences, tensions as also similarities, hence increase reliability of findings. Hence it draws from two research fields, first from the field encompassing service oriented approaches, like servitization, PSS, servicizing etc. and secondly, from the field of strategic management, encompassing the concepts of competitive advantage arising from different schools, the concept of coopetition and understandingly the value chain concept. The test of servitizing the value chain will be performed in the field of service oriented approaches, whereas the reliability of the results will be analyzed through the concepts of strategic management, with the clear objective to unravel opportunities, but foremost inconsistencies and tensions in the scrutinized concept. Such rest of robustness of the findings substantially increases their level of reliability.

3 Relation to Existing Work

3.1 Strategic Management

Competitive advantage of a manufacturing enterprise is a dependent research variable, which is affected, by applying servitization to the usage phase of the product or potentially to a value chain. Therefore, the most prevailing views are depicted in the continuation. Porter [4] defines two main determinants for relative performance: a) the operational effectiveness and b) the choice of strategic positioning or simply the choice of strategy. The latter defines which activities to perform and in what combinations [5], thus it is not just a list of individual activities. Meanwhile operational effectiveness defines how efficiently those activities are performed. If commencing with the view where the business environments has most influence, the next prevailing view arises from the behavioural school, where one of its most visible representative is Mitzberg [6]. It is characteristic for this view, that the enterprises will be able to develop their own environment, meaning that they can create new non-existing needs, enter new markets, but of course all this at the price of potential failure. In this category fits also Schumpeter's view, especially on the role of the entrepreneur as the prime cause for economic development, hence implying that he creates new markets and offerings and is not defined by the environment. Lastly the Resource Based View [7] focuses on the resources and their bundles of the enterprise based on which competitive advantage is achieved and sustained.

Coopetition is depicted, as it can be one of the potential results of servitizing the value chain. It argues that one single relationship can comprise of both cooperation and competition and those two enterprises can compete and cooperate simultaneously. The concept can be described in a wider context by Nalebuff and Brandenburger [8], where two enterprises cooperate with different products (e.g. sportswear and healthy food) [8]. Though, there also exists a more focused view on coopetition taken up by Bengtsson & Kock [9], where two enterprises compete on the end user's market, but cooperate in activities along the value chain (e.g. two breweries compete in selling bier, but cooperate in dealing with empty bottles).

Value Chain is introduced as the concept to where servitization could be applied. Therefore, its definition must be clear. Many concepts have been developed since its conception, like value constellation, but this article goes to the root and therefore uses Porter's [1] definition. Value chain analysis describes the activities within and around an organization, and relates them to an analysis of the competitive strength of the organization. He distinguishes two main areas. The first is the primary set of activities and is directly concerned with the creation or delivery of a product or service, being logistics, operations, marketing and sales and service. The second set of activities represent the support activities (human resources, technology, infrastructure, procurement), which are linked to the primary ones helping them to improve their effectiveness or efficiency. Lastly, it must be emphasized that it is considered that the competences needed to design and manage a value chain, which designs and offers a P-S, are included in the value chain.

3.2 Service Oriented Approaches in Manufacturing

At least two main types of service oriented approaches exist in literature. In 1988 the definition of servitization was coined by Vandermerwe and Rada [10], which defined it as "market packages or bundles of customer-focused combinations of goods, services, support, self-service and knowledge". The other mainstream is called the PSS.

It is a Scandinavian concept offering a promising avenue to achieve sustainable consumption and production patterns and to improve the competitiveness of industrial manufacturers [11], [12]. The adoption of a PSS involves an orientation toward selling a product's functionality instead of selling the product itself. It is defined as "integrated offerings of products and services that deliver value in use" [13]. Of course there also exists other definitions, such as from Ren and Gregory [14] stating that servitization is "a change process wherein manufacturing companies embrace service orientation with the aim to satisfy customer's needs, achieve competitive advantages". Other concepts are servicizing [15], functional sales [16] or even full-service contracts [17] and also Industrial PSS [18]. Lastly, Baines [13] has proposed that PSS becomes a subset of servitization, concluding that servitization is the widest term used in the service oriented strategies.

Thoben's classical representation of servitization [19] provides benefits to the customers of the P-S, hence the benefits of servitization are generated during the P-S usage phase. Its first level deals with the pure product, the second level includes services that support the product and can already generate revenues (e.g. warranty, maintenance). The third level adds services that differentiate the product (e.g. Hilti International's „pay per hole model" [20]). Lastly, the forth level predicts that the product is still present, though remains in the ownership of the manufacturer and the revenues are generated by the services, selling the functionality (e.g. the manufacturer sells a constant temperature in a specific place and not the heating system). This is the highest level of servitization that can be found in literature.

3.3 Hypotheses Development

All the above mentioned forms of service oriented approaches have in common at least one characteristic; they are all applied onto the usage phase of the product or put differently, the benefits of the service oriented approaches are intended for consumers using the product. As servitization is a process of adding or generating additional value for all involved parties, the article thereby endeavours to fill this gap and to extend the application of servitization throughout the manufacturer's value chain. This would enable practitioners to substantially increase the exploitation level of their value chain and to increase their competitive advantage. As for scholars, they will be able to expand the limits of the applicability of servitization.

As already indicated, the two hypotheses are developed out of two essential fields for testing the possibility to servitize a manufacturer's value chain. Servitization as the widest concept was used, where Thoben's representation of servitization is widely used. Therefore, by taking the highest concept in service oriented approaches and a widely recognized representation of servitization, it is considered satisfactory that Thoben's representation is used to test the applicability of servitization onto components of a manufacturer's value chain. Consequently the following hypothesis arises: "Can Thoben's representation of servitization levels [19] be applied onto a component of a value chain, which consequently becomes servitized?" The next hypothesis assays two matters; first, the impact of servitizing its own value chain on the level of competitive advantage and the second, the effect on the buyer's competitive advantage of acquiring such a value chain component. Hence the second hypothesis is the following: ”Servitizing the value chain of a manufacturer has a positive impact on its level of competitive advantage and its sustainability as also on the buyer’s competitive advantage.”

4 Findings

This section presents the findings of applying the concept of servitization using Thoben’s representation, onto the components of the value chain. In order to perform the test, if servitization is applicable onto the value chain, two activities from the primary set (operations and sales) and two activities from the secondary set (technology and human resources) of activities from Porter’s value chain [1] were chosen to be applied onto Thoben’s four servitiztion levels. The first chosen activity from Porter’s secondary set of value chain activities is Technology, where the Product (first level) can be an existing software (SW) for product personalization owned by the manufacturer. In the second servitization level supporting services are added to the product, like maintenance and partial modularization. In the third level, where the Product is differentiated with services, the SW with existing maintenance services can be leased. Finally, the highest level, being Product as a service, only the functionality of the output is sold; in this case the buyer pays only for the functionality delivered by the SW and its related services. The second component of the value chain, deriving also from the supporting set of Porter activities, is Human Resources. This value’s chain component is special, because it is needed in order to servitize all other parts of the value chain. Therefore, this component is servitized through the servitization of other components (e.g. the competency of SW development is be sold through the servitization of the SW). The third component is Operations, arising from the primary set of Porter’s value chain activities. For this activity, the example for the Product, the first servitization level, is the setting up of a flexible manufacturing network supporting the provision of a servitized product. Interestingly the product in this level is a service. In the next serivtization level, additional basic services are added, like maintenance and additional modularisation or its optimization. In the third level of servitization, where services differentiating the product are introduced; hence, the flexible manufacturing network is not sold anymore, but its usage is sold, like the model “pay per use”. The buyer does not own the network and pays only for its usage. The forth level indicates that the buyer pays only for the output or the functionality provided by such network. The forth component of the value chain to be tested is Sales, arising from the primary set of activities. The product in the first level of servitization can be the setting up of sales network, which again interestingly is not a product per se. In the second level, basic services are added, like sales network optimization. In the third level, only the usage of the sales network is sold, which can reflect the usage of sales network, where the payment is effectuated by the actual sale. The forth servitization level, where the product is offered as a service, can be for example the functionality of generating a certain profit, regardless of the basic product, which is the sales network.

After exemplifying the servitization of different components of Porter’s value chain, it is evident that servitization is applicable onto the value chain. Furthermore, the core product around which servitization revolves, is not necessarily always a pure product, but can be a pure service, constituted from formalized relations with different manufacturers with a set of predefined business terms (price, flexible delivery ...), which is also called a manufacturing network or even an ecosystem.

4.1 Guidelines for Servitizing the Value Chain

The manufacturer has to identify first which of the activities in the value chain are the most different and effective [5]. Secondly, one should identify what is the nucleus of its competitive advantage and decide what is to be protected. Then the manufacturer can offer: a) classical, but valuable parts of its value chain (e.g. access and sales network) and/or b) components of the value chain that were the most affected by the servitization; those are usually the one that maximizes flexibility, personalization and customization of P-S. The latter are especially interesting for manufacturers wanting to servitize their business with lesser risk, almost "on the fly". In addition, servitization is a more and more pervasive trend, meaning that the demand for components of the value chain fitted for P-S generating and/or delivering will be on the rise.

5 Discussion

The benefits of servitizing value chain components are depicted from two points of views, the seller's, which is the manufacturer, and from the buyer's. The seller can generate additional income, by increasing the exploitation level of its existing resources. This means that additional products or P-S are created, thus enlarging its portfolio. Furthermore, if the manufacturer is on a B2C market, it enables him to enter into a B2B market. Lastly, if the manufacturer is already present on the B2B market with a non-servitized product (e.g. manufacturer of fuel pumps), such seller has the opportunity to servitize its business; though not its end product, but different components of its value chain. This can increase the manufacturer's competitive advantage. However, if a component of the value chain is sold, from which the core of the strategy is duplicable, this can have negative consequences. To alleviate such risk, the manufacturer must master its strategy and be able to recognize its core strengths and weaknesses. Finally, the proposed strategy is harder for competitors to imitate and replicate and secondly it decreases the need to sell its products on a mass scale on a lower price, as additional revenues are generated through servitizing the value chain. Such behaviour could help substantially lead a manufacturer to sustainability.

In the previous paragraph, the effect of selling the value chain components was analyzed. In the current one, the effect of buying the value chain component is discussed. It increases its competitive advantage due to the capability of faster entrance into new markets or market segments; for instance it opens up the possibility to swiftly servitize its business, especially as literature and practitioners are still on the search for numerous methods and tools for easier servitization of the end product. Also as already known, servitization can represent an additional stable income stream. Besides, the buyer is acquiring components of the value chain that are not characteristics of the usual set of internal resources, which means that such business is becoming harder to imitate and replicate. However, if the buyer is not conscious enough regarding the concept of the strategic fit, a wrong buy can be made, which will decrease its competitive advantage. Therefore, before the acquisition, the buyer must perform a strategic fit of the new component with its current strategy (e.g. one acquires the usage of a flexible manufacturing ecosystem, which generates only expensive, high-end products, but the current customer base of the buyer appreciates only low-priced products). Anyhow, buying a component of the value chain with high added value enables the buyer to quickly enhance its competitive position and to retain it due to the higher level of complexity of its strategy.

It can be concluded that the first hypothesis can be fully accepted, as servitization, as presented by Thoben [19], can be applied to the components of the manufacturer's value chain. As for the second hypothesis, it can be concluded that the seller and buyer increase their level of competitive advantage as also its capability to reach sustainability. However, this is feasible only under the following two sets of conditions: first, both parties must be highly conscious of their strategy, their strengths and weaknesses and secondly, they must possess an understanding of the strategic fit between the component of the value chain and their internal strategy. Though, the limitation of this article is quite obvious, as it has not yet been tested on multiple use cases.

6 Conclusion

As literature still struggles with the problem of how to create and offer P-S, some manufacturers have already succeeded in doing so. Through servitizing their products, their value chains are fitted to generate and deliver innovative P-S. Those components can be offered to other manufacturers so they can servitize their product as well. Namely, the effect of servitization is not only the servitized product, but also a more customized, flexible, efficient, technologically advanced and efficient value chain that can become a new product or product as a service per se. Furthermore manufacturers positioned in the middle of the value chain (e.g. car fuel pumps manufacturers) can now apply the concept of servitization, though not on their end product, but onto their value chain. The presented concept opens up a new palette of opportunities, but also unknowns. One of them to be tackled, is to assay, if servitization of the value chain can underpin the current business models that are based on the idea to sell as much products as possible, hence not being adequate in terms of sustainability and must be carefully revised [21].

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Part IV
ICT and Emerging Technologies

ICT-Enabled Integrated Operations: Towards a Framework for the Integration of Manufacturing- and Maintenance Planning and Control

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Abstract. With the onset of increased competitive pressures from the likes of globalisation and various other factors, there has recently been a greater focus on the systematic integration of operations within and beyond enterprises. One such area has been the integration of maintenance planning and execution with the planning and control of manufacturing. Such a novel concept is denoted as Integrated Planning (IPL). In this paper we investigate developments within this area, and propose a conceptual framework which should be used to guide subsequent advances in the field.

Keywords: Manufacturing Planning and Control, Maintenance Planning and Control, Integrated Operations, Integrated Planning.

1 Introduction

As the management of physical assets now accounts for a rapidly increasing share of operational costs, greater attention is being directed to maintenance thinking [9]. However, in the industrial environment, the relationship between production and maintenance has been conflicting in nature [25]. Nowadays, with increased global competition and decreasing profit margins, the need for an effective maintenance planning and control system is obvious. Yet maintenance often retains a negative image and is sometimes regarded as a necessary evil [4, 36]. As such, in companies that have production as their core business, maintenance is constantly subordinated to production, which otherwise consistently gets priority. This attitude is perpetuated regarding the planning and execution of each function. Though much time is spent on the production planning and control task, the most common maintenance strategy observed in business has been "we fix it when it breaks". Fortunately however, maintenance thinking has more recently evolved towards the concept of World Class Maintenance (WCM) where the maintenance discipline is seen as a competitive advantage. For example in Oil & Gas industry, an observable trend is that maintenance is no longer comprehended as a necessary evil but a value-added discipline that has considerable business impact [5]. Nevertheless, a common dilemma is the decision of whether to manufacture a product (which may result in the deterioration of the process) or to maintain the equipment for

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a possible improvement [14]. In order to resolve such a dilemma, the issue of integrating production planning and preventive maintenance is becoming an active area of research [2].

This article assesses the research gap between production and maintenance planning and control and further develops and proposes a conceptual framework for Integrated Planning (IPL). It is a conceptual paper and the primary research methodology is literature review. We take insight from both the maintenance management and production management domains and explore the possibilities for the successful integration of both disciplines. We identify important aspects and pertinent factors that should be considered when integrating manufacturing and maintenance planning and control, and develop a conceptual framework for such systematic integration.

The remainder of the paper is composed as follows: Part Two presents an overview of the relevant literature and discusses important elements from both production- and maintenance planning and control, before we develop and propose our conceptual framework for IPL in Part Three. We discuss our findings and limitations and draw necessary conclusions in Part Four, before finally present some areas for further research in Part Five.

2 Theoretical Background

The issue of integrated planning of production and maintenance is a recent problem [25]. For example, [8] state that maintenance management must be integrated with other functional departments such as production and quality control. A further challenge is the development of computer aided maintenance management (CIMM) systems that enable manufacturing companies to integrate, schedule and control production and maintenance. For example, though attempts have certainly been made to integrate the maintenance function into contemporary ERP systems [e.g. 27], any effort to integrate maintenance and production planning and control within ERP systems is lacking, at least to the knowledge of the authors.

Historically, there have been considerable efforts directed towards developing approaches that help increase machine availability by minimising downtime through more effective planning and control of maintenance operations [31], for example, Reliability centred maintenance (RCM) [28]; Total Productive Maintenance (TPM) [26]; and Risk-based maintenance (RBM) [15]. More recently, the concept of lean maintenance has become more popular [19, 35]. In order to support world-class manufacturing concepts such as lean manufacturing, several maintenance concepts have been developed. This has led to the concept World Class Maintenance (WCM) [29]. Similarly, the operations management community has also developed a variety of methods for improving manufacturing planning and control systems, such as the shift towards lean production [18, 38] and the onset of ERP systems [12, 13].

In fact, in both domains, issues of production modelling and maintenance modelling have experienced an evident success from both theoretical and applied viewpoints. However, paradoxically, the issue of combining and integrating production and maintenance plans has received much less attention [1]. For example, *"Relatively* *few models combine production and maintenance scheduling issues"* [34]. In fact, Al-Najjar [3] states that *"of 140 papers surveyed, only eight made any reference to the integration of the manufacturing planning and control system with maintenance planning. In computer integrated manufacture (CIM) "everything" is integrated except maintenance"*. Yokota [40] performs a case study that examines the maintenance of ERP systems in Japanese manufacturing firms. However, this study does not consider the issue of production planning and control. Thus, it also comes as no surprise that ERP solutions with generic functional applications do not provide the full range of functionalities required for the planning and scheduling of complex maintenance tasks. In particular, current ERP systems lack the functionality needed for simultaneous planning and execution of both production and maintenance operations, including a lack of integrated data structures. In other words, "*existing data structures are designed for supporting individual techniques to operate in standalone mode with limited capacity for interfacing and integration*" [31]. In some (or even most) cases, even local systems rarely exist which can provide the data needed for such integration of maintenance management and manufacturing planning and control [33].

Faced with unplanned downtime caused by a production line failure, a manufacturer's productivity is often significantly reduced, thus rendering the current production plan obsolete. The subsequent revision of the production plan in such an emergency situation is very expensive, and often has a detrimental knock-on effect on product quality and customer service level. [11] indicates that the common practice of making maintenance and production decisions separately can be rather costly and that there are significant benefits for making these decisions in an integrated fashion [8]. It is therefore essential that production planning and preventive maintenance activities are carried out in an integrated manner to hedge against such frequent yet avoidable failures and re-planning occurrences [2]. Though such integration is becoming an active area of research, it is frequently tackled solely at the operational (or scheduling) level. A case in point is exemplified in Malhotra et al. [21] where manufacturing planning and control is identified as both a strategic and tactical issue, yet maintenance is listed only as a tactical matter. On the other hand, [6] presents the maintenance management process as three tiers – Strategic (from business plan to maintenance plan); Tactical (from maintenance plan to task scheduling); and Operational (task completion and data recording). Such structuring can be likened to the three levels identified in the manufacturing planning and control (MPC) system framework of Vollmann et al. [37] - the strategic level of the planning system, which aligns the long term production plans with the overall business plan; the tactical level, which encompasses all decisions for detailed material and capacity planning; and finally, the operational level, which represents supplier systems and shopfloor systems (production activity control), and also includes performance measurement.

Though recent authors have developed models for integrating maintenance and production planning [e.g. 17, 39], such models have not been operationalized in practice [30]. Yao [39] contributes with knowledge for integrating preventive maintenance policies with shopfloor queuing systems in terms of production-inventory systems. The limitation of this contribution is that it deals mainly with scheduling issues for operational decisions, leaving out both tactical- and strategic level decisions. Kovács

[17] contributes with the integration of production planning and production scheduling. The limitation of this contribution is that only certain periods of planned maintenance are given, i.e. there is no real integration between maintenance planning and production planning.

3 Towards a Conceptual Framework for the Integration of Manufacturing- and Maintenance Planning and Control: Integrated Planning

Based on the previously described theoretical background and insights gained from our observations in practice, in this section we develop and propose a conceptual framework for the integration of manufacturing and maintenance planning and control, for which we use the term Integrated Planning (IPL). It has been shown in the extant literature that there is indeed a significant and positive indirect relationship between TPM and manufacturing performance through Just-in-Time (JIT), for example in the work of Mckone et al. [22]. Therefore, in developing such a framework for integrated manufacturing and maintenance planning and control, TPM from the maintenance domain and JIT and Lean production planning and control techniques from the production management literature could have been emphasised for application. However, when designing the roadmap to future maintenance it is not sufficient to solely implement TPM as a traditional concept for the business [32]. This view is also supported by Kodali et al. [16] where the shortcomings for TPM are elaborated. This leads then to the development of the world class maintenance (WCM) systems. Instead of relying purely on TPM, it is pivotal that the businesses can develop their own tailor-made WCM concept [32]. In order to belong to WCM it is important that the business develop and maintain future oriented tools such as Computerized Maintenance Management Systems (CMMS) with functions such as real time data input from assets and that this is integrated with other technical and business systems. Galar et al. [7] have proposed a future CMMS system and suggest that it be aligned with a performance measurement system such as that suggested by Muchiri et al. [24]. In this paper we have assessed current WCM-systems [e.g. 16, 23] and typical MPC system structures [37], and suggest integration as shown in Figure 1, which illustrates our conceptual framework for an Integrated Planning (IPL) system.

At the top level the business plan is outlined and consists of the production plan that delivers value for customers. This business plan is harmonized to both MPC and Maintenance Management. Functionality in the ERP system must ensure integration with both MPC system and Maintenance Management system. We also emphasise the importance of the performance measurement system in order to assess performance in line with the alignment of the business plan with integrated operations.

It is anticipated the realisation of such an integrated planning framework would enable manufacturers to gain improved performance, particularly in terms of world class maintenance and OEE. For example, in using a more contemporary advanced planning and scheduling (APS) system tightly coupled with the company's ERP system, a more accurate, integrated plan can be composed that makes important considerations

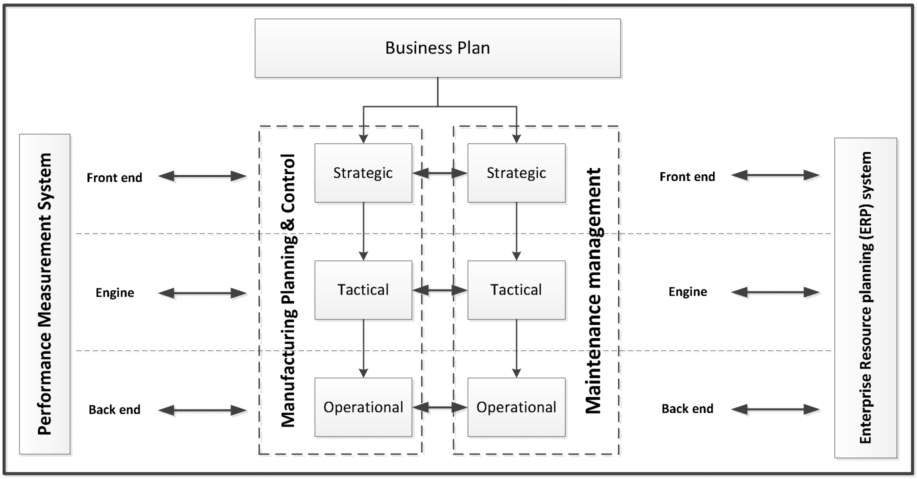

Fig. 1. Conceptual Framework for "Integrated Planning" – IPL

regarding the maintenance activities as well as enabling improved finite plans for production. In turn, this will also influence a shift in thinking towards value creation, making such a framework well aligned with lean principles.

4 Conclusion and Further Work

By combining relevant theory from two fundamental areas – production management and maintenance management – we have developed and proposed a conceptual framework for Integrated Planning (IPL). We position our contribution in Table 1, which has been adapted from Riezebos et al. [30] and Liyanage [20].

Table 1. Maintenance in a time perspective [adapted from 20, 30]

<1950	1950-1975	1975-2000	2000-2010	2010<
Manpower – Reactive; fix it when broken	Mechanisation – Preventive; Total productive maintenance	Automation – Proactive; Reliability-centred maintenance	Globalisation – Proactive; Risk-based maintenance	**Integration – Integrated; World Class Maintenance**
"Necessary evil"	"Technical speciality"	"Profit impact"	"Partnership"	**" Value-added "**

The table illustrates the shifting role of the maintenance function over time, for example from the 1950s when maintenance was viewed as a "necessary evil" and was very much performed on a reactive basis, through the more preventive and proactive approaches deployed during the 1970s and 1980s and the focus on risk at the turn of the millennium, to what we suggest as a more integrated approach in recent years. We believe that such an integrated approach will enable a greater focus on "value-added" as the maintenance planning and control tasks become even more tightly meshed with production planning and control.

Our conceptual framework should be used by researchers and practitioners to develop solutions that enable the systematic integration of "world class maintenance" planning and execution with "lean" production planning and control. We suggest that such integration will provide increased performance in terms of quality, cost and delivery metrics, and will generate enhanced competitive advantage of producers who are able to realise the integration of their critical operations.

In the mid-1990s, [33] pointed out that although computer-integrated manufacturing (CIM) systems encompassed the whole product cycle from design, through resource planning to manufacture, they did not encompass any maintenance. It was also stated that there exists a great gulf between the theoreticians and the practitioners which ensures that even the more practical operations research (OR) models are not widely applied. More than a decade later, Riezebos et al. [30] similarly identify a gap between the significant modelling efforts in theory (e.g. for the planning and control of preventive maintenance activities) and the limited application of such approaches in practice. Therefore, further work should address this gap. The existing efforts from OR should be developed into contemporary ERP modules to enable such integration of maintenance management into the manufacturing planning and control systems of today to become a reality.

In the future we intend to apply our conceptual framework to a number of case studies in order to gain important practical insight into the phenomenon of integrated planning. In gaining a better understanding of the practical challenges relating to the realisation of IPL, we will be in a better position to bring out the pertinent factors and implications for the design of a contemporary integrated production and maintenance planning system.

Also, though we have developed the IPL framework in the context of "land-based" production, due to the generalized and conceptual nature of our framework we anticipate that it could indeed be applied elsewhere, for example in the context of integrated operations in the petroleum industry, as the Integrated Operations (IO) Center is currently encouraging different disciplines and functions to shift from the traditional "silo" model to a more collaborative one [10].

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Set Based Concurrent Engineering Innovation Roadmap

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Abstract. SBCE (Set Based Concurrent Engineering) is an element of lean practice in product development (PD), and it composes theoretical principles to apply it at early phase of a design process. However, executing principles of SBCE in practice require extensive efforts. Thus, a systematic methodology is required to identify and priorities potential areas (product's subsystems, components, features) where SBCE brings its utmost benefits. This paper proposes such a methodology called SBCE Innovation Roadmap (SBCE IR) that is used as a guideline by product designers to begin SBCE processes. A case study on Adiabatic Humidification System (AHS) is discussed to elaborate the SBCE IR methodology. Furthermore, an experimental SBCE process has been conducted on rack subsystem that shows a significant cost reduction.

Keywords: Set Based Concurrent Engineering (SBCE), Theory of Inventive Problem Solving (TRIZ), Contradictions.

1 Introduction

The traditional approach to develop a product concept typically starts with breaking it into its subsystems, defining detail requirements for each module and deriving a small number of alternative solutions which appear to meet the initial requirements. Engineers then quickly assess the solutions and select one option to be pursued. This process however, rarely turns out to be linear in nature. Usually, engineers discover that the chosen design solution does not meet the requirements formulated at the onset and the choice may have resulted in a variety of adversities issues. A series of iterative loops follow to either modify the concept until it satisfies the requirements or start the process over by selecting a completely different design solution. Because of the iterative nature where engineers move from point to point in the realm of searching for feasible designs, this process has been termed Point Based Concurrent Engineering (PBCE) [1], [2].

SBCE is an alternative approach first used by Toyota [1]. It is started with dividing the product into small subsystems and modules, however, unlike in PBCE, no detailed requirements are defined for subsystems and engineers only identify broad targets for each module. Based on these targets, a much larger number of alternative solutions

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are developed early in the process. Then, designers test, analyze and build multiple solutions for every subsystem in parallel [3]. Unless designers have acquired sufficient knowledge through analysis, simulation, prototypes, and tests to eliminate an alternative, it will remain as a feasible design option. Finally, feasible design alternatives can be evaluated against objective criteria (cost, time, quality) for convergence.

Though the principles of SBCE are sound and the theoretical benefits are promising, there are fundamental impediments for its practical success. The following gaps are underlined in this paper.

- *SBCE is an extensive process*: - to conduct an SBCE process, designers should go through extensive phases such as exploring, communicating, testing, and converging sets. Doing all these requires considerable time, investment and capabilities. Thus, a systematic method is needed to identify and prioritize subsystems or components or design parameters a priori of pursuing such an extensive process. Otherwise, efforts made will be wasted without achieving value. This paper proposes such a methodology called SBCE IR that enables to breakdown design problems and derive rules for SBCE implementation.
- *The use of tradeoffs in SBCE*: - in extant literature, SBCE has strictly been related to use of trade-offs. Toyota, for example, reported to base on trade-off analyses for exploring, evaluating and communicating sets [2]. However, using trade-offs restricts the level of innovation. Altshuller, in his prominent theory of inventive problem solving (TRIZ), underscores the limitation of accepting trade-offs in design [4]. In TRIZ, trade-offs or compromises are not accepted, rather they are eliminated if innovative design solutions are sought to be discovered. Moreover, in practice, understanding design tradeoffs is often too complex. Thus, SBCE has to be discussed along with existing established theories of innovation both to simplify it and enhance innovation. If TRIZ is integrated with SBCE process, there will be significant methodological improvements in identifying potential areas for innovation. Moreover, the search efforts for new design solutions can be formalized. The proposed SBCE IR methodology integrates TRIZ and SBCE.
- *'Psychological inertia'*:- is another practical bottleneck for SBCE's success. It is a phenomenon in design practice, where designers often tend to explore solutions within known design spaces [5]. Thus, it often becomes unlikely for designers to observe 'out of the box' solutions. Although, the SBCE IR doesn't have a direct contribution to avoid the phenomena, it allows design problems to surface and TRIZ principles will help to explore innovative solutions.

In summary, the above gaps are important to address to make SBCE pragmatic. The contribution of this paper is to develop a systematic methodology that helps designers to identify and prioritize design problems for further SBCE implementation. In section 2, SBCE IR will be introduced. A case study on AHS is discussed in section 3. Section 4 is dedicated to briefly present the results obtained from an SBCE process on rack subsystem of AHS. Finally in section 5, conclusions of the paper and possible further researches needed are outlined.

2 SBCE IR

SBCE IR can be described as a step wise methodology that guides product developers to make rational choices to pursue SBCE processes at a sub-system or component levels. It will be used for matured products, and when developers need to identify and prioritize improvement areas. Six steps are needed to build it for a product.

Before going in detail on the steps, the assumptions and criteria taken for its construction are three: **(1)** *Identification of system contradictions lead to improvement areas:* the SBCE IR bases on identifying and overcoming contradictions for a product. Identifying system contradictions will instigate potential areas where SBCE can be executed (i.e. exploration, communication, testing and convergence) [4, 6]. There are two types of contradictions that need solutions, physical and technical. The former occurs when a product has a requirement that should exist in opposite states at the same time. The latter occurs when two different requirements cannot be achieved without one gets worse; **(2)** *Improvement areas should be prioritized based on customer value information,* it is not uncommon that designers spent considerable amount of their time developing features that the customers are not interested in [7, 8]. Thus, information on customer value is paramount to be integrated before starting on a particular SBCE process. Once contradictory requirements are identified, customers' judgment on importance can be used as one criterion to prioritize contradictions; **(3)** *Improvement areas should be prioritized based on competitive advantages*, while building the SBCE IR, competitor analyses are used as an additional criterion to prioritize contradictions (i.e. how important will solving a contradiction be for competitiveness?).

In sum, from the above discussions, it should be clear that SBCE IR is the identification, prioritization and mapping of contradictions (taking customer and competition as criteria). The steps (see also Figure 1) and the associated methods used to build SBCE IR are:

- Identify customer requirements and assign importance
- Assess competitors' products and set targets
- Identify system contradictions
- Identify dependent and independent contradictions
- Derive rules to prioritize and select contradictions, and
- Map contradictions to products' design factors[1].

The first step is to gather the right customer requirements, and assign the relative importance vector ($0 \leq W \leq 1$) using a pairwise comparison method of AHP (Analytical Hierarchical Process) [9]. For each requirement, in step 2, the performance level of the design will then be evaluated against those of competitors' products. Then, by setting the present and target values, each requirement will be assigned the degree of difficulties, $D \in \{0, 1, 2, 3\}$, where 0, 1, 2, 3 represent that a requirement is already

[1] Design factors can be defined as design variables that designers have the opportunity to change in SBCE process (e.g. material types, design configurations, number of components to use in a design, etc.)

achieved, easily achievable, moderately difficult to achieve, and difficult to achieve respectively [10]. Now each requirement has information related to customer importance (W) and competitive advantages (D). To set priorities P for requirements, an aggregation of (P = W X D) is used. If requirements are grouped based on categories (technical performance, cost, usability, etc.), they can be assigned ranks (R = 1, 2, 3…) within the respective categories according to their P values.

In the next steps 3 and 4, contradictory requirements will be identified and contradictions (T) can be defined. However, two contradictions can be either independent or dependent [11]. Two contradictions said independent if design solutions proposed to overcome one will not solve the contradiction in the other. Otherwise, they are dependent. Moreover, if solutions proposed to a contradiction potentially solve many other contradictions, then that will be considered as the root contradiction. In order to identify independent/dependent contradictions, a method called DEMATEL (Decision Making Trial and Evaluation Laboratory) is used [12]. It's aimed to find the direct/indirect relationships between variables (in this case contradictions), and use a matrix and causal diagram to express the casual relationships and influence level between variables in a complicated system.

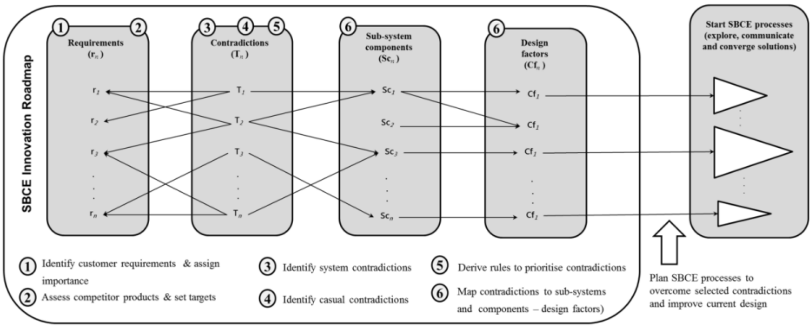

Fig. 1. Steps to build an SBCE IR for a product

Once the above steps are completed, rules to prioritize and select contradictions for further SBCE projects initiations will be the next step. In SBCE IR, three rules are identified: (**a**) rule of independent contradictions; select a dominating contradiction (**b**) rule of independent contradiction but tie; select based on experts' judgment; (**c**) rule of dependent contradictions, select the root contradiction. For example, assume three contradictions T1, T2, T3, with the ranks (R) of the corresponding contradictory requirements as (r_{up}, r_{down}) ~ (1, 2), (1, 4) and (2, 1) respectively. T_1 dominates T_2, but both T_1 & T_2 are in tie with T_3. Assuming all are independent, based on rule (a), designers should select T_1 over T_2 to initiate an SBCE project, but should impose judgment (other than customer importance and competitive advantage) to select either T_1 over T_3 or T_2 over T_3 (rule b). However, if for example in step 4, it is found that T_2 is the root contradiction for T_1 and T_3, then rule (c) is employed, and SBCE process should be initiated to search for sets of solutions to solve T_2, communicate and test the sets for convergence.

The final step to build SBCE IR is to map selected contradictions to product's design factors. This can be done by experienced engineers that can associate the inherent design factors that have to be improved to solve the selected contradictions.

The steps provide logical approach to arrive to prioritized areas where SBCE process should be initiated. Furthermore, it enables designers to think about solutions for smaller, focused and important design problems than doing random innovation. The next sections provide concise details on the case study conducted on the AHS, and some of the results obtained on SBCE process implementation on rack subsystem.

3 Case Study

The steps have been conducted in one of the AHS designed by Carel Industries (which is called HumiFog, [13]). The system has been in the market for the last 10 years and primarily used for industrial applications (such as hospitals, residential buildings, textile factories, paint shops in car industries, and so on). It's priced at 8,700 € and sold all over the world. The main function of the system is to control the temperature and humidity levels. The product is the state of the art among other systems in terms of energy savings. The working principle is based on spraying atomized water mists at a high pressure (around 70 bars). The basic sub-systems are three: *Cabinet* (C), used to protect main components such as PLC (programmable logic control), water filters, water pump, etc.; *Drop Separator* (DS), used to achieve a highly purified water content and contains components such as module separators, frame support, housing, etc.; *Rack* (R), used to spray water to an ambient, and includes components as modulating and drain valves, nozzles for spraying, frames for support, and manifolds to carry nozzles and transport water. The SBCE IR steps for AHS are:

- Step 1: the requirements are classified in two levels, macro and micro, see Figure 2. Within each macro-requirement there are associated micro-requirements. Five macro-requirements are identified: (1) Technical performance (P), which is related to the technical quality characteristics that the product should satisfy; (2) Usability (U), which is related to the product's simplicity during use; (3) Application (A), which is related to the flexibility of the system to be used in different applications (paint shop, data centers, hospitals, etc.); (4) Costs (C), aimed to reduce product and component costs; (5) Maintenance (M), to achieve easy repair of components and reduce the time between checkups. For each of the five macro-requirements, specific micro-requirements are defined. For P, U, A, C, and M, 11, 4, 5, 5, and 1 micro- requirements are identified respectively. For example, for usability (U): U1 (wide option range), wider operations during user-product interactions; U2 (fitting into customers sites); U3 (easy installation), reducing time to install at sites; U4 (friendly user interface). The designers conducted pairwise comparisons (1, 2…9) within the categorized requirements, and AHP method is used to determine the weight vectors. The global weights (GWs) of micro-requirements are obtained by multiplying the weights of each with the weights of the corresponding macro-requirements (see Figure 2).

- Step 2: four competitor products designed in Germany and Italy were evaluated for their performances. After the experts analyze the current HumiFog design with the competitors' designs for each customer requirement, they are assigned the degree of difficulties to fulfill the performance gaps identified (see Figure 2).
- Step 3/4: twenty three system contradictions are identified in the HumiFog system. Among which 22 are technical and 1 physical. For example, the contradiction T21 shown in Figure 2 is a physical contradiction between C5 (non-VDI requirement) with itself. The product has a European hygienic requirement called VDI 6022. However, once the company is expanding its business to different countries and sectors, VDI 6022 is not needed for some markets such as China or in some industrial applications (e.g. Tabaco industries). Thus, the contradiction type here is physical, where the product should stratify VDI 6022 requirement for some markets and applications, and in some others it is not necessary.

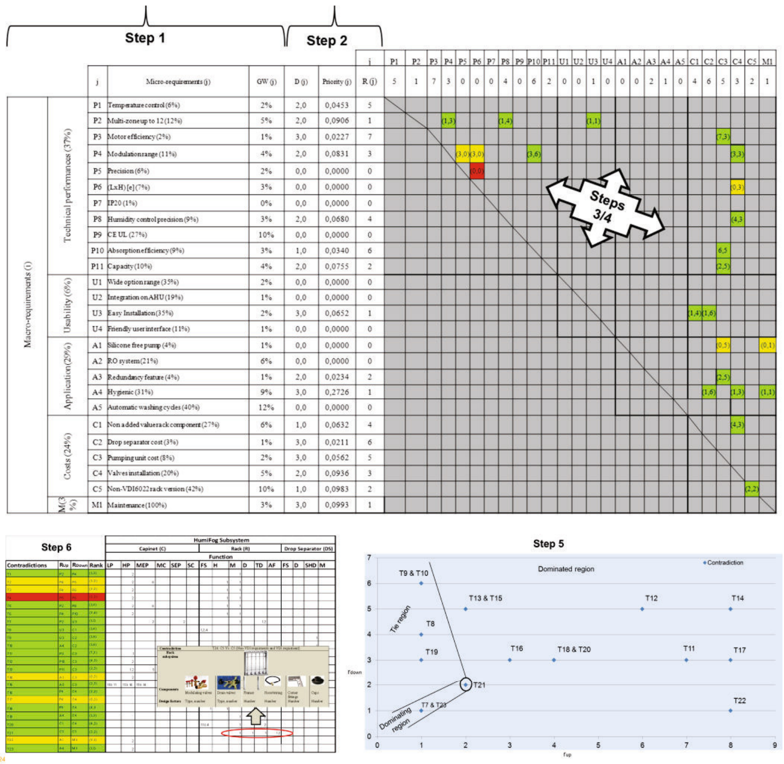

Fig. 2. Steps to build SBCE IR for HumiFog

- Step 5: based on the previous steps, ranking of independent contradictions can be made using the rules proposed in section 2. Looking at Figure 2, for example, T21 has dominated T13, 15, 16, 18, 20, 12, 11, 14, 17, 22, is in tie with T19, 8, 9, 10 and is dominated by contradictions T7 and T23. On the other hand, root contradictions can be considered as priorities in case of selecting dependent ones. Thus, designers can make rationale choices to pursue SBCE processes to solve selected contradictions.

- Step 6: once contradictions have been ranked and prioritized, designers can relate the selected contradictions with the associated physical design factors that need to be modified. For example, Figure 2 shows the design factors that have to be addressed to solve contradictions T21, the main subsystem that has to be modified is called rack, and its components design factors such as modulating valves (type and number), drain valves (type and number), the number of vertical frame needed, number of hoses needed, and number of corner fittings.

  To experiment one SBCE process taking a contradiction, T21 is taken as a pilot. Although, it is dominated by other contradictions (T7 and T23) and it is in tie with others, T21 is considered simple by the designers taking into account the research time frame available during the preparation of this paper. In the next section, the result obtained in the SBCE application to solve contradiction T21 is presented.

4 SBCE Process on Rack Subsystem

As mentioned before, T21 is a physical contradiction where the VDI hygienic requirement is needed for some market and not for others. However, there is a growing market base that is requesting cheaper system without having the requirement, and thus the current configuration is overly designed. TRIZ principle of separation [4 and 6] is used to provide two different platforms for the two markets. Then, the SBCE process begins to remove non-value adding features for the non-VDI customers.

The target subsystem is rack which is used as a structure to distribute highly pressured water to an ambient. During operating condition, highly pressurized water will be pumped from pumping unit (motor and pump). The solenoid valves (normally open) modulate the water flow to vertical manifolds. Since the desired pressure level in the rack increases step by step, the water passes through many manifolds and the modulating valves are connected by hoses. Nozzles are used to spray the pressured water (mist) to the ambient. Holes which are covered with cups are provided along the manifolds for cleaning purposes. Once the rack subsystem finishes its operation, water comes out of the rack through drain valves.

- *Concepts generation*: three brainstorming workshops have been conducted to generate solutions to the non-VDI customers. Four concepts have been proposed: (1) frameless rack (2) changing the solenoid drain valves to mechanical valves, (3) using one solenoid valve for two manifolds, and (4) reducing the number of holes/ cups on the manifolds. In the first concept, the metal frames (used to slide the rack from the AHU) in the current design are removed and will be welded. Since the non-VDI clients will not require cleaning operations the concept is valid and 10% material cost reduction can be obtained. In the second concept, the VDI requirement strictly dictates the valves to be stainless steel (13 €/piece), thanks to the separation of the markets, the drain valves used in the rack can be substituted with cheaper brass valves (5 €/piece), allowing 13 €/piece cost savings. Moreover, the current design embeds electrical control system (electrical wiring connected to valves) for precise water flow control, but the new design won't require the wiring systems, and thus cost reductions are possible. In the third concept, one modulating valve was dedicated to one manifold for higher hygienic quality water spray but the new design uses one valve for two manifolds. This concept allows number of valves to be reduced (20 € for every valve reduced). The last concept is to remove the holes and the cups used to cover the holes which have been added in the original design for frequent cleaning operations.

- *Concepts testing*: in SBCE process, testing concepts before detail design is paramount. It allows avoiding late design changes and helping to understand the limits of components to realize concepts. For example, mechanical brass valves from three suppliers were tested for concept 2. The nominal working pressure for drain valve is 70 bars, and any valve should withstand 10% more than the nominal. Moreover, the minimum pressure that any drain valve (which is normally open) will close should be investigated. If the minimum pressure that makes a valve to close is higher than 0.5 bars, there is the risk that the valve will not close when it is needed, and water kept draining. Once the components from three suppliers are tested, a supplier which passes both constraints will be chosen for bidding.
- *Concepts merging*: once concepts are generated and tested for constraints, the next step in SBCE process is convergence. In this particular case, the generated concepts can be merged to offer a high value rack platform for non-VDI customers. The new rack has 30% cost reduction compared to the original design which used to be overly designed for non-VDI clients. Thanks to the separation principle of TRIZ, it has been possible to eliminate non-value adding features from the current rack design. This new design has been taken as a project to be launched soon.

5 Conclusion and Future Research

The systematic methodology (SBCE IR) is proposed to identify and prioritize improvement areas where SBCE processes can be launched for matured products. It will help companies to avoid random approach to begin SBCE process and lead designers where innovation should take place to maximize customers' value. Moreover, the paper presents a case study on the AHS system (HumiFog) to validate the roadmap. Using it, the SBCE process on the rack subsystem to resolve contradiction T21 is discussed. The final result of 30% cost reduction is obtained by utilizing the SBCE IR, TRIZ principle of separation and followed by the SBCE process.

Some future researches can be identified. First, generating SBCE IR is time consuming; automating the steps will be next stage of the research. Second, the SBCE IR is based on evaluation of customer requirements, but in this type of market there are hierarchies of customers (contractors, installers, final customers) with different priorities for requirements. Finding ways to entertain in the best possible way the different customers in building the SBCE IR will be another possible research.

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Functional Requirements for a Collaborative Order Management Tool for Use in an Engineering Setting

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Abstract. When products are engineered to order, meeting customers' expectations requires efficient order management. Despite its importance, literature on order management in the engineer-to-order production situation is scarce. This paper contributes to filling this gap by presenting functional requirements for a collaborative order management tool for use in an engineering setting. The functional requirements were derived from theory and validated and expanded through interviews with two case companies. Feedback from the case companies supports the usefulness and validity of the proposed requirements.

Keywords: Order management, engineer-to-order, collaborative tool, functional requirements.

1 Introduction

In 1996, Lampel and Mintzberg [1] concluded on the basis of a comprehensive literature review that "we are in the midst of a fundamental technological change in manufacturing, communication, distribution and retailing – a virtual renaissance of customization" (p.28). Nearly a decade later Fredriksson and Gadde [2] found that more recent literature showed a continuance of the attention to customization, and argued that the increasing interest in customization could partly be explained by the fact that customers demand highly customized products and services, and partly by its marketing drive; it is claimed to improve the competitive position of the company.

A high degree of customization makes it increasingly difficult for an organization to collect, store and process the information describing customer orders [3]. This is the case when products are engineered to order; i.e. manufactured to meet a specific customer's needs by unique engineering or significant customization [4]. In this environment efficient order management is a prerequisite for meeting customers' expectations, and there is a need for information systems supporting the engineering organization throughout the whole order management process [5]. However, literature on order management in the engineer-to-order production situation is scarce and focuses mainly on production planning and control, due date setting and how tools developed for make-to-stock apply to order-driven production situations [6]. Little literature describing what kind of information is needed throughout different phases of the order management process, how it should be shared and by whom, has been

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identified. This paper contributes to filling this gap by presenting functional requirements for a collaborative order management tool for use in this setting.

The remainder of the paper is structured as follows: First, the research method is described. This is followed by a literature review, where functional requirements for a collaborative order management tool are derived from theory. Thereafter, two case companies are briefly presented together with their requirements for collaborative order management. Their requirements are then matched with the requirements derived from theory. Finally, conclusions including limitations and opportunities for further research are presented.

2 Research Method

When the research is of an exploratory nature and the researchers investigate contemporary events while being unable to manipulate behavioral events, Yin [7] proposes a case study research method. One weakness of building theory from cases is that the researcher is not able to raise the level of generalizability of the theory [8]. In this respect, evidence from multiple cases is generally considered more compelling than a single case study [7]. With these characteristics prevailing, it was decided to conduct a multiple case study of two rather different companies within the EU FP7 project LinkedDesign (Linked Knowledge in Manufacturing, Engineering and Design) consortium; an offshore design and engineering company and an automation systems manufacturer (these are described further in chapter 4). A semi-structured, focused interview was conducted with each of the companies – aiming to validate, refine and expand a list of functional requirements for a collaborative order management tool that were derived from theory. The interviews were transcribed and data from each company was sorted in four categories: main focus of order management in the company; current situation; tools used; and future needs and challenges of the company. Thereafter, the information was compared to the requirements derived from theory; allowing validation and concretization of the requirements.

The differing characteristics of the case companies forced the researchers to come up with rather general functional requirements for a platform facilitating collaborative order management. Consequently, the results from the research should prove valuable beyond the context within which they were created.

3 Literature Review

In engineering projects, products are manufactured by means of unique engineering design or substantial customization based on orders specifying what to produce and when it should be finished. Order management involves creating and maintaining this information about product specifications and the promised delivery dates [9]. It can be divided into two phases: order acquisition and - fulfillment [3]. The latter is sometimes used interchangeably with the overall term order management [10, 11]; however, as the two phases have different challenges [9] the distinction between order acquisition and order fulfillment is adopted in this paper.

Order Acquisition. In the order acquisition phase, the goal is to obtain an order whose terms are a consensus between the project organization and the customer, by eliciting customer needs and communicating available options [9]. In an engineering setting, this will typically happen through two succeeding stages: marketing and tendering. In the marketing stage, the decision of whether or not to respond to an invitation to tender is made based on customer requirements, commercial factors, the organization's ability to compete and the likelihood of success [12]. If the organization decides to respond to the invitation to tender, preliminary development of the conceptual design and definitions of major components and systems are conducted, including technical features, delivery terms, price and commercial terms [12].

Muntslag [13] makes a distinction between three types of order-dependent risks in engineer-to-order situations; *technical risk*, *time risk* and *financial risk*. Technical risk refers to the situation where a product cannot be technically produced, which necessarily leads to more product engineering and detailed design. Time risk is the risk of encountering a throughput time in engineering and manufacturing that is longer than what was estimated in the tendering stage, whereas financial risk is the risk of engineering and production being more costly than estimated in the tendering stage.

Order Fulfillment. Given that the order acquisition phase led to the generation of a customer order, the purpose of the order fulfillment phase is filling, delivering and servicing what is ordered within the agreed delivery date [11]. Possible activities carried out in this phase are order entry, routing, assembly and picking, shipping, installation, invoicing and collection [10]. The risks associated with order acquisition are inherited to the order fulfillment phase, where inaccurate estimates of product specifications and delivery due date may become evident.

The main challenge in the order fulfillment phase is to cope with occurring modifications to product specifications and delivery dates [9]. Such *change orders* are a common feature for engineer-to-order companies [14], and the capability to respond to these short term dynamics is a prerequisite for success in many engineering organizations [5]. Change orders are not always a disadvantage for the project; they may as well result in additional income, cost savings or performance improvements [15]. Further, not all change orders are initiated by the customer. It may also be engineering changes proposed by designers that need to be communicated to e.g. sales/marketing, production planning and the customer [16].

Collaborative Order Management. Managers often view order management as part of a firm's logistics function [11]. However, order management activities cut across several functions within a company as well as other supply chain actors [17], necessitating integration between them [11].

Coordination in the order management process often lacks due to differing objectives of sales and manufacturing [16, 18-20]; sales/marketing wish to maximize their number of orders received, adapting quickly to shifting market demand and cutting quotation prices and delivery times. Manufacturing, however, prefer a stable and smooth workload over time, to cut product-, overhead- and inventory costs [18]. Overcoming this type of sub-optimization through increased collaboration between the functions is likely to result in more realistic lead times quoted to the customer [21] and fewer production planning problems [19] as order-dependent risks incurred are eliminated, or at least severely reduced.

Technology Supporting Collaborative Order Management. Technology generally enables a higher degree of integration between various actors in the supply chain. Order management is now supported by technology that facilitates supply chain visibility [22] and eases sharing of information [23], e.g. about production/delivery schedules and order status for tracking/tracing [24]. IT systems, such as product configurators, ERP- and PLM systems may help ensure technical feasibility by formalizing the rules about how products can be configured and providing user interfaces that helps sales/marketing with translating customer requests into technical specifications together with estimating costs and delivery dates [9].

According to Hicks et al. [12] effective sharing of information "requires use of common databases that support tendering, design, procurement, and project management. This requires records of previous designs, standard components and subsystems, together with costing, planning, vendor performance and souring information" (p.189). It should be noted that information sharing is merely an enabler of coordination and planning in the supply chain; companies will have to develop the right capabilities to effectively utilize the shared information [24].

Based on literature, we propose the following requirements for a collaborative order management tool for use in an engineering setting (**Table 1**):

Table 1. Requirements derived from literature

	Requirements:	**Sources:**
Totality	Should support both order acquisition and order fulfillment activities	[3, 9-12]
External	Should facilitate information flowing between the market and the organization	[9, 12]
Internal	Should facilitate information flowing rapidly within the organization	[11, 17, 19, 21]
Reliability	Should address and mitigate technical, time and financial risk	[13]
Transparency	Should enable sharing of current order and production statuses as well as plans and forecasts for partners involved on a real-time basis	[22-24]
Simplicity	Should ease order management and minimize administrative time	[9]
Conformance	Should align customer requirements, finished product and delivery date	[9]
Flexibility	Should facilitate rapid handling of change orders	[5, 9, 14-16]
Compatibility	Should be compatible with existing technology	[12]
Repository	Should store records of previous designs, standard components and subsystems, costing, planning, vendor performance and sourcing information	[12]

4 Case Descriptions

A) Offshore Design and Engineering. The company is a leading global oil services company that provides engineering services, technologies, and products for the oil and gas industry. The company employs approximately 18 000 people in about 30 countries. The Engineering business area delivers engineering, procurement and project management services to clients in the oil and gas industry. Three representatives from the engineering unit were interviewed regarding support for collaboration in the company's supply chain. Table 2 below summarizes Company A's input to requirements for the order management process in the company.

Table 2. Company A's requirements for collaborative order management

Order acquisition	• Support risk identification *(Reliability)* • Support resource sharing internally, especially during front-end studies *(Internal)* • Communication of good solutions; lessons learned and experience *(Repository)*
Order fulfillment	• Collaboration support across multiple time zones. *(Internal, Transparency)* • Communication with sub-contractors and fabrication units *(External)* • Supply chain visibility; see status from fabrication *(Transparency, Simplicity)* • Timely detection of errors, reasons and context and the actions taken *(Flexibility)* • Share lessons learned from previous projects; reuse smart solutions *(Simplicity, Repository)*

B) Automation System Manufacturer. The company is a global supplier of industrial automation systems and service. They deliver robots and automated production lines to several industrial sectors, including automotive, aerospace, steel, transportation and energy. The company serves as a system integrator and offers complete engineering solutions, from product development to manufacturing and maintenance. In this work representatives from the Powertrain Machining & Assembly business unit were interviewed. Table 3 below summarizes Company B's input to requirements for the order management process in the company.

Table 3. Company B's requirements for collaborative order management

Order acquisition	• Understanding of the cost of delivering what the customer wants *(Conformance)* • A way to easily propose multiple solutions in the same proposal *(Simplicity)* • A way to include life cycle cost data in the proposal *(Repository)*
Order fulfillment	• Role based functionality with easy access to most used systems *(Compatibility)* • Transforming customer needs to requirements and costs *(External, Conformance)* • Frequent change orders, both from external customers and process improvements identified internally *(External, Internal, Flexibility)* • Support passing around change orders in the project between technical personnel and project managers before approval *(Internal, Flexibility)* • Records of how previous problems were resolved *(Repository)* • Possibility to search within knowledge history *(Repository)*

5 Functional Requirements

The cases made validation of the requirements derived from literature possible, and helped refine several of them – for example by stating actors involved and what information should be shared. By combining this information, the following functional requirements for a collaborative order management tool are proposed (Table 4).

Table 4. Functional requirements for a collaborative order management tool

Requirement	Description	Found in cases
Totality	Should support both order acquisition (marketing and tendering) and order fulfillment activities (order entry, routing, assembly and picking, shipping, installation, invoicing and collection)	(A, B)
External	Should facilitate information flowing from the market (subcontractors, customers, partners) to the organization, and vice versa	(A, B)
Internal	Should facilitate information flowing rapidly within the organization, e.g. access to domain experts and available resources	(A, B)
Reliability	Should address and mitigate technical, time and financial risk	(A)
Transparency	Should enable sharing of plans and forecasts, current orders and production status in real-time and across multiple time zones	(A)
Simplicity	Should ease order management and minimize the time used on administrative matters, e.g. by easily proposing multiple solutions in the same proposal	(A, B)
Conformance	Should support conformance between customer requirements, finished product and delivery date	(B)
Flexibility	Should facilitate rapid handling of change orders	(A, B)
Compatibility	Should be compatible with existing technology	(B)
Repository	Should store and facilitate searching in records of previous designs and solutions, standard components and subsystems, costing, planning, vendor performance and sourcing information.	(A, B)

6 Conclusion

This paper has presented functional requirements for a collaborative order management tool for use in an engineering setting. These were structured along ten dimensions: totality; external; internal; reliability; transparency; simplicity; conformance; flexibility; compatibility; and repository.

Feedback from the case companies supports the usefulness and validity of the proposed functional requirements. Some limitations still need to be mentioned. First, we acknowledge that more empirical validation is needed in order to generalize our findings. Based on our requirements, we have developed a series of mock-ups describing a possible collaborative order management tool. Further research should include prototyping a tool for collaborative order management based on these mock-ups, and validating this against more companies. Second, we do not claim to have a complete list of requirements for order management in an engineering setting. Other companies may require other functionality than we have presented here. However, basing the work on two specific use cases has made it possible to come up with requirements and design that can be directly relevant for the industrial partners and companies with similar characteristics, increasing the probability of improving their collaborative order management processes.

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Supporting Rapid Product Development with Sketch-Based Modeling

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Abstract. Nowaday, rapid product development (RPD) becomes a crucial approach for the success of a company in a competitive market when the complexity and diversity of products keep increasing while their lifetimes are getting shorter and shorter. Freehand sketch is a tool that is closer and more practical for customer to communicate his/her ideas to manufacturer. The sketch is typically transformed to be a 3D model for technologies such as rapid prototyping where a physical prototype is fabricated from a 3D model. Presented in this paper is a review of sketch-based modeling that allows customers-manufacturers to speed up the idea realization. Sketch-based modeling has been developed not only to transform a sketch to be a 3D model but also to interface with rapid prototyping.

Keywords: Rapid product development, Rapid prototyping, Paper-based overtraced freehand sketch, Single line drawing, Sketch-based modeling.

1 Introduction

Technologies and tools play significant role in easing the collaboration, and in helping members from different disciplines, who share their expertise to come up with a product, to stimulate and to rapidly realize their ideas. These cover from a basic tool such as a paper and pencil to recent technologies such as computer supported cooperative work or rapid prototyping. Five core technology areas supporting rapid product development are knowledge management, tele-engineering, man machine interface, rapid prototyping, and rapid tooling as shown in Fig. 1 [1].

A prototype is also necessary in product design and development for gaining design insight and for making communication more effective, and prototyping technologies help speed up the process. It can be manufactured quickly with rapid prototyping (RP) technology that allows designer-customer realize and experience their ideas quickly. In RP process, a physical prototype is constructed without using molds and dies. A 3D CAD model is translated into a stack of 2D contours which are used to

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generate machine commands for constructing a prototype layer by layer. Since commercial CAD software use different data formats, the created model will be converted first to a common format, called Stereolithographic (STL) file. The stack of contours representing constructed layers is obtained from slicing the STL model. Post processes may be required depended upon the selected RP technique. SLA, SLS, LOM, FDM and 3D printing are examples of commercially available RP systems. RP concept has been extended further to rapid tooling [2] and rapid manufacturing [3] for rapid creation of tools and of final products respectively.

Besides creating a 3D CAD model on commercial software, today's technologies makes it happens for the 3D CAD model to be created from its physical object as well as engineering drawing when they are available. Manufacturer can use reverse engineering, RE, to reconstruct a CAD model directly from a product that customer brings in. By coupling RE with RP its physical prototype can be delivered back to customer in a short period of time. Several researchers have tried to improve and to realign steps in both processes to make their direct integration work more effectively [4-5]. The similar idea has been extended to reconstruction of a physical prototype directly from orthographic views drawing, used universally for a long time for communicating designer's ideas to part manufacturing on a shop floor [6].

Another media that is closer and more practical for customer to communicate his/her ideas to manufacturer is a sketch. Freehand sketch is a quick rough drawing for portraying ideas, and commonly used during the conversation to help make ideas easier

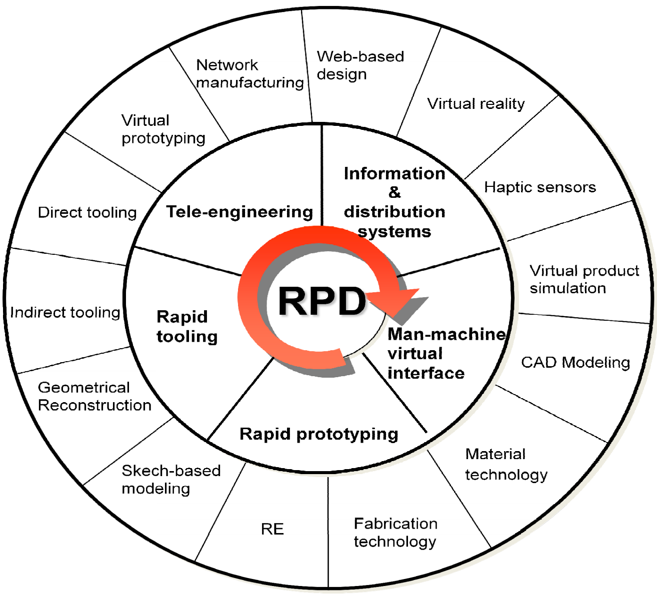

Fig. 1. Rapid product development (modified from [6])

to be understood. Furthermore, it is a good interactive media where participants can get involve making correction or revision by drawing together during discussion [7]. Since a freehand sketch is commonly found in practice, a success of its sketch-based modeling will open up several opportunities. It will ease communication and allow customer to visualize clearly the idea. Further extension to direct integrating with rapid prototyping will even make significant impact on product development. Several ideas can be realized and explored. Both customer and manufacturer can gain insight quickly not only from a virtual prototype but also a physical one. Product development time is foreseen to be shortened drastically. Presented in this paper is a review of sketch-based modeling that allows not only a 3D model to be reconstructed from a sketch but also a physical prototype to be fabricated from the 3D model directly to be realized rapidly. The next section presents sketch-based modeling, followed by interfacing sketch-based modeling with RP. The conclusion is addressed in the last section.

2 Sketch-Based Modeling

Sketch-based modeling, SBM, has been introduced for a CAD model reconstruction from a freehand sketch. Several approaches have been proposed and they can be classified into two main groups: evocative-based 3D modeling and constructive-based 3D modeling [8]. Based on prior knowledge, evocative-based modeling reconstructs a 3D model from a set of primitive objects or templates that is pre-registered in a database. A pattern of intended strokes is compared with registered patterns, and the information of the matched pattern is retrieved. Two main approaches for evocative-based 3D modeling are iconic [9], and template retrieval [10]. In case of constructive-based modeling, a 3D model is reconstructed systematically by applying visual rules on obtained sketch information. Two main approaches are optimization and progressive. For optimization approach, the depth information of an object is determined from an objective function that is constrained by geometrical regularity rules [11-13]. Instead of identifying 3D coordinates of all vertices simultaneously, the progressive approach determines the coordinates of the vertices in order by propagation [14-16].

Illustrated in Fig. 2 is the general constructive-based 3D modeling steps taken for 3D model reconstruction from a 2D freehand sketch that can be classified into four groups: a non-overtraced online freehand sketch, an overtraced online freehand sketch, a non-overtraced offline freehand sketch, and an overtraced offline freehand sketch. Typically, a sketch is converted to be a single-line drawing which can be considered as the projected image of a 3D object on a plane from where junction points, segments and junction loops can be extracted, and used to determine vertices, edges and faces for recreation of the model in a 3D space. The 3D model is then reconstructed after 3D coordinates of all vertices become available. The details are presented in the following subsections.

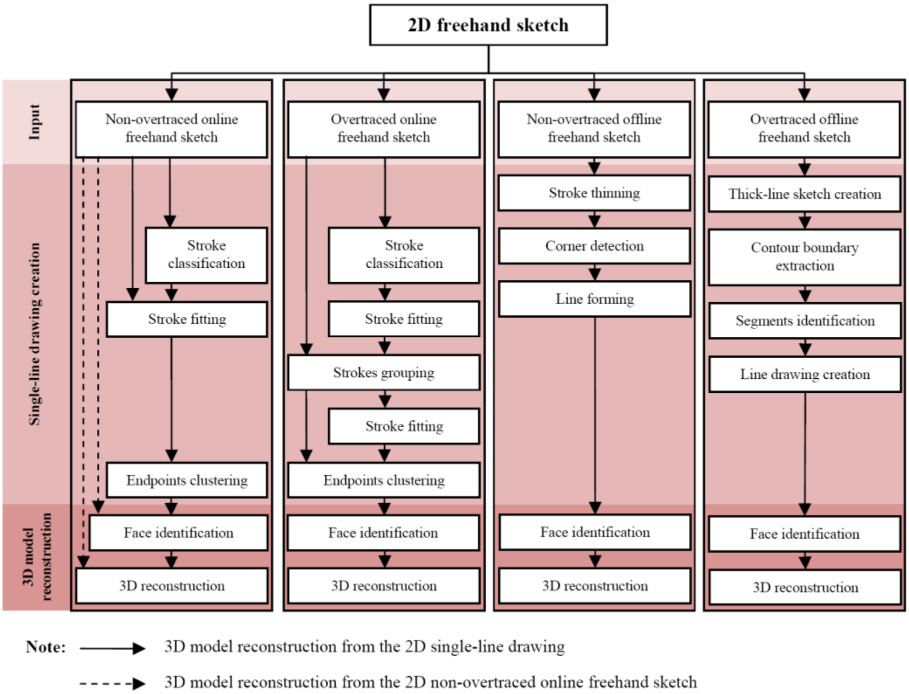

Fig. 2. Overview for constructive-based 3D modeling process from 2D freehand sketch (modified from [21])

2.1 Single-Line Drawing Creation

As aforementioned, besides Kang et al. [12] and Masry et al. [13] that construct a 3D model directly from a 2D non-overtraced online sketch, most of the constructive-based modeling techniques start with creating a single-line drawing from a sketch. In case of a non-overtraced online sketch, obtaining a single-line drawing is considered to be the simplest one as each stroke represents a segment on an intended sketch, and stroke information, including their two endpoints, is available for all strokes [17]. Usually, these strokes are beautified before their endpoints are connected to form a single-line drawing. In case of an overtraced online sketch that the data on each stroke are arranged in order while the entire set of data representing overlapping strokes is unordered, additional steps are required to group overtraced strokes and to determine their representatives [15]. In case of a non-overtraced offline sketch that data are available as a batch of point in a scanned sketch image from which these points represent closed contours of single solid lines, they must be extracted before their endpoints are linked to form a single-line drawing [18-20]. In case of an overtraced freehand sketch, Chansri and Koomsap [21] have recently introduced an approach on identifying a single-line drawing from a paper-based overtraced freehand sketch. In their approach, image processing techniques have been applied to cluster strokes to form a thick-line sketch. Contour expanding and shrinking concept has been applied in this approach for identifying segments from every pair of extracted contours that are said to be neighbor. A single-line drawing is created after all junctions are identified.

2.2 3D Model Reconstruction

In this step, faces are identified from the obtained single-line drawing. Line labeling is a popular technique that works well for identifying faces from a single-line drawing with hidden lines free where all identified non-self-intersecting closed loops represent actual faces [14, 18]. Line labeling, however, may not be appropriate for a wire-frame drawing that some of non-self-intersecting closed loops do not represent actual faces. Possible faces that are checked for their coexisting have been introduced to identify actual faces on the wireframe drawing [11, 22]. Besides, there is an attempt to identify faces from a 2D freehand sketch directly [23]. After all faces are obtained, the 3D model is reconstructed by using one of the two approaches as mentioned earlier.

3 Rapid Prototyping and Its Interfacing with Sketch-Based Modeling

Reverse engineering and sketch-based modeling are in common that they all give a 3D CAD model as an output, which can be an input for rapid prototyping. Their direct integration with RP will allow quick creation of a physical prototype from its physical object and freehand sketch. However, attempts toward rapid prototyping have been different. Fig.3 illustrates existing links between RE and SBM with RP.

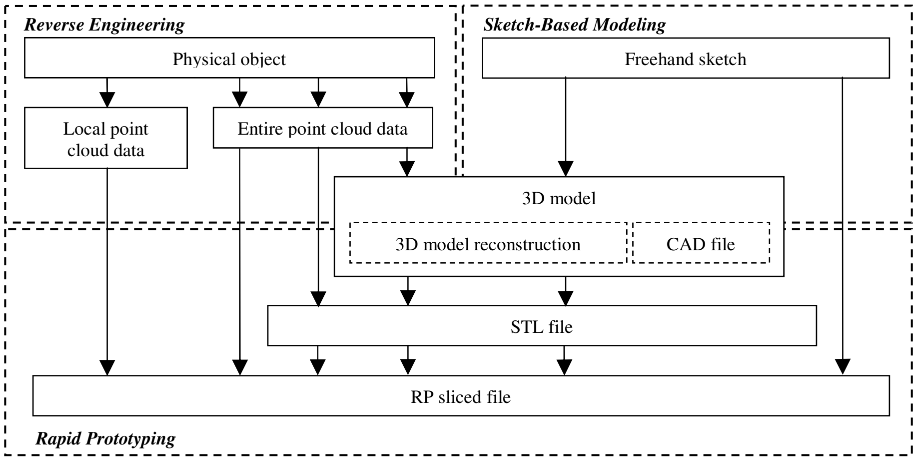

Fig. 3. RE-RP interface and SBM-RP interface

For reverse engineering, research is not limited to 3D CAD model reconstruction. Several researchers have tried to strengthen and make a connection between RE and RP more effective. It can be classified into four approaches. The first approach is commonly found in practice. Point cloud data are acquired from an object and gone through regular RE process to reconstruct a 3D CAD model. The obtained model is then fed into RP process. However because surface reconstruction consumes 90-95% of the RE processing time comparing to 5-10% of that for digitizing physical prototype [24], it is skipped in the second approach where an STL file is created directly from the point cloud [25]. Inherent errors from STL conversion process have inspired the third approach where commands are generated directly from the point cloud [4]. For these three approaches, however, the entire surface data come in a large batch with data redundancy that need to be removed to simplify subsequent operations. Selective data acquisition has been introduced as an alternative for direct interfacing RE with RP [26]. Instead of acquiring entire point cloud data, it scans an object selectively from the bottom up according to the complexity of the object. The scanning result appears as a stack of contours which can be directly used to generate machine commands.

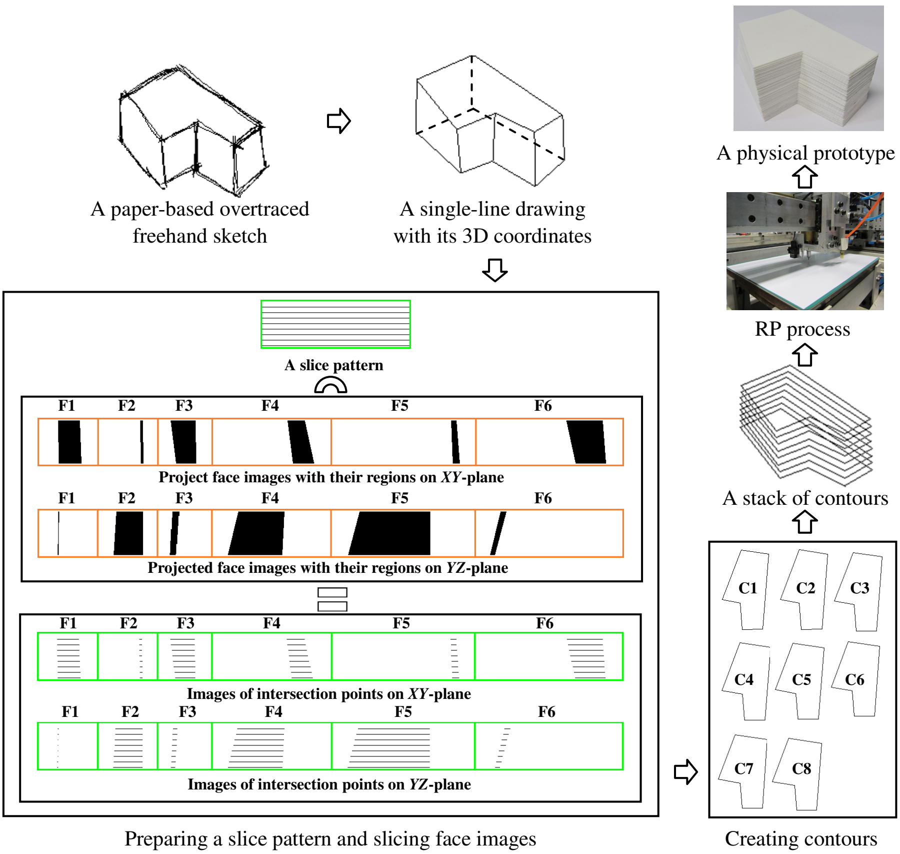

Fig. 4. Overview of direct interfacing sketch-based modeling with rapid prototyping

Similar concept has been applied to create direct integration between sketch-based modeling and rapid prototyping, instead of leaving a sketch-based modeling be a stand-alone technology. Recently, image-based direct slicing has been introduced as a first attempt for direct interfacing sketch-based modeling with RP [27]. This approach composes of three main steps: preparing a slice pattern, slicing face images, and constructing a stack of contours. The input to this approach is an isometric single-line drawing and its projected face images on the vertical principal planes. The process starts with projecting all faces obtained during identifying the 3D coordinates of vertices [16] on their principal vertical planes where uniform direct slicing is conducted layer by layer simultaneously on these planes. Segments, obtained from the faces, are connected to form a closed contour for each layer. The output is a stack of closed contours that will be used to generate commands directly for RP fabrication process. Fig. 4 illustrates the overview of direct interfacing sketch-based modeling with rapid prototyping.

4 Conclusions

This paper presents a review of sketch-based modeling to support rapid product development. Sketch-based modeling has been developed that allows a 3D model to be reconstructed from a sketch and a physical prototype to be fabricated from a 3D model. However, except for using pre-defined information as in evocative-based 3D modeling approrach, sketch-based modeling is limited to an object that composes of only planar surfaces. The contours generation for rapid prototyping needs further study to handle the object with curve surfaces.

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Lean and Automate Manufacturing and Logistics

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Abstract. This paper presents the Lean and Automate method on how to streamline and automate simultaneously the production and logistics processes in order to improve quality, reduce waste, and increase agility using Lean Six Sigma with the support of some advanced technologies. The approach is based on research which showed that for the best application of Lean Six Sigma to production and logistics, the new processes should be improved taking into account also the possible use of advanced automation. The case studies provide good practical examples of the applications and implications of advanced technology in production, with theoretically grounded insights. The findings suggest that Lean and Automate could be a key enabler of Lean Six Sigma in the manufacturing organizations.

Keywords: Lean Six Sigma, Production, Logistics, Automation, ICT.

1 Introduction

The economic crisis has pushed the organizations to become more agile and leaner, in order to adapt rapidly to changing socio-economic conditions. The re-engineering of production and logistics processes must take into account this imperative. Lean Six Sigma combines the better of two distinct methods [1]: Six Sigma, which helps in reducing the number of defects and the variation of the outputs, and Lean Thinking which helps in reducing the cycle times. A certain number of organizations have achieved excellent results by the use of these methods in different fields. There is another extremely important aspect in the optimization of the processes not included in this approach, which is the flexible integration of the processes and their activities. The lean approach includes the principle of flow. The recipe to achieve flow is to balance the work in the process. This approach often assumes a constant production. It becomes a hard coded integration.

Lean and Automate aims at the same time to streamline and automate the production and logistics processes and make them agile and lean at the same time. Out of a long experience in different types of organizations and several research works in production and logistics process design and management and tools and digitization techniques [2], this approach shows clearly the sequence of activities to integrate the methods of business process improvement and automation in any production and logistics organization.

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2 Literature Review

Lean Six Sigma includes a set of principles and tools that assist in the identification and steady elimination of waste (*Muda*) and the reduction of defects and variability in the output of a process Quality and costs in production and logistics are strategic elements [1], Flexibility is paramount in modern times. There is the need to use in the world of production and logistics the flexible automation technologies, now more and more available at lower costs, applying them to re-engineered processes.

Lean Six Sigma implementations provide several benefits, among them: cost reduction, productivity increase, quality improvement, lead time reduction, supplies reduction, and customer satisfaction improvement. Lean Thinking has been applied in the production context through Lean Production studies, However, these studies do not take into account new technologies more and more available. Actually, Sugimori *et al.* argued that the use of the automation for production introduces unnecessary costs, overproduction, and uncertainty [3]. This theory contrasted with the trends since the 80's, when the interest on MRP and ERP systems, numerical control machines, and fully-automated production lines has been huge. The highly automated organizations were less vulnerable to the typical problems of manual work. However, there were examples of over-investment in automation that have worsened the flexibility and the ability to respond to the demand changes (General Motors in the'80s; CIM),

The automation alone to improve performance remains uncertain [4]. This is the reason why the automation must be flexible and connected with an improvement in the processes. Powell and Skjelstad [5] applied a specific sensor technique (RFID) to the manufacturing processes. They presented a method and two business cases which proved the usefulness of this type of advanced technology in manufacturing companies.

This paper is a descriptive study [6]. Inductive reasoning is used to propose a conceptual framework for the use of advanced technology as an enabler in the development and further support of the Lean Six Sigma approach. The primary research method deployed is multiple case study research. The scientific foundation for the research is the literature from the production and logistics management with a focus upon the advanced automation technologies [7] and [1].

3 The Lean and Automate Method

The Lean and Automate method can be divided into six macro phases and 20+1 micro phases (see Fig. 1)[1]. The 21st phase is optional.

Macro Phase 0: Preliminary

- Context: Identify the requests of the stakeholders and the EHS;
- Culture: Detect the culture of the organization and of the community;
- Vision: Tackle the effectiveness, efficiency, economy, quality, and flexibility;
- Strategy: Define the processes to be improved and the plans;

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[1] This is a modified version of the Lean and Digitize method presented in [1] to take into account the peculiarities of the manufacturing environment.

Macro Phase 1: Define and Measure

- Kick-off: Launch the project and notify the stakeholders;
- Governance: Define who and how should manage the project; set up the Team;
- Voice of the Customer: Listen to the Voice of the Customers (Voc);
- Metrics: Translate the VoC in Critical-to-Quality (CtQ) factors;
- As-Is: Map the existing process;

Macro Phase 2: Analyze and Process Design

- Lean: Define how to improve the process during workshops;
- Kaizen Plan: Define the improvement intervention plan.

Macro Phase 3: Architecture Design

- Architecture Design: Define the process and the automation architecture;

Macro Phase 4: Build, Test and Deploy

- Build and Test: Implement and test the chosen solution;
- Change management: Manage the transformation;
- Deploy: Implement the chosen solution;
- Documentation: Issue/update the documents of the new automated processes;

Macro Phase 5: Verify

- Verify: Control the improvements,
- Benefits: Assess the external and internal benefits;
- Lessons Learned: Learn from the initiative;
- Celebration: Acknowledge the team's work;

Optional Macro Phase 6: Replicate in Similar Situations

- Rollout: Replicate the solution to the different departments.

For the purpose of continuous improvement, once the project is completed, one must use DMAIC. which typically leads to the need of a technological change.

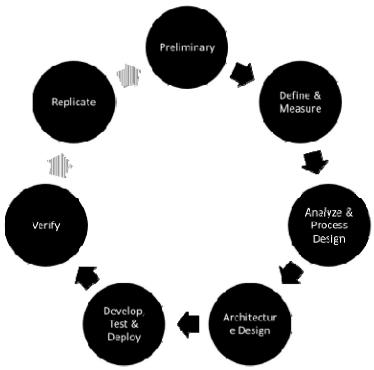

Fig. 1. The Lean and Automate Method

The organizations must treat the initial Lean and Automate project as the beginning of an iterative cycle that generates continuous improvement. Process improvement should not be triggered by a problem, but be part of the organizational culture.

4 The Changing Environment

A research on the trends in production showed that one of the most relevant aspects for improvement is the technological optimization of processes[2]. Modern technologies improve the efficiency of processes. The manufacturers will buy more and more equipment to save costs and optimize business processes.

We state that it is important to move from the automation of machines to the automation of processes. Machining centers are sophisticated Computer Numerically Controlled machines that can perform milling, drilling, tapping, and boring operations at the same location with a variety of tools. They are still isolated. An important development is to automate the full process rather than just one of its components. In order to reach this goal, it is essential to integrate different machines or entire sectors of the production cycles. This paper concentrates on an architecture based on four technologies that can help on this respect: The Internet of Things (IoT), Sensor technologies, either with bar codes or RFID; Big Data; and Business process intelligence.

The following sections define each one of these technologies and analyze each one of them and their possible contribution to process improvement. Their implementation should be done according to several generations, implementing one technology at a time and using some generalized middleware for managing interfaces in a more standardized way[3].

4.1 IoT

Internet of Things (IoT), also called Machine to Machine (M2M), refers to technologies that allow both wireless and wired systems to communicate with other devices. Such communication can be accomplished by having a remote network of machines relay information back to a central hub for analysis. Normally, a multi-tier architecture is used to exchange information at lower levels

IoT when combined with Internet and with cloud computing is an excellent way to add flexibility and investment saving to the collaboration also with vendors [8]. A variation to IoT is to use a ZigBee network.

4.2 RFID

Radio-frequency identification (RFID) is the use of a wireless non-contact system allowing radio-frequency electromagnetic fields to transfer data from a tag attached to an object. The purpose is automatic identification, possible storing of data, and

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[2] http://en.wikipedia.org/wiki/Productivity_improving_technologies_(historical)

[3] One example of standard for interfaces is for instance XLM and OAGIS, as powered by OAGi (http://www.oagi.org/dnn2/, accessed 10 March 2013).

tracking. Unlike a bar code, the tag does not need to be within line of sight of the reader. It may be embedded in the tracked object. An RFID tag attached to a product during its manufacturing can be used to track its progress through the production line. In the last few years, three key factors drove a significant increase in RFID usage: decreased cost of equipment and tags, increased performance to a reliability of 99.9%, and improved international standards [9].

4.3 Big Data

Big Data is a collection of data characterized by high volume, variety (structured and unstructured) , and velocity (in terms of speed of access) so complex that it becomes difficult to process using traditional database management tools or data processing applications.

Data sets grow in size in part because they are increasingly being gathered by information-sensing mobile devices, aerial sensory technologies (remote sensing, for instance RFID), software logs, video, cameras, microphones, radio-frequency identification readers, and wireless sensor networks.

4.4 Business Process Intelligence

Business Process Intelligence (BPI) is an innovative approach focused not only on measuring and reporting but also on managing the processes. through their data and workflows, differently to traditional Business Intelligence.

BPI supports also analytics, with production of statistics, reports, and dashboards. They allow a better visibility of the processes. For example in the case of production, the analytics tools allow analyzing the KPI and help take actions.

4.5 Flexible Integration Technology

As sensor technology and network technology develop, a computer system (or a machine) is becoming able to collect information about the real world by communicating with other machines without any help from human beings. In conventional IoT systems, servers for collecting and analyzing information from machines were developed individually. Now, virtualization and cloud technologies have enabled the IoT cloud or ZigBee network, in which all the functions such as communication with various devices and the collection, storage, and use of Big Data and BPI can be managed centrally. These clouds have the following features:

(1) Data collection and storage: An IoT cloud can communicate with any devices, collecting, storing data, and managing devices. A combination of multiple data sources can be analyzed easily thanks to a large amount of information available;
(2) Data analysis: The Big Data allows performing statistical calculations;
(3) BPI can operationalize the decisions in a flexible way.

An example of the integrated solutions can be the use of a e-Kanban to replace the Kanban cards with RFID tags. This allows to fully automating the 'identification' of the status of the processes, with greater reliability and without operator intervention [10] and [11]. E-Kanban can reduce the levels of inventories of work in progress (WIP), maintain tight control, and integrate with suppliers.

Another application is to use automated sensors, wireless networks and Big Data to update digital billboards. This allows organizations to implement what is called Andon and allows quick changes for messages [1]. The system may include the stop of production so the issue can be corrected. Some modern alert systems incorporate audio alarms, text, or other displays.

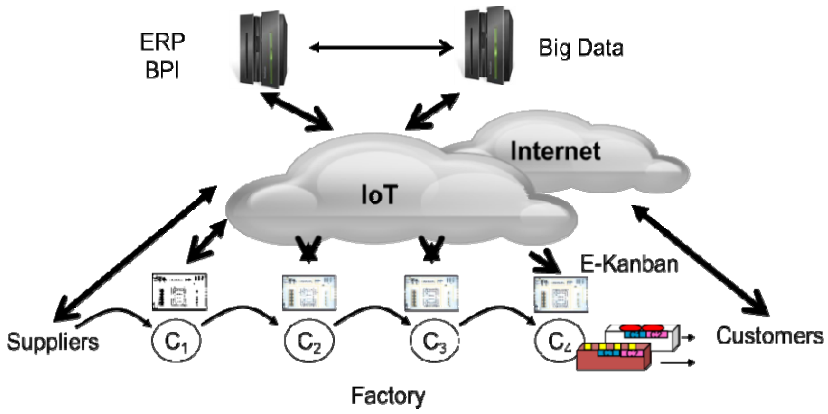

Fig. 2. The Final Architecture

The final architecture is shown in Fig. 2. It takes time to build. It is important to have the vision of where one want to arrive and then build in a multi-generation plan. Each generation will bring substantial benefits *per se*. The final generation brings all the components together and reaps the synergies.

5 The Support of New Technologies to the Lean and Automation Method

This architecture allows reaping the benefits of flexible integration. IoT, RFID, Big Data, and Business Process Intelligence introduce additional benefits *per se*.

- RFID can bring the benefits of automatic sensing in processes.
- IoT can improve the flexible integration of the activities in the value stream;
- Big Data can help in making the flow pulled by the customers, by allowing adding an intelligence of the demand of the customer;
- BPI can bring the benefits of the combination of Business Intelligence and the management of process workflows.

All together these technologies and the improvement of processes can add value thanks to their characteristics: Traceability, Visibility, Memory, and Positioning/ localization. Lean and Automate can improve these macro-phases of the Lean Six Sigma approach:

- Define and Measure, and Verify:
  - o Managing the life cycle of the components (that is tools);
  - o Compliance;

  - Plan of routine and non-routine maintenance;
  - Identify problems related to specific lots and take immediate maintenance actions;
  - Improvements in production due to an immediate measure;
  - Source of statistical data for the definition of process improvement and analysis of materials;
  - Identification and status changes on a component;
  - Paper savings.
- Analyze and Process Design:
  - Improved security by storing the relative weights, needs qualification, requirements of Quality Assurance, and so on;
  - Configuration management;
  - Improved communication of critical data.

The new architecture can help especially in reducing some of the seven wastes, listed in Lean Six Sigma, such as waiting time, by the improvements in search times, waiting, and movements; reduction in repairs/errors/faults, thanks to the identification of non-standard components, any failure or theft, and help in the analysis of the root causes; reduction in stocks, by the identification of components not good to be phased out.

6 Case Studies

In order to explore the practical relevance of Lean and Automate, we report a summary of two case studies, which compare the situations where advanced technology is used versus when it is not used [12]. In both cases, engineering manufacturing companies were considered with each job being different from another one, each one with either one or few items. The products were dies for aluminum extrusion. In both cases, we analyzed the management of a tool inventory with 2500 tools for ten work stations for the processing and production of hot channels for plastic materials. In one of the companies, RFID tags were applied to the tool holder cone on machining centers. BPI software was used to analyze and manage processes.

The possible inefficiencies in the tool management on the side of the machines are their possible damage, the times for the data entry and setting up the tools.

The possible inefficiencies on the side of the tools are the times to find the suitable tool, the reduction in the useful life of the tools, oversizing of the tool inventory, improper choice of the tools, and loss of historical information.

The advanced technology can impact on all the inefficiencies listed above. Quantitative benefits are the savings and the improvement in the Overall Equipment Effectiveness – OEE, a hierarchy of metrics to evaluate how effectively a manufacturing operation is utilized [13]. OEE is based on three separate but measurable components: Availability, Performance, and Quality.

Leaving aside the details of the two cases, the use of advanced technology brought the reduction in the number of tools in the inventory, in the unscheduled events and errors in the data entry; the possibility of implementing policies of tool sharing among the machines; the choice of the right tools: the reduction in the machine downtime doing in parallel the operations and the search of the right tools, the reading of the part program and the presetting. From a quantitative point of view, the advanced technology brought an increase in the average value of the OEE per each machining center of 27% [12].

7 Conclusions

Lean and Automate responds to the lack in the literature of a consistent method that manages and integrates the classical activities of streamlining production and logistics processes with the activities of flexible automation. Our research implies:

Proposition 1: Unlike the traditional production and logistics context, where the Lean Six Sigma method requires a reduction of digitization, automation is essential for the improvement of the processes, especially to make them flexible;

Proposition 2: Automate a process not streamlined is counterproductive.

The practical examples in this paper represent a starting point for the application of advanced automation to enable the deployment of Lean and Automate throughout the manufacturing and logistics processes. More examples are necessary. Further research should investigate the applicability of advanced technology for the optimization of fields such as production scheduling by using real-time information

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Proposal of an Interoperability Standard Supporting PLM and Knowledge Sharing

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Abstract. This paper presents an overview of the proposed QLM standard under development within the QLM Work Group of The Open Group. QLM aims to become a reference set of standards to be used to provide and exchange information between "intelligent" products and other systems. A part explains an introduction to QLM, the paper presents also an application scenario where QLM standards are already used in industrial practice.

Keywords: QLM, Product Lifecycle Knowledge, PLM standard, IoT standard, Open standard, Intelligent Product.

1 Introduction

The Quantum Lifecycle Management (QLM) is the name of a Work Group of The Open Group where Work Group members work to establish open, vendor-neutral IT standards and certifications in a variety of subject areas critical to the enterprise.[1] In particular, the QLM Work Group provides the framework to develop and consolidate open standards necessary to enable lifecycle management to evolve beyond the traditional limits of Product Lifecycle Management (PLM).[2] QLM aims to support the "Internet of Things" (IoT) paradigm, pushing it to achieve a business impact next to Internet. The IoT tends to be defined in different ways by different people. The QLM definition is based on an IoT where products can have many degrees of "intelligence", from barcodes or RFID tags that have only an identifier to smart houses, vehicles and other products that have advanced sensing and actuating capabilities, as well as powerful processing, memory and communication capabilities [1].

[1] http://www.opengroup.org/
[2] http://www.opengroup.org/getinvolved/workgroups/qlm

V. Prabhu, M. Taisch, and D. Kiritsis (Eds.): APMS 2013, Part II, IFIP AICT 415, pp. 286–293, 2013.

The QLM initiative comes from past research activities and the EU PROMISE Project where a preliminary way to exchange data between intelligent products has been developed [2-5]. Actually there are three QLM standards: Messaging Interface (MI), Data Model (DM) and Data Format (DF). The Messaging Interface allows to create ad hoc information flows between different products and systems. It is used for transmitting lifecycle related information mainly intended for automated processing by information systems. The Data Model identifies different information to collect during the product life, grouping them in logical classes with appropriate relations, cardinalities and links. The Data Format defines the structure of the message exchanged by different products and systems.

Communication between different systems, products or combination of both will follows a “peer-to-peer” model, the header and the footer of the message will contain the MI specifications while the content of the message will follow the DF structure while DM structure could be used to collect automatically the message. These there standards can be managed easily together, however although each of them can also be used also as independently from the others. QLM is of interest to business leaders, system planners, and technology providers seeking to manage dispersed lifecycle information from disparate physical and technology objects that transcend enterprise boundaries [6].

2 QLM Work Group Standards

2.1 QLM Messaging Interface

The QLM connectivity model is similar to that of the Internet itself. Where the Internet uses the HTTP protocol for transmitting HTML-coded information mainly intended for human users, QLM uses the QLM Messaging Interface (MI) for transmitting XML-coded information mainly intended for automated processing by information systems. The MI provides a flexible interface for making and responding to requests for instance-specific information. A defining characteristic of the MI is that nodes do not have predefined roles, as it follows a “peer-to-peer” communications model. This means that products can communicate directly with each other or with back-end servers, but the MI can also be used for server-to-server information exchange of sensor data, events, and other information. The MI allows one-off or standing information request subscriptions to be made. Subscriptions can be made for receiving updates at regular intervals or on an event basis – when the value or status changes for the information subscribed to. The MI also supports read and write operations of the value of information items. The following xml code shows an example of an MI response after to a request of for information. The parts of code between brackets with the acronym qlm represent elements of the MI while the parts with the term pmi represent the message (or payload) exchanged with a structure different from the QLM Data Format.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<qlm:qlmEnvelope
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:qlm="QLM_mi.xsd" xmlns:pmi="pmi.xsd"
xsi:schemaLocation="QLM_mi.xsd QLM_mi.xsd pmi.xsd
pmi.xsd" version="0.2" ttl="10">
<qlm:response>
<qlm:result format="pmi.xsd">
  <qlm:return returnCode="200"></qlm:return>
  <qlm:requestId>REQ654534</qlm:requestId>
  <qlm:msg>
    <pmi:targetList>
    <pmi:target>
    <pmi:id>AutomaticLine22334411</pmi:id>
    <pmi:infoItemList>
    <pmi:infoItem>
    <pmi:id>FailureRate</pmi:id>
    <pmi:value>
    <pmi:int>0</pmi:int>
    </pmi:value>
    </pmi:infoItem>
    </pmi:infoItemList>
    </pmi:target>
    </pmi:targetList>
  </qlm:msg>
</qlm:result>
</qlm:response>
</qlm:qlmEnvelope>
```


[Example of QLM Messaging Interface Response XML code]

2.2 QLM Data Model

The QLM Data Model (DM) was initially conceived as the basis for the information model for the Product Data Knowledge Management/Decision Support System (PDKM/DSS), one of the most important components of the overall PLM system developed by the former EU PROMISE Project.

It enabled detailed information about each instance of a product to be enriched with “field data”; i.e., detailed information about the usage and changes to each instance during its life. It also allowed the aggregation of instance-specific data from many different software systems; e.g., CAD, CRM, and/or SCM and other legacy systems as part of a company’s IT infrastructure in order to allow specific decision support information to be generated and made available through the PDKM system.

DM is represented by different classes of information to individuate activities, processes, resources, documents, field data and other aspects through the whole product life. Each class contains dedicated attributes to explain information suggested to collect different information about product. Fig. 1 shows classes, attributes and relations of the DM objects. Specifications of the model will be presented in further works.

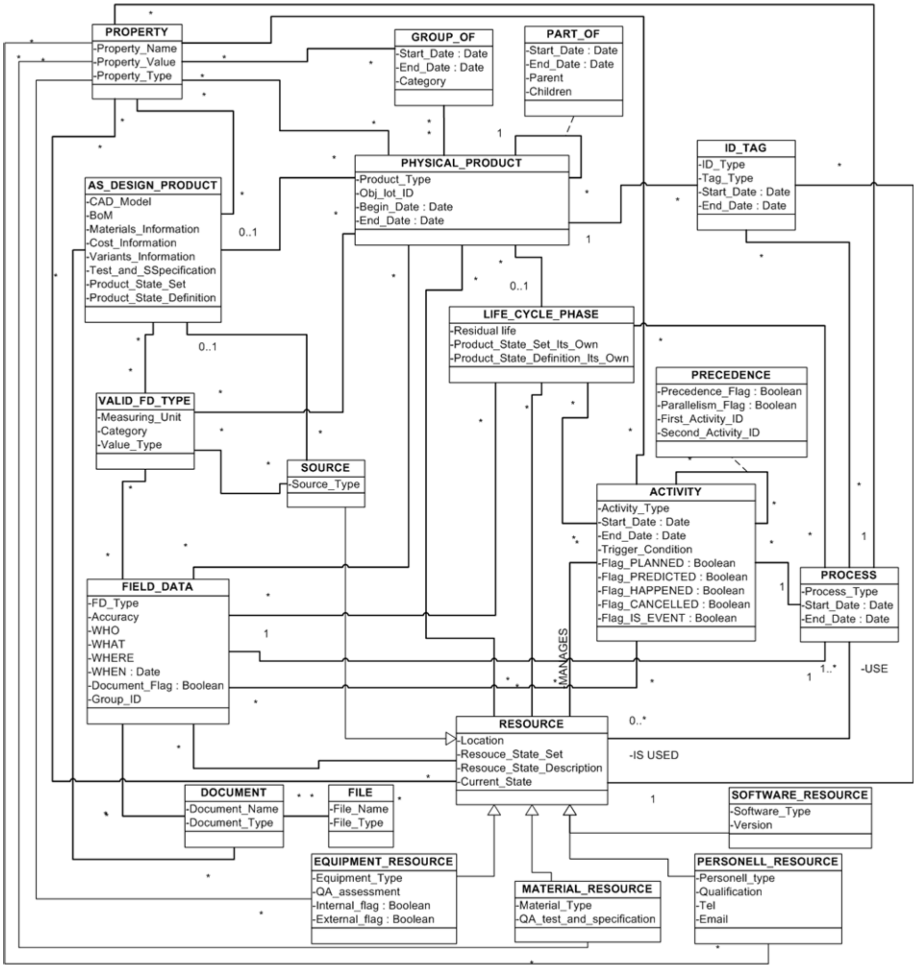

Fig. 1. Data Model Schema

2.3 QLM Data Format

The QLM Data Format (DF) represents, through a xml schema, the structure of the message exchanged between many products and/or systems. The structure of the message is similar to the Data Model schema so that it could be easily recognize by a system QLM DM compatible, thereby automating the data collection. In the schema there are elements with similar structure of DM classes with related relations represented by the hierarchical structure. For instance in the structure of Physical_Product are modeled its attributes as Product_Type, Object_lot_ID etc. plus different relations allowed by DM schema as Property, Part_Of, Resource and so on. Moreover in the DF schema there is a new element called Object that allows to represent new components not modeled with the basic schema. The Object structure could be used to represents new classes in the QLM DF improving the schema for different end users requirements. Each element in DF schema is described with a UDEF attribute. UDEF is a standard framework, managed by The Open Group, for describing data to improve data quality and to enable interoperability.[3] Each element identified in DF schema has the same structure of the other. A name identifies the type of element (Product, Resource, Object and so on), a complex type element called "qlmId" identifies univocally the object, a "description" element is used to explain its means with a human readable text. Moreover there are some different elements specific for that object and relation allowed with other DF classes. Finally, information of each element in the DF is identified through the element called "value". The value has some non-mandatory attributes used to identify easily the content of the value tag. The value attributes are: Type, dateTime and UnixTime. Type is used to describe if the value is an integer, a string, a floating number and so on while dataTime and UnixTime are used to identify when this value has been recorded.

The following xml shows an example of DF message about product CZF073, where is possible to find product type, batch number and creation date information.

```
<?xml version="1.0" encoding="UTF-8"?>
<qlmDataModel
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:noNamespaceSchemaLocation="DataFormatSchemaV0.23.xsd"
>
<qlmPhysicalProduct udef="o.0_8">
    <qlmID udef="9_8">
      <value>CZF073</value>
      <qlmID_Type>
        <value>internal_company_codify</value>
    </qlmID_Type>
    </qlmID>
    <qlmProductType udef="9_5.8">
    <value>CFZ</value>
  </qlmProductType>
    <qlmObjectLotId udef="9_34.8">
      <value>ABC123</value>
    </qlmObjectLotId>
    <qlmBeginDate udef="9_11.6">
      <value>2001-09-31 12:00:00</value>
    </qlmBeginDate>
  </qlmPhysicalProduct>
</qlmDataModel>
```

[Example of Data Format xml code message from the product CZF073 hot stamping process]

3 http://www.opengroup.org/udef/

3 An Example of QLM Standards Application Scenario

QLM standards could be used in a manufacturing scenario where a quality controller needs to collect data about product through a production line. Products go through different machines and processes. The quality controller wants to monitor hot stamping and cutting processes verifying parameters from both machines, such as pressure, times, presence of cracks, cooked temperatures and so on to individuate rejected products. QLM standards are used to export data from machines and collect information about products. Monitoring products through the production line allows to individuate rejected products in few/real time, avoiding to increase the value of a scrap product and decreasing the number of rejected products. Moreover, real time information collected from different machines in a standard way, can be easily used and elaborated by many systems supporting decisions, avoiding failures, evaluating process parameters and implementing maintenance activities.

In this application scenario the Messaging Interface is used to request information about hot stamping and cutting resources, the message is sent using the Data Model where information about field data temperature will be collected. The message exchanged follows the structure of the QLM Data Format.

The following xml code shows a request of temperatures from an oven with five different values of temperature gathered. Elements between brackets with the acronym qlm refer to Messaging Interface elements while parts between brackets with the text df are Data Format elements.

```
 <?xml version="1.0" encoding="UTF-8"?>
<qlm:qlmEnvelope
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:qlm="QLM_mi.xsd" xmlns:df="QLM_df.xsd"
xsi:schemaLocation="QLM_mi.xsd QLM_mi.xsd QLM_df.xsd
QLM_df.xsd" version="0.2" ttl="10">
<qlm:response>
<qlm:result format="QLM_df.xsd ">
  <qlm:return returnCode="200"></qlm:return>
  <qlm:requestId>REQ323452</qlm:requestId>
  <qlm:msg>
  <df:qlmFieldData>
    <df:qlmID udef="9_8">
      <df:value>oven012</df:value>
      <df:qlmID_Type udef="o.0_8">
      <df:value>internal_oven</df:value>
    </df:qlmID_Type>
    </df:qlmID>
    <df:description>oven_temperatures</df:description>
       <df:value dateTime="2012-10-
26T15:33:21">150.5</df:value>
```

```
      <df:value dateTime="2012-10-
26T15:33:50">150.7</df:value>
      <df:value dateTime="2012-10-
26T15:34:15">151.3</df:value>
      <df:value dateTime="2012-10-
26T15:34:35">150.5</df:value>
      <df:value dateTime="2012-10-
26T15:34:52">150.3</df:value>
          <df:qlmValidFDType>
            <df:qlmMeasuring_Unit>
              <df:value>celsius_degree</df:value>
            </df:qlmMeasuring_Unit>
          </df:qlmValidFDType>
  </qlmFieldData>
  </qlm:msg>
</qlm:result>
</qlm:response>
</qlm:qlmEnvelope>
```

[XML code shows the response to oven temperatures request]

4 Current Implementations

QLM standards are being used in some industrial and research applications.

The QLM Data Model has been used by Holonix[4] as a starting point to develop the i-LiKe platform, a modular and integrated solution for item lifecycle knowledge and traceability. It is composed by cross sectorial modules which cover all product lifecycle phases and industrial operation modules dedicated to phase-specific requirements and needs.

LinkedDesign[5] is a European project that will develop an integrated, holistic view on data, persons and processes across the full product lifecycle as vital resource for the outstanding competitive design of novel products and manufacturing processes. To achieve this goal the project will develop an integrated information system for manufacturing design. In LinkedDesign the middleware will implement the Messaging Interface specifications while a first version of Data Format has been used to collect data from the field about oven temperatures and rejected products in an automotive production line as presented in the third part of this paper.

BOMA[6] is another European project where partners are developing an integrated platform for Leisure Boat Lifecycle Management, enabling services addressing intelligent maintenance, sustainability, upgrades and the used boat market. In particular a black box will be placed on new boats to collect useful data about its usage which will be sent to the platform using QLM standards.

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4 www.holonix.it

5 www.linkeddesign.eu

6 www.boma-project.eu

5 Future Work

Data about product could be used for particular companies or people in different ways so that it is necessary improve QLM standards with an element to allow privacy and security of information exchanged between many products and/or systems. Further work will be required for evaluating how the security and privacy aspects could be managed through QLM standards.

Another work will be to extend the QLM Data Model with classes for specific sectors, in fact the actual version of the Data Model is a cross sectorial model that allows to close the loop of product lifecycle information with general and not specific requirements from industrial operations. It could be necessary to increase the model if needed from particular end users or sectors such as nautical, healthcare, logistics or military.

Finally it will be possible to improve the QLM Data Format developing a modular approach so that there will be standard classes with specific elements and attributes that will be used easily by end users. The final user will select the type of class he wants to use and the different element of that class will appear automatically so that DF messages can be specified by users more easily.

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Is Environmental Innovation Worth It? The Case of the Civil Aviation Industry of Emerging Markets

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Abstract. This paper analyses the case of emerging markets by studying the impacts of the airline companies' environmental innovations on airlines' financial results and customers' willingness to pay. Environmental innovations have been classified into technology based and market based innovations. It has been found that both types of innovations are proven to be positively related to airlines' financial performance although the interaction between the two does not show significant causal relationship. As to customers' willingness to pay, none of the two types of innovations not their interaction has been tested with significant causal relationship. As one of the first studies on this field of emerging markets, this paper fills the academic void, and its results and conclusions can provide some guidelines for airline companies operating within and beyond emerging markets.

Keywords: innovation, environment, emerging markets, civil aviation.

1 Introduction

The civil aviation industry plays an increasingly important role in promoting the world economic growth. Air transport has gained unprecedented growth in the last few decades, and has become the only rapid long-distance network making worldwide economic and cultural communications possible. The aviation industry currently produces around 2% of the world's manmade emissions of carbon dioxide. As the industry grows, it is forecasted that its share on global emission will increase to around 3% by 2050 (IATA 2010). It is of particular importance to study airlines from emerging markets. Emerging markets are playing a prominent role in global economic and political issues, and along with the rapid growth, their environmental responsibilities are growing as well (Nayyar, 2011) .

This paper assesses the issue through environment related innovations, adopted by airlines from emerging markets. In this study, we have classified the environmental innovations into two types: technology based innovations, and market based innovations. For technology based innovations, we have built our own index taking the following three variables: use of biofuels, use of winglets, and use of continuous descent approach. For market based innovations, another three variables are taken to build the index: CO2 offset program, online check-in, and charge for checked-in luggage. Both

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types of innovations are treated as independent variables to analyze their effects on the airlines' financial results—measured by total revenues, and customers' willingness to pay—measured by aircraft occupation rate. Meanwhile, the interaction between the two types of innovations is also taken into account and is treated as another independent variable. It is found that both types of innovations are proven to be positively related to airlines' financial performance. However, for customers' willingness to pay and the interaction between the two types of innovations, no significant relationship is found.

The rest of the paper is organized as follows. Part 2 to 4 respectively draw on the literature of civil aviation, drivers of airlines innovations and the two types of innovations. Part 5 proposes the hypotheses. Part 6 explains the data and methodology used in this study. Part 7 presents the results. Lastly, Part 8 concludes.

2 Civil Aviation Industry

The commercial aviation industry plays an important role in promoting the global economic development. Air transport moves over 2.2 billion passengers annually. The air transport industry generates a total of 32 million jobs globally. Aviation's global economic impact, both direct and indirect, is estimated at USD 3,560 billion, equivalent to 7.5% of the world gross domestic product (ICAO 2010).

Airlines across the globe are gaining increasing social impacts and responsibility. Among all responsibilities, the environmental issue is of alerting importance (ATAG, 2011). Air travel is the most energy-intensive form of transport, followed by road, rail and sea. The greenhouse gas emissions from airplanes and their implication for climate change have been a growing concern for the industry.

It is of particular interest to study the case of emerging markets, as these markets, to some extent, mean the future for the global civil aviation industry (Table 1). Growing market implies growing responsibility, airlines of emerging markets are ever alarmed about the negative environmental impacts they leave, and are taking various measures to demonstrate their environmental awareness.

Table 1. Fleet size of some airlines from developed and emerging markets

Airlines (DM)	Fleet Size	Airlines (EM)	Fleet Size
Airlines 1D	721 (+206 orders)	Airlines 1E	399 (+139 orders)
Airlines 2D	256 (+60 orders)	Airlines 2E	308 (+250 orders)
Airlines 3D	183 (+70 orders)	Airlines 3E	291 (+110 orders)
Airlines 4D	147 (+24 orders)	Airlines 4E	193 (+220 orders)

DM: Developed Markets EM: Emerging Markets

3 Drivers of Airlines Innovations

Driver 1: Fuel costs. With the global economic downturn and an increased focus on environmental concerns, airlines are scrutinizing every step of their operations for new ways to gain efficiencies and cut their fuel bills. Fuel is their single biggest expense. In 2003, 15% of airfare went to pay for jet fuel; in 2013, it is 40 %, according to the IATA. Aiming for further improvement, airlines have pledged to increase fuel efficiency by another 25 percent by the year 2020 (Honeywell, 2011).

Driver 2: The current movement on global climate change and sustainability. As demand for passenger and cargo air transportation continues to rise, the reduction of aviation's environmental footprint becomes even more critical (Bows et al., 2009). Commercial aviation is increasingly being targeted by legislators such as the EU Emission Trading Scheme for mandatory carbon-trading schemes and limits on aircraft emissions. Some important consequences of air transportation are related to noise, decreased air quality, roadway congestion, and local water quality.

Driver 3: Social Demand. Technological innovation is not only driven from innovators but also influenced by society. Currently, the general public is not well aware of the effects of aviation emissions on the global climate (Becken, 2007; Thomas, 2002). Green innovation in aviation is neither a fashion nor an end in itself. It is rather a means to the overarching goal of growth (Lykotrafiti, 2012).

4 Technology Based and Market Based Innovations

Recent studies further differentiate two types of breakthrough or radical innovations based on their advances of existing technology and departure from the existing market segment (Benner and Tushman 2003). The first type, which is defined as technology based innovations in this study, adopts new and advanced technologies and improves the services or products compared with existing ones. The second type, defined as market based innovations here, departs from serving existing mainstream markets by new and different technologies with the goal of creating a set of fringe, and usually new, customer values (Benner and Tushman 2003; Christensen and Bower 1996).

In this study, we have classified the environmental innovation adopted by airlines into the above explained two types: technology based innovations and market based innovations. For the former, three most commonly adopted innovations have been included: use of biofuels, installation of winglets, and adoption of continuous descent approach. *Biofuels*: this type of fuels is produced from renewable biological resources such as plant or animal material rather than traditional fossil fuels like coal, oil and natural gas. *Winglets*: these are the angled extension to the end of some aircraft wings which help with fuel efficiency by reducing the drag caused by airflow patterns over the wingtip. *Continuous descent approach*: this is a new technology that creates a much smoother descent from the cruising level to the ground, cutting fuel use and noise at the same time (ATAG 2012).

For market based innovations, another three common practices are included in our study: CO2 offset program, online check-in, and charge for checked-in luggage. *CO2 offset programs*: these programs are offered by airlines to let their passengers calculate the CO2 emissions they would leave by taking their flight and encourage them to compensate the environmental impact. *Online check-in*: it is a facility offered by most airlines nowadays to allow passengers confirm their presence on a flight via the internet and typically print their own boarding passes before getting to the airport. *Charge for checked-in luggage*: this is a charge imposed by a growing number of airlines for checked-in luggage. This policy, though understandably negative from passengers' perspective, can save airlines a considerable amount of fuels and thus reduce the environmental impact (IATA 2012).

5 Research Hypotheses

As Baylis et al. (1998) argued, environmental activities go along with a higher amount of financial and human resources, that is why larger firms tend to have better capabilities and more resources to reduce environmental impacts. Several empirical studies show that, in general, firm size has a positive influence on environmental innovation (e.g., Rehfeld et al., 2006; Arimura et al., 2007). Airline companies included in this study are major airlines of emerging markets, and should therefore have more resources and capabilities to adopt environmental innovations and later on benefit from them through economy of scale.

Hypothesis 1: Technology based environmental innovations are positively related to the financial results of airline companies in the emerging markets.

Similarly, for market based innovations, as stated by Johnson et al. (2009), innovation is the response of market based companies to profit potential and other market based incentives. Through the above mentioned market based innovations, airline companies are expected to directly save money by, for instance, using less paper from check-in and burning less fuels thanks to less checked-in luggage.

Hypothesis 2: Market based environmental innovations are positively related to the financial results of airline companies in the emerging markets.

Additionally, we have looked at the interaction between technology based and market based innovations. No previous literature has been found concerning the effect of this interaction on airlines' financial results. However, since the both types of innovations are proposed to have a positive effect on financial results, it follows that their interaction should all be positively related to the financial results:

Hypothesis 3: The interaction between technology based and market based environmental innovations is positively related to the financial results of airline companies in the emerging markets.

For customers' willingness to pay, we have proposed similar hypotheses. Note that we did not propose the hypothesis concerning the relationship between technology based innovations and customers' willingness to pay, as most customers are not aware of the technology innovations that airlines are adopting.

Hypothesis 4: Market based environmental innovations are positively related to customers' willingness to pay of airline companies in the emerging markets.

Hypothesis 5: The interaction between technology based and market based environmental innovations is positively related to customers' willingness to pay of airline companies in the emerging markets.

6 Data and Methodology

Data are collected from 40 major airlines of emerging markets. Airlines were selected mainly by their fleet size. And only medium-large sized airlines of their respective country or region were included in our sample. Geographic coverage of the airlines is fairly complete. Airlines' data were of the year 2011. All data were manually collected from various sources such as annual reports, corporate social responsibility reports, International Air Transport Association (IATA), International Civil Aviation Organization (ICAO), and Air Transport Action Group (ATAG).

The dependent variables of this study are airline companies' financial results and customers' willingness to pay as explained earlier. These two variables are measured respectively by airlines' total revenue, and aircraft's occupation rate. The independent variables are both technology based innovations and market based innovations. Due to the lack of existing environmental indexes for the aviation sector in emerging markets, we have constructed our own indexes using a series of key indicators for both types of innovations. For technology based environmental innovations, we have taken the average of the three indicators to generate the combined index. Likewise, the average of the three market based innovations is taken to generate the index for market based environmental innovations. As to the interaction between the innovations, we have multiplied the above mentioned two indexes to create the variable. Each of these six innovations and their measurement are displayed in the following tables (Table 2 and 3):

Table 2. Airlines' technology based innovations and measurement

Technology based innovations	Measurement
Use of biofuels	Percentage of flights using biofuels
Use of winglets	Percentage of aircraft with winglets
Continuous descent approach	Percentage of flights using this approach

Table 3. Airline's market based innovations and measurement

Market based innovations	Measurement
CO2 offset program	dummy variable (1 or 0)
Online check-in	dummy variable (1 or 0)
Charge for checked-in luggage	dummy variable (1 or 0)

We have also included two control variables in our study: fleet age and market conditions. Fleet age is included due to the fact that fuel consumption of an aircraft is directly related to the age of the aircraft and the model of the engine. It is measured by the average age of an airline's entire operating fleet. Market condition is included in order to control for any common economic or political circumstances that benefit or deteriorate the entire market of a specific country or region. It is measured by the local stock exchange index by the end of the year 2011.

7 Results and Analyses

In order to test the hypotheses we have proposed, multiple regressions by Stata have been conducted. We took the natural log of the revenue since total revenue is considerably large compared with all other variables. Below are the two tables with the results of the regressions. They are taking log of the total revenue and aircraft occupation rate respectively as the dependent variables.

Table 4. Regressions of Log of Revenue (t-statistics in parentheses)

Technology based innovations	1.562** (2.17)
Market based innovations	1.172*** (2.76)
Interaction	-0.706 (-1.78)

** Significant at the 5% level, *** Significant at the 1% level

Table 5. Regressions of Aircraft Occupation Rate (t-statistics in parentheses)

Market based innovations	0.005 (0.17)
Interaction	0.014 (0.50)

As can be seen from Table 4, both innovations are tested to be positively related to airline companies' financial performance, and both of them have statistical significance. Thus, Hypothesis 1 and 2 are supported. However, the interaction between the two types of innovations is tested to be negatively related to the financial results, though not significantly so. Thus, Hypothesis 3 cannot be supported. Table 5 gives the results for airline customers' willingness to pay. None of the two variables, the market based innovations and the interaction, are gaining statistical significance, which disapproves both Hypothesis 4 and 5.

Additionally to the testing of the five hypotheses, we have also conducted a more detailed analysis measuring each of the six practices by looking at their impact on airline companies' total revenue and aircraft occupation rate. The procedure and methodology remain the same. The results are as follows:

Table 6. Regressions of Log of Revenue (t-statistics in parentheses)

Use of Biofuels	5.578 (1.33)
Use of Winglets	-0.486 (-0.64)
Continuous Descent Approach	0.779** (2.59)
CO2 offset program	0.630** (2.32)
Online Check-in	1.062** (2.26)
Charge for Checked-in Luggage	0.107 (0.13)

** Significant at the 5% level

Table 7. Regressions of Aircraft Occupation Rate (t-statistics in parentheses)

CO2 offset program	0.053** (2.52)
Online Check-in	0.032 (0.88)
Charge for Checked-in Luggage	0.052 (0.84)

** Significant at the 5% level

As can be seen in Tables 6 and 7, among the three technology based innovations, use of biofuels and continuous descent approach are both showing positive coefficients with the financial results of the airlines, and the use of winglets is tested to be negatively related to the financial results, though not significantly so.

For the relationship between market based innovations and airlines' financial results, it can be seen in Table 6 that the first two innovations are proven to be positively related to the airlines' financial results and both of them are statistically significant, while the last one also shows positive relationship though without statistical significance. Thus we can conclude that CO2 offset program and online check-in can positively contribute to airlines' financial performance. As to customers' willingness to pay, we can see from Table 7 that all of them are showing positive relationship, but only CO2 offset program gains statistical significance. Therefore, we can draw the conclusion here that CO2 offset program as a market based innovation is positively related to customers' purchase willingness.

8 Conclusions

This paper assesses the issue of environmental innovations with the focus on airlines from emerging markets. Innovations are treated in two groups depending on whether they are technology based or market based. For each group, three commonly adopted innovations among airlines are used to analyze their effect on the airlines' financial performance and customers' willingness to pay, measured by airlines' total revenue and aircraft occupation rate respectively.

Both types of innovations are found to be positively related to airlines' financial performance. However, it is worth noting that the interaction of technology based and market based innovations does not seem to do contributions to airlines' financial performance. Therefore, it is important to know which innovations are key contributors. As our additional testing suggests, Continuous Descent Approach, CO2 offset program, and online check-in are showing significant contributions to airlines' financial performance. Therefore, airline companies could be advised to give more weight to the above mentioned three key practices.

For the other three practices which are not proved to be positively related to airlines' financial performance, it implies that, on the one hand, for environmental innovations heavy in investment, airlines may not see immediate rewards as the initial investment on those innovations can counterbalance possible benefits in the short run; on the other hand, airlines adopting those innovations are often under pressures from their competitors which somehow impede them from fully assessing the necessity of adopting certain innovation before making the decision.

As to customers' willingness to pay, however, no significant findings are obtained; neither technology based nor market based innovations play an important role in customers' purchase decision-making. This implies that for airlines of emerging markets there is still a lot to do to enhance their customers' environmental consciousness and provide them with the type of products and services that are both ecological and good value for money.

These results, though preliminary, can shed some light on environmental innovations for the airlines industry. As probably the first study dealing with this issue in emerging markets, this paper fills the academic void by raising the issue and giving grounded analyses. It also provides some managerial implications with the most updated cases and results for airlines in and beyond emerging markets.

Among future research avenues we might cite to focus on how to manage emerging airline pilots, -as in Harvey, Williams, and Probert (2013)-, who have unparalleled opportunities to affect green performance through their control of the machines that directly impact the industry's carbon footprint.

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Technological Innovation, Ethics and Legislation as Factors for Quality of Life

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Abstract. The aim of this article is to show that technological innovation, ethics, and the law contribute to an improvement in the quality of life of society, considering also that the major technological changes are followed by economic, social and institutional transformations, requiring legal supports, economic motivation and appropriate political and institutional conditions to be developed. Besides dealing with the concepts of ethics and technological innovation, are also addressed the laws of innovation and industrial property, since both are directly related to the theme of the paper. Quality of life is also conceptualized according to the World Health Organization, being understood that, to achieve advantages in quality of life of society, ethics must be present in all relations. Technological innovation, that generally boosts the economic growth of the country, should be encouraged and, simultaneously, the laws that enforce the relations in society rules must be adequated and improved according to the needs of the citizens and organizations.

Keywords: value aggregation, social responsibility, sustainability, quality of life.

1 Introduction

This article deals with concepts that are being increasingly recognized by their importance in the present actuality of humanity and the relations among them.

According to [1], the concepts of ethics, legislation, product and service quality, sustainability and social responsibility are related to the improvement of quality of life of society, as shown in Figure 1.

It is worthy to notice that the concept of ethics was considered outside of the dominion of law, since it extrapolates legal requirements towards legitimate issues.

This article will show that technological innovation is also a factor that can contribute to the improvement of quality of life of society. However, it must be considered that, for a country to be technologically developed, it is necessary that its people have education, work, adequate health care system, properly applied laws, besides ethics and transparency in relationships, not only due to organizations in general, but also from the Government, the rulers and citizens, in all spheres.

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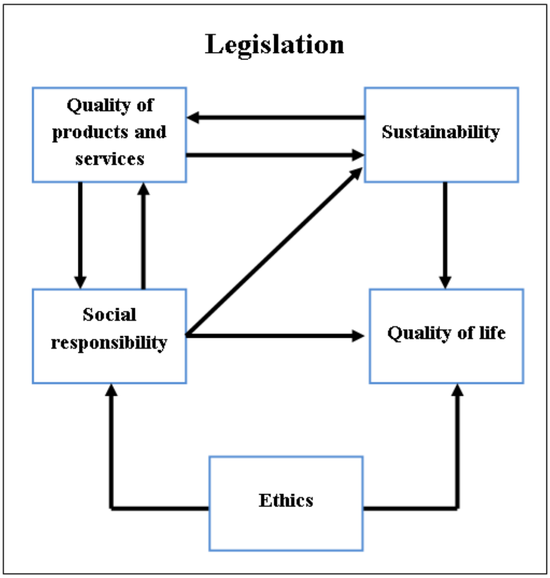

Fig. 1. Relations among concepts. Source: [1]

In addition, technological innovation has also its negative face, as may be seen, in the course of History, through the arise of several machines and equipment with innovations replacing human labor, causing unemployment and serious social problems [2]. It may also be considered the new products and services imposed to population by massive propaganda which become a necessity, frequently forced and of doubtful usefulness.

In fact, according to [3], the reasons for unemployment in Brazil are, among others, the low professional qualification of workers together with technological innovation, what is leading an increasing number of enterprises to change human work for machine work.

[4] considers that the major technological changes are followed by economic, social and institutional transformations, because technology does not spread in the vacuum, requiring legal support, economic motivation and appropriate political and institutional conditions to develop.

The Brazilian industrialization model has not demonstrated a strong capacity for innovation, because Brazil has historically imported most of the technology which uses and spent low effort on research & development. The actual Brazilian industrialization came only from about 1950, when was basically set up the model of imports substitution, based on the importation of foreign capital and technologies [5].

Even at present, quantitative surveys indicate that the Brazilian system of science and technology has made a small amount of general investment, supported mainly by government initiatives and with little involvement of companies. This system is inefficient compared with other countries like United States, Germany, Japan, France, Canada and South Korea [6].

Moreover, the quick development of South Korea deserves to be highlighted since 1967, when this country began an extensive development programe aimed to support its growth by continued increase of competitiveness of the economy and the achievement of an ever-growing share of international trade. South Korea is now in a safe route of enrichment, with all its economic indicators and research performance rising much faster than the Brazilian ones [7].

The Koreans have identified the pillars that sustain a stand-alone development, such as education of qualified basis and the previlege for the training of technicians and engineers, factors that have favored learning technological development through reverse engineering and business management [5].

[8], speaking about the major changes in South Korea, summarizes: *"...there was therefore progress in obtaining a business structure less concentrated, more transparent relations and an economic model more responsive to market signals".*

Transparent relations, ethics and legislation are factors to achieve a better quality of life of society. Likewise, technological innovation is also a factor for a better quality of life, since it is an essential tool for increasing productivity and competitiveness of organizations, so as to boost the economic development of regions and countries [4]. However, it should be stated that companies need to be prepared to receive the advantages of innovation, otherwise social problems may be increased.

2 Ethics in Organizations

According to [9], morality consists of values, principles and norms of behavior of man in society, while ethics is a systematic set of rational knowledge and goals of human moral behavior.

Ethics currently relates with work, politics, life in society and interpersonal relationships, among many other ways in which human behaviour is important [10].

In a pluralistic society like ours, where the tolerance in coexistence in terms of respect for different ways of thinking and behaviour has reached an advanced stage, there is a risk of falling into the temptation of indifference. In general, any way of thinking and behaving is allowed, not necessarily with concerns about this position or correction of the performance. Just check out how currently, by saying: "This is wrong!" or "It is not correct to proceed in this way!", easily one is taxed of moralist, retrograde or other similar expressions. What would be a breakthrough, the healthy pluralism, turns this way to a dangerous relativism, preventing the possibility of serious ethical actions [11].

According to a study carried out by the Ethos Institute of Companies and Social Responsibility, in partnership with the newspaper Economic Value and the enterprise Public Opinion Indicator, 63% of participants answered that they take in consideration the treatment given by the enterprises to their employees, besides their concern with the environment and business ethics [12]

Based on this, one can increasingly realize that social responsibility and ethics are still going inside of the mind of organizations, a fact that should bring reflection, since it must be the path to sustainability, to business success and to build a more prosperous and just society [13].

Ethics, besides being essential for businesses today, is also beneficial to society. In current society, operating in fast-paced and complex environment with increasing instability, organizations are challenged to put ethical issues as essential to survival [14].

Ethics in business is the application of ethics in a concrete domain, with the identification of rules and ethical principles in the economic and commercial context. The related concept of corporate *compliance*, very discussed in our days, may be defined as the set of procedures adopted by an organization with the aim of enforcing applicable laws, corporate policies, values and ethical standards, including to identify and prevent any violation or misuse that may occur [15].

Companies of today must deal not only with legal risks, but also with the risks related to image and reputation. The reputation of a company is strongly linked to the level of public trust that it enjoys, amid a growing pressure from consumers and society in general by a more ethical stance. Companies that do not cultivate ethical and environmental values are at risk of losing business [15].

3 Technological Innovation

Innovation is usually associated with a process of new technologies. According to [16], technological innovation is defined in the PINTEC – Industrial Research in Technological Innovation by the implementation of products (goods or services) or technologically new or coming from substantially improved processes. The implementation of innovation occurs when the product is placed on the market or the process shall be operated by the company. Technological innovation refers to product or process new (or substantially improved) for the company, not necessarily new to the market/sector of activity, and may have been developed by the company or by another company/institution.

Innovation is also the establishment of something new that represents the aggregation of economic value. It may be of product or of process. In fact, product innovation generally come together with technological innovation of the production process, to enable this innovation to be carried out in practice and reach its potential consumers [17].

For marketing, the definition of innovation, or technology-intensive product, relates the concept with the extent of disruption that a new product may result in infrastructure and in the patterns of behavior. About the consumer behavior in relation to innovation, several researchers sought to understand the factors that lead the consumer to embrace or resist to an innovative technology [18].

For [19], the manifestation of the entrepreneur (producer of innovations) responsible for the project (new combinations of production factors) constitutes the fundamental element of economic development.

[20] argues that technological innovations, which lead to economic development, employment, income growth and social inclusion, also depends on the existence of a large numbers of small, medium and large companies permeating the productive sectors and disseminated in all segments of the economy and regions of the country.

However, in order that technological innovation brings economic results for the country, it must be transmitted to the market and used by consumers or by the production process of goods or services.

The most dynamic and profitable companies in the world are precisely those most innovative that, rather than compete in saturated markets, create their own niches and enjoy temporary monopolies through patents and industrial secret [2]

It is also important that these innovative companies do not forget ethics, social responsibility and sustainable development of the planet, so that society reach the utmostly aimed quality of life.

According to [21], many organizations have achieved a good advantage in sustainability because they always look to the future and plan new environmental technologies. It is what Wal-Mart is doing, since it opened two super experimental stores designed to test dozens of technologies for efficient use of energy that do not harm the environment.

Companies are re-examining their connections with the social values and responsibilities with the planet where we live. As the environmental and social movements mature, companies suffer pressures to assume greater responsibility for environmental and social impacts of their actions. Corporate ethics and social responsibility have become important topics in virtually all areas of business, and few companies can bypass the renovated and demanding environmental movements.

4 Laws: Technological Innovation and Industrial Property

The law is a system of rules governing human behaviour [22]. Therefore, it is essential that there are laws well prepared and properly applied, mainly to improve the quality of life of society.

The stimulus to innovation brings to the market more competitive products and services, generates employment, income and development. In this respect, the new legislation aims to regulate the situation of private companies and create a system of tax incentives for their development, starting with hiring researchers and companies without competitive bidding [23].

An innovation law exists in Brazil since 2004, as a new instrument for fostering innovation and scientific and technological research in the productive environment, which seeks mainly to promote and encourage the scientific research and to develop technology excellence, as put in articles 218 and 219 of the Federal Constitution. However, so that the legislation is actualy efficient, it is important to resolve important issues still to be addressed, such us the lack of flexibility in the management of research institutions.

In this way, it is necessary to go beyond the approval and regulation of technological innovation, since it does not end in itself. To overcome these difficulties and achieve their purposes, the implementation of the law of technological innovation will require an effective interaction of government action with the private sector, the scientific and technological community and the workers [24]. For these authors, the law of technological innovation emerges as a relevant institutional instrument to support industrial and technological policies in Brazil.

Beyond this, Industrial Property legislation also deserves to be considered in the context of this article. It is, of course, very important to incentive and to protect researchers' rights, as a fair compensation for their efforts. It is understood by industrial property rights those resulting from the conceptions of human intelligence that arise and produce novelties in the industrial sphere. In Brazil, these rights are regulated by the law Nr. 9,279/1996 [25]. Intellectual Property makes it possible to transform knowledge, in principle an almost-private asset, into a public asset, being the connecting link between knowledge and the market [26].

The intensity of scientific and technological development; the approach and interpenetration between science and technology (approaching science from the market in a way not previously experienced); the dramatic reduction in time required for technology development and incorporation to the results of the productive process; the reduction of the life cycle of products on the market; high research and development costs and the risks implicit in technological option; the incorporation of innovation as an expansion of competitiveness; and, particularly, the ability of codification of knowledge, all these aspects increase the importance of intellectual property protection as a mechanism to guarantee the rights and investment stimulus [25].

A set of statutes and laws regulates industrial property in its several dimensions and defines the object of legal protection. Industrial property covers a set of activities related to the industrial application of inventions, industrial design, trademarks, geographical indications and designations of origin, unfair competition and information not revealed (business secrets).

However, a detailed analysis of this legislation deserves a specific work by the importance of the subject, because it is true that there are flaws in the process of granting trademarks and industrial records.

The process of patent grant presents itself as a bottleneck. The time difference between the deposit and the grant indicates the lag in the ability in the examination of requests [27].

5 Final Considerations

Every man wants to improve his physical and mental welfare or, namely, his quality of life. The World Health Organization (WHO) defines quality of life as "the individual's perception of his position in life, context of culture and values system in which he lives and in relation to his goals, expectations, standards and concerns".

The present study sought to demonstrate through the concepts of ethics, technological innovation and some laws, in particular the industrial property and innovation ones, that there is an interconnection between them, and this interface is capable of improving the quality of life of a society.

So, there must be a place, in Figure 1, for technological innovation. The authors still did not arrive to a consensus about the best way to do it, and shall thank for any help from the readers on this issue.

Ethics and transparency must be present in all relations, in the development of technological innovation and in the preparation and application of laws, for an adequate economic growth and social well-being.

Laws exist to support the entire society. Analyzing the laws of innovation and industrial property, briefly addressed in the text, it is clear that in Brazil they certainly need upgrades, in order to promote the technological development of the country. This is, of course, a challenge to be faced.

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Sustainability Impacts in the IT Strategic Alignment

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Abstract. Information Technology (IT) has been undergoing changes in their way of being governed. These changes has made proximity IT and business generating strategic alignment business, where business objectives are deployed in IT objectives. This strategic alignment may be affected and impacted for various external and internal factors to the business, including sustainability which is based on three pillars: economic, social and environmental. The aim of this paper is to evaluate the Influence of these three pillars in the IT strategic alignment processes, using the Delphi Method to obtain the IT experts consensus about influence on these processes. The main result shows there is preponderance that of the Influence of the economic pillar in most cases, but that the social and environmental pillars are already considered relevant processes in risk management and strategic planning.

Keywords: COBIT, IT Governance, Sustainability, Green IT, Sustainable IT.

1 Introduction

The evolution that the Information Technology (IT) area has experienced in recent years has generated greater integration with corporate business areas. This integration has meant that IT area support increasingly competitive advantages and add value for business strategy. As a result, boards of directors have been concerned with the IT responsibilities, controls and targets, in other words, emerged the IT governance need [1; 2; 3].

IT Governance is responsibility of board of directors in the definition of leadership aspects, organizational structures and processes to ensure that IT supports and extends the organization's goals. One of the main implementation governance consequences in Enterprises is the emergence of the IT strategic alignment, which is also considered one of the focus areas, aiming to sustain the relationship between business plans and IT, align IT operations with the business, defining the value proposition [1; 4; 5; 6; 7].

The COBIT Model, one of the most widely used in IT Governance, is based on the use of processes and controls, divided into four domains, mapped in five IT governance focus areas. The domains are: Plan and Organise (PO); Acquire and Implement (AI); Deliver and Support (DS), Monitoring and Evaluation (ME). The

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focus areas are: Strategic Alignment; Value Delivery; Resource Management; Risk Management; Performance Monitoring [5].

Strategic Alignment is impacted by factors resulting from internal and external environments to the business. Among the external factors, sustainability is one of that impact not only the IT strategic alignment but the entire organizational environment. Sustainability is designed as the capacity to meet the present generation needs without compromising the future generations ability to meet their own needs. Sustainability is achieved through the integration of three dimensions also known by pillars, forming a theory of the Triple Bottom Line (TBL). The three pillars are: economic, social and environmental [8; 9; 10; 11; 12].

Energy savings in data centers, virtualization, consumables planning disposal, use of suppliers with the sustainable practices and Green IT practices are some of the consequences of the sustainability impacts in IT strategic alignment [13; 14; 15; 16].

Believing in the existence of these impacts and influences, the this article purpose is to evaluate qualitatively the pillars influence of the TBL in the IT strategic alignment processes. Specifically, the evaluated processes integrate domain PO COBIT model.

2 Methodology

The paper object consists of two sets of elements: PO domain Processes, which map the Strategic Alignment; pillars of sustainability. The PO domain choice gave up just by being in it that starts the alignment between IT and Business. The processes studied were: Define a strategic IT plan; Define the information architecture; Communicate management aims and direction; Manage IT human resources; Manage quality; Assess and manage IT risks; Manage projects [4].

Once entries are important elements in a process, an sustainability influence analysis was performed on each input the PO domain processes. Table 1 shows the number of inputs on each PO domain process.

Table 1. Numbers of processes inputs

Process Code	Process	Total input
PO1	Define a strategic IT plan	10
PO2	Define the information architecture	5
PO6	Communicate management aims and direction	4
PO7	Manage IT human resources	2
PO8	Manage quality	3
PO9	Assess and manage IT risks	8
PO10	Manage projects	4

The Delphi method was used for the analysis of each input and the response if they are not influenced by each pillar of sustainability, which was made from a consultation of experts. The choice of this method of research is justified because there is no large-scale distributed knowledge on the subject which favors consulting experts and not restricted to a survey on a larger scale [17; 18; 19].

The Delphi method is conceptualized as a tool for identifying trends and processes to support decision making, possessing three basic characteristics: anonymity; controlled feedback and statistical group responses. The anonymity among respondents is the way to minimize the reciprocal influence between participants. The feedback controlled decreases noise that commonly arise in the participants interaction in a discussion. Statistical group responses reflects the opinion of the respondents appropriately aggregated around individual opinions predominant [17].

Iterations and feedback-controlled obtains a forecast that contains the view of the majority of research participants, where recommend participation from 10 to 18 experts in at least three iterative rounds [17; 18].

In this study, thirteen IT experts were asked, where in the first round, respondents answered only multiple choices questions. From the second round questions were accompanied by a feedback from the previous round and the responses were accompanied by a review of each respondent. Some details about the IT expert can be seen in Table 2.

Table 2. Detail about the IT expert

Level of education	**Experience**	**Total expert**
Master degree	Academic and professional	3
Master degree	Academic	3
Doctoral degree	Academic and professional	2
Doctoral degree	Academic	1
Specialization	Academic and professional	3
Specialization	Professional	1

There were eight possible answers for each processes input: all pillars influence, no influence pillar, only economic pillar influences, only social pillar influences, only environmental pillar influences, and combinations two by two pillar influence. Consensus was considered when more than 50% of the respondents agree with one of these possibilities.

After the experts consensus about questions asked, we found the inputs percentage affected by sustainability pillars in each case, thereby establishing, through the scale shown in Table 3, the degree of influence. This scale Influence levels are based on the same Likert levels used in traditional surveys.

Table 3. Influence scale of the processes

Level	Degree of Influence	Metrics
0	Null	Process inputs are not influenced
1	Low	Between 1% and 40% process inputs are influenced
2	Average	Between 41% and 60% process inputs are influenced
3	High	Between 61% and 99% process inputs are influenced
4	Total	All inputs are influenced by the process

3 Results and Discussion

For the first round consensus was found in 28 of 36 entries, as seen in Table 4.

Table 4. First round result

Process Code	Input	Pillar	Consensus
PO1	Business strategy and priorities	All	77%
PO1	Enterprise Strategic direction for IT	All	77%
PO1	Programme portfolio	All	62%
PO1	Report on IT governance status	Economic	69%
PO1	New/updated service requirements	All	54%
PO1	Updated IT project portfolio	All	54%
PO1	Updated IT service portfolio	All	54%
PO1	Performance input to IT planning	Economic	54%
PO1	Cost-benefits reports	All	54%
PO2	Strategic and tactical IT plans	Economic	54%
PO2	Performance input to IT planning	Economic	54%
PO2	Performance and capacity information	Economic	54%
PO2	Post-implementation review	None	54%
PO6	Report on effectiveness of IT controls	Economic	54%
PO6	Strategic and tactical IT plans	Economic	54%
PO6	IT project and service portfolios	All	54%
PO6	IT-related risk management guidelines	Economic	54%
PO8	Strategic IT plans	Economic	54%

Table 4. (*continued*)

PO8	Detailed project plans	All	54%
PO8	Remedial action plans	All	54%
PO9	Strategic and tactical IT plans	Economic	54%
PO9	IT service portfolio	All	54%
PO9	Enterprise appetite for IT risks	Economic	54%
PO9	Historical risk trends and events	All	54%
PO9	Security threats and vulnerabilities	All	54%
PO9	Contingency test results	All	54%
PO10	IT project portfolio	All	54%
PO10	Post-implementation review	None	54%

After the second round consensus was reached in 6 inputs, as can be seen in Table 5. Two entries were pending with the consensus for the third round.

Table 5. Second round result

Process Code	Input	Pillar	Consensus
PO1	Risk assessment	All	100%
PO2	Business requirements feasibility study	All	83%
PO7	Business requirements feasibility study	All	83%
PO7	Documented roles and responsibilities	None	66%
PO9	Project risk management plan	All	66%
PO9	Supplier risks	All	83%

At the second round end there were still two inputs in which there was a consensus. Started the third round with questions and feddback controlled on 2 inputs with pending consensus. The consensus was reached at the third round end and Table 6 shows the result.

Table 6. Third round result

Process Code	Input	Pillar	Consensus
PO10	IT skills matrix	Economic	60%
PO10	Development standards	None	54%

From the information about the each pillar influence on each input and using the scale levels shown in Table 2, found the influence level of each pillar on each of the processes of strategic alignment in the PO domain. The results are shown in Table 7.

Table 7. Sustainability Influence in the Processes

	Economic Pillar	**Social Pillar**	**Environmental Pillar**
Define a strategic IT plan	Total	High	High
Define the information architecture	High	Low	Low
Communicate management aims and direction	Total	Low	Average
Manage IT human resources	Average	Average	Average
Manage quality	High	Average	Average
Assess and manage IT risks	Total	High	High
Manage projects	Average	Low	Low

It is considered in the analysis processes for which the consensus percentage was greater in the first round have greater certainty in the art. The processes for which consensus took longer to be achieved and have greater doubts or lack of specialists.

Analyzing the data presented in Table 6, it was found that the pillar that most influences the processes contained within this study is the economic. It was also an influence almost similar between the social and environmental pillars. And more about the processes influenced by sustainability in general are the PO1 (Define a Strategic IT Plan) and PO9 (Assess and Manage Risk).

It is believed that the process PO1 Total influence of economic factors and the high social and environmental factors is due to the character's own IT strategic planning to deploy the corporate strategic planning, which considers sustainability in the following ways:

- Economic: making decisions based on profit increase, customers, brand value;
- Environmental: prioritizing strategies that less environmentally friendly;
- Social: the understanding of the role of the corporation in society.

The high influence in PO9 is understood due to sustainability always be included in the risk environment, as a matter considered by the management of corporations. The risk that IT poses to the company's image to society when there are established environmental strategies, or even the risk of IT investments must be considered. Disregarding the economic pillar, the other five cases examined (PO2, PO6, PO7, PO8 and PO10) receive an influence ranging from low-and middle pillar of sustainability.

4 Conclusions

Given the goal of qualitative assessment of the degree of sustainability pillars influence, it appears that it was hit. The table with sustainability nfluence in IT processes found summarizes the experts perceptions about the economic, social and environmental pillars influence in the processes of the strategic alignment Plan and Organise (PO) of the COBIT model.

A possible continuation of this research can be given towards the use of the Delphi method to evaluate the influence of sustainability on other processes such as transaction, transition, architecture as well as in other areas of focus of governance.

This research was restricted to the COBIT model, but suggests the influence of sustainability assessment processes and / or practices of other models of management and IT governance, such as ITIL, CMMI, ISO2000, ISO38500, to discover correlations that help organizations to have their IT departments increasingly aligned to the concepts of sustainable development.

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Development of Agile Supply Chains in Brazil

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Abstract. Agile supply chains or agile supply networks are those that adopt strategies for innovation and create customer/client needs before the customers/clients actually understand that they need such innovative products. Brazil is a developing country and belongs to the group of nations denominated BRICS, which, in addition to Brazil, involves Russia, India, China and South Africa. The purpose of this research was to study active companies in Brazil to verify the existence of agile companies in developing countries. First of all, this article applied the methodology to evaluated two companies considered agile in Brazil. Furthermore, this paper evaluated the scenario of the 100 largest companies in the country in the year 2012 (not included the two evaluated companies). The results show that among these companies, only one may be considered agile according to the methodology applied in this study.

Keywords: Agile Supply Chain, Supply Networks, Developing Countries, Brazil.

1 Introduction

Competition among companies increases as it moves out of the organizational context and includes the supply network. This kind of competition is no longer between individual firms, but rather between networks of companies [1], [2]. Thus, supply networks that are able to better manage their agents will be more successful in the market.

In fact, the condition that the value attributed to the product by the consumer in retail sales will be responsible for the profitability of the entire network is ever more evident because organizations that manage their network in an efficient and joint manner have better results than organizations that are involved in a competitive battle within their own networks, with results searched by each firm separately [2], [3].

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In this context, there have been diverse studies of networks, correlating the strategies applied in them to the fact of the products being innovative or functional [1], [2], [3], [4], [5], [6].

Functional products are those products that satisfy the basic needs of the consumer, that do not change much with the course of time, and that have stable and predictable demands with long life cycles. Innovative products are those products that, through innovation and technology, become popular at certain times and generate an additional attraction for the consumer to buy them. This increases the profit margins. Nevertheless, their demand is unpredictable, their life cycle is short (some months) and the companies live in innovation cycles [3], [4].

These products are bound up with four types of strategies: lean supply networks, which aim at efficiency of the network and reduction of its losses; flexibility, which involves the capacity of the network in being flexible in two or more actors of the network; responsiveness, related to the response capacity of the network in meeting a demand generated by the market; and, agility, which consists of anticipating the needs of the market through innovations. While the first two strategies are related to functional products, the latter two are related to innovative products (Figure 1) [4], [6].

		Demand Uncertainty	
		Low (Functional Products)	**High (Innovative Products)**
Supply Uncertainty	**Low (Stable Process)**	Grocery, basic apparel, food, oil and gas **Efficient or Lean Supply Chains**	Fashion apparel, computers, pop music **Responsive Supply Chains**
	High (Evolving Process)	Hydro-electric power, some food produce **Risk-Hedging or Flexible Supply Chains**	Telecom, high-end computers, semiconductors **Agile Supply Chains**

Fig. 1. Supply network strategies bound up with functional and innovative products

With the course of time, innovative products tend to become functional products and thus tend to move from an agile strategy to a lean strategy. Although organizations can participate in different types of networks and have different types of strategies according to their product portfolio, a trend is observed for these organizations of concentrate their products and efforts in one type of segment. In Table 1 are shown, based in references such [3], [4] and [6], characteristics of some aspects of products according to their classification on functional or innovative.

This paper seeks to address the relationship of agile companies with developing countries. In this paper, specifically, Brazil is under study, as an integrand of a group of countries including also Russia, India, China and South Africa called BRICS, an economic term criated to designate the most promising developing countries on the international scene [7].

Table 1. Innovative products versus functional products

Item	Features	Functional Products	Innovative Products
1	Aspects of demand	Predictable	Unpredictable
2	Product life cycle	More than 2 years	Up to 2 years
3	Contribution margin	Up to 20%	More than 20%
4	Product variety	Low	High
5	Average margin of error in the forecast at the time production is committed	Up to 10%	More than 10%
6	Average stockout rate	Up to 2%	More than 2%
7	Average forced end-of-season markdown as percentage of full price	Up to 10%	More Than 10%
8	Lead time required for made-to-order products	3 weeks or more	Up to 2 weeks

2 Methodology

The purpose of this study is to show that agile companies have increasingly sought to sell their technologies in Brazil, but they see the Brazilian market only as a consumer market and not as a potential source of technological development. Brazilian consumption of technologies has increased due to the stability of the currency and the economy; nevertheless, these technologies arise from international conglomerates that do not invest in the country as a source of development. This research is of an exploratory nature and its purpose is to examine the proposed theme in the light of scientific knowledge [8]. Thus, this study was carried out as based on the following steps:

a) A study regarding the concepts of agile supply chains and their relationship to innovative producers;

b) A study of two multinational companies present in Brazil considered to be agile based on the methodology developed by Reis and Costa Neto [6] which involves identifying if the products are functional or innovative based on Table 1, and then classifying them according to the supply chains presented in Figure 1;

c) A survey of the 100 largest companies in Brazil and their classification from the point of view of innovative and functional products and of supply chain strategies, also based on the methodology developed by Reis and Costa Neto [6];

d) Discussion of the data collected based on the development of agile supply chains in Brazil.

3 Agile Supply Chain

Among the strategies of supply networks, one may perhaps be considered as standing out from the thus, which is the agile supply chains. This is due in large part to technological innovations, reduction of the product life cycle, variety of products and increase in international competition, together with a change in the supply and demand relationship and changes in consumer profile.

Agile supply networks can be considered an evolution of agile manufacturing, which is a structure within which each company can develop its own business strategies and products, being sustained by three pillars: organization, people and technology [9].

The English professor of the Cranfield School of Management, Martin Christopher, was one of the first to introduce the concept of agility in the supply chain [1], [10]. From this work followed a sequence of studies published in various periodicals which are recognized as basic for the conceptual foundation of the agile supply chain [10], [12], [13], [14].

The idea of agility in the context of supply chain management focuses on the context of the response to the market, being driven by demand and having shorter lead time as a characteristic based on information [1].

Agility Supply Chain (ASC) fits the capacity of a network and all its members for rapid alignment in responding to the dynamic and turbulent requirements of demand from the network. Its main focus is on the structure of the business environment, which should have an adequate level of agility to respond to changes, as well as to proactively anticipate these changes and find new emergent opportunities [12].

4 Results and Discussion

4.1 Diagnostic Products and Equipment Company

The diagnostic products company is a subsidiary of a multinational founded in the 19th Century. Present in Brazil for over 100 years, the German company is active in severed areas and product segments. The subsidiary is responsible for manufacture, sale and distribution of products and systems for laboratory diagnosis, which involves reagents for *in vitro* diagnosis and equipments. In Brazil it only carries out sales and distribution of products from manufacturing plants located abroad. Considering Table 1, some characteristics presented by the company indicate the condition of its products as innovative.

Production is made in lots, aiming to ensure quality control of the products and the stability of the active ingredients and its preservatives. Nevertheless, theses materials are produced based on forecasts of demand. Company products have a volatile demand depending on negotiations with distributors and sales to public agencies. Product life cycle is about 12 months. The contribution margin is from 58 to 60%.

Final price of products may vary for each customer through what the company calls "transfer price", which are specific tables for each customer adjusted annually. Product variety is of around 300 items. Average margin of error between the demand forecast and manufactured products was 65% and absolute error was around 35%. The stockout rate, when it occurs, is at a percentage from 2% to 4%; nevertheless, the company operates with safety stocks to reduce or eliminate this loss. End-of-season markdown of the product is from 30% to 40%; however, as the contribution margin is high, the initial earnings compensate for the reduction, and they pay for investments in technology.

The lead time up to delivery is 45 days. Although this characteristic is that of a functional product, it is fully justifiable through the global condition of the supply network and importation of the finished product, since the factory is not in Brazil but rather in the United States of America.

In regard to supply uncertainties and demand uncertainties that allow the classification of the company supply network strategy, the first one is considered high, due to the difficulty of supply sources and customs barriers, while the second one is high because the demand frequently changes, especially in the cases of government public bidding and orders from large customers.

Innovative products and demand uncertainties indicate that the company is in an agility stage, i.e., it may be considered as an agile supply chain through adopting agility measures and developing innovations.

4.2 Industrial Instrumentation and Technology Company

The technology company is focused on innovation as a competitive factor. Founded in 1976 in the USA at the peak of the information systems revolution, it has two factories, one in North America and the other in Europe, as well as an outsourcing and consolidation company in Asia.

It is currently active in 40 countries, including Brazil, where it has a business unit for distributing its equipment and solutions in the country, including technical support services. The company has 5280 employees, with 1529 of them working with innovation, in which it invests a fifth of its sales revenue.

The foreign market of the company represents 61% of its sales revenue. The main products sold by the company involve modular measurement and hardware control systems, software and integrated platforms, which are used by scientists and engineers in projects, tests and control of processes and products. Its products are sold in a market that currently amounts to around 13 billion dollars.

These systems are applicable to telephony, the automotive sector, the semi-conductor, electronics and aeronautics industries, etc. The products are distributed worldwide from its stocks, generated according to estimated demand and orders.

Company demand, although it has experienced a growth trend in recent years, as volatile, with constant variation from one quarter to the next, without establishment of a predictable sequence, being subject to diverse external and internal factors. Product life cycle has a mean duration of up to two years, due to being subject to an industry under great transformation, which is the information services and electronics industry.

The contribution margin of products is greater than 20%. Gross profit, which involves company income, deducting all costs and expenses, was around 77%. The made-to-order nature of the products for companies generates high variation of products per segment, although they have similar and modular foundations.

The volatile demand of the company results in a large number of products in obsolescence, as company strategy is concentrated on agility; in other words, it prefers to have loss of stocks instead of not being able to meet market needs, especially because the profitability rate is high. Causes of obsolescence are technological changes, demand, engineering, and emerging standards of the new industry and competitors.

Due to the need for rapid responses, the company has a low stockout rate of finished products because it generates stocks in large quantities to keep the market supplied. Another factor that leads to speed in service is that as the company clients are other companies and not the final consumer; so it only receives the payment from 30 to 90 days after installation of its equipments, leading the network to become agile in responding to markets. End-of-season markdown cannot be determined because the company understands that it depends on various situations, such as relationship to the market and customers. Analyzing the products of the organization as based on Table 1, it is possible to determine that the products are innovative.

The company has supply uncertainty, for it processes a broad number of components in several markets, such as Europe and Asia. Diverse resources used have limited supply sources, with few participating actors, which represents problems for demand in the business and for product quality and delivery. This represents a problem for manufacturing activities, which may generate additional costs.

The demand forecast is founded on sales estimates based on the economies in which it is active. As demand may vary due to many market conditions, constant review is needed. These demand uncertainties, associated with the supply uncertainty, make the company reorganizes itself in an agile manner to meet the needs of these markets, with time and technological development as fundamental factors.

4.3 Agile Companies in Brazil

The two studies presented above clearly show the scenario of companies considered agile in relation to the country, i.e., it is a great potential market, but not a source of technological development. In a certain way, these organizations focus on their region of origin and those nearest the supply and labor sources, located in Asia.

Brazil, just as its Portuguese colonizers, has always been a technology purchasing country and not a technology developing one; this is not bound up by a lack of technical knowledge, but rather with the development model based on mineral exports and on the use of land for planting. Brazil is currently one of the main countries for diverse agricultural crops, with yield indexes envied by many countries in the world; nevertheless, the technology employed in its activities, whether in the field, in telecommunications or in industry have their origins of development in other countries.

A reflection of how complicated the situation is can be seen in the fact that high technology and innovation companies have not factories in the country, while the companies that manufacture or assemble products in the country are found in the other three points of network development, which are the efficient, the flexible and the responsive areas. Notice that this last type of network has advanced more in recent years due to the arrival of some technology companies and the development of domestic companies that deal with patents already established or not on the initial phase of innovation.

Analyzing the 100 largest companies in Brazil in the year 2012 [15], 42% of them are in the services area; most of the theirs are base industries that work with functional products in mature chains in which elimination of waste and the lean strategy are fundamental, such as mining and iron and steel plants.

The automobile industry corresponds to ten companies, in which nine are vehicle assemblers and one is a manufacturer. These companies are in a flexible stage and work with consolidated products with little embedded technology. Vehicles with the greatest degree of innovation are imported. However, from the point of view proposed by [2], [6], innovative products must attend to the characteristics proposed in Table 1 and, although the vehicles currently have innumerable innovations, they are pieces of equipment embedded in the vehicles, i.e., the electronic equipment is an innovative product, but the automobile is still a vehicle which assumes the condition of a functional product in a mature chain.

Thus, of the 100 largest companies in Brazil, only 5 work with more innovative products, but have products considered as functional in their portfolios. Of these organizations, only one is of Brazilian origin, directed to the cosmetics area and which has innovative products and is within the concept of an agile company according to the characteristics proposed by [3], [4] and [6].

In addition, although the country has a large oil company, with technologies for removing oil from deep waters, and a large airplane assembling company, the former works with a functional product, a commodity, and the second is in the same case as the automobile industries – the embedded electronics in the airplanes may be innovative, but the aircraft, in the context of its basic function, continues to be a functional product.

5 Conclusions

The conclusion of this study is that Brazil is still far from being a technology developer and, although with steady growth, this is a consequence of the high value given to agricultural commodities on the international market.

The country will only achieve sustainable growth if it is able to strengthen agile supply chains which can develop technology and innovation that continue having a very high added value compared to the cost of production.

The discussion in this paper addressed the fact that, although Brazil is considered to be a solid and emerging economy, it is not in the route of agility and of technological development. Its focus continues, as it has been for 500 years, in the use of its land for crop, livestock production and mineral extraction.

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Technical Noncompliance Evaluation Criteria for Sustainable Production of IT Support Services in the Ministry of Work and Employment at Brazil

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Abstract. The design and materialization of quality indicators for support services in information technology are still activities of difficult execution in Brazil. The very analysis of noncompliances is often done improperly, as in Ministry of Work and Employment, with no standardized classification routines to aid management tasks. In addition, the high number of mistakes in recognizing the nature of the problems to be solved lead to an increasing cost of displacement of technicians, since there are no teams in Regional Superintendencies of Work and Employment to meet local demands. Present work discusses and proposes a technique for sizing noncompliance during audit processes on support services in situations where a robust quality program was not deployed yet. The central idea is to establish indicators geographically adjusted to reflect reality with minimum distortions to guide the endeavor for cost containments as well as to give contributions to minimize environmental impacts due to the excessive transport of specialized people.

Keywords: noncompliance, indicator, performance, sigma techniques.

1 Introduction

The geographic map of the information technology (IT) in Brazil clearly overlaps the map of regional exclusion that still stratifies our society, especially in terms of access to technology. Constant efforts have been made in favor of changing this scenario, but progress is slow mainly by severe contractual restrictions of outsourcing upon human and material resources.

The country's cultural discrepancies associated with investment inequalities outline an irregular behavioral way, very difficult to correct, especially since one vainly insist on a counterproductive technological regionalism unflattering to the old ideals of FUST (the Brazilian Fund for Universalization of Telecommunication Services).

In some government institutions it is practiced an evaluation of noncompliances without any objective criteria, a fact that causes unsustainable conclusions about the outsourced's performance. The lack of understanding about the national reality as described above and the non-trivial task to determining plausible indicators lead to merely palliative fiduciary – sometimes unfair – techniques.

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As we previously said, there are no teams in Regional Superintendencies with sufficient technical competence to meet local demands, so that the displacement of technicians from technological towns is expensive, even more in view of the occurrence of classification errors of calls, causing wrong displacements. This study shows how to establish preliminary rules for the control of technical support noncompliances in the ambit of the Work and Employment Regional Superintendencies at Brazil, assuming misclassification of support services, by means of data supplied by a historical series between October 2011 and February 2012. The monitoring of the classification of calls shall reduce the cost of displacements and the waste of time, contributing to the overall reduction of environmental impacts caused by excessive airborne, since distances in Brazil have continental dimensions.

2 A Bit on Performance Indicators

Quality has been the *agenda* in services since well before the onset of globalization. Important contributions to the subject can be found in [5], [9] — one of the great works on quality impact —, [7], [8], [11], [1], [10], [6] and [4] (in chronological order). According to the best practices advocated in the market, the management of IT services, specifically the technical support services, should be treated as an opportunity to improve quality — adding value to the business of the organization or institution — and not as a bureaucratic barrier. Once the contract administration is an execution process as assumed since PMBOK 2000, and, being essential for the success of projects, it must include periodic evaluations about the outsourced's performance comparing to their deliveries, it is very important the identification of items of improvement by means of the so-called performance indicators, derived quantities of checklists applied to the contract and the enterprise under legal agreement. Such indicators are byproducts of contract administration and they are prevalent even in the selection of suppliers. Through the use of these indicators, the registration of any disputes and noncompliancies should lead to improvement actions. Thus, the indicators act as regulators of the performance of the outsourced, allowing advancement feedbacks and consequential adjustments or adaptations. In short, the use of checklists and their derivatives (performance indicators) is *sine qua non* for the implementation of an Integrated Management System (IMS) based on standards ISO 9001:2000, ISO 14001:2004 and OHSAS 18001:1999 (updated in 2007).

3 The Sigma Approach

Modern enterprises and some government institutions in initial levels of maturity, looking for their guarantees, attempt to set quality parameters using only pieces of large frameworks, never acting by effective programs of incremental true quality. In general, they seek to establish an SLA, the Service Level Agreement between customers and suppliers. Nonetheless, there are situations where no SLA was implemented, even less the principles that guide the terms of some future SLA, since this agreement shall be also the result of a negotiation as a non-cooperative sequential bargaining game with conflict among self-interested players [14]. In all cases it is necessary to establish a "flooring" of quality from which one can think of SLA or some planning based on sigma techniques for gradual implementation of quality.

Considerable improvements in the service sector can be achieved by the application of relatively simple management changes such as the introduction of new concepts, the planning of a system over customer support services and the definition of a measurable patterning of services, the latter directly related to performance indicators.

Performance indicators have been proposed and used in IT Governance at Brazilian organizations, widely documented in the Information Technology Development Planning – ITDP – and its annual ammendments. Despite that, in many cases they are not able to promote satisfactory control, or even help the consolidation of information from a proactive interpretation of data to solve problems. It is also a fact that, by following market practices only, we do not make the necessary abstraction on the theme "service indicators" to adapt them to the characteristics and business rules of each organization.

In particular, with regard to the monitoring of noncompliancies nowadays, we have some indicators, such that:

- ICAC (Index of Compliance in Application Checklists): indicator calculated dividing the number of possible points by the number of points obtained from the checklists, averaging the results of applied lists;
- IPEN (Index of Closed Pendings): indicator calculated dividing the number of closed pending by the total backlog detected according to checklists;
- ICNC (Index of Closed Noncompliance): indicator calculated dividing the number of ended noncompliances by the total detected noncompliances according to checklists.

However, from the viewpoint of the geography outlined above, in order to avoid the improper practice of assigning a generalized noncompliance to the entire package of services rendered in a particular span of days, based on the log of noncompliances in one or more types of customer services, but not all, such static indicators do not show enough. It is necessary to take a dynamic approach, where the indicator will provide, beneath regional conditions, acceptable ranges of compliance, highlighting that "flooring" of quality we refer earlier. We call this indicator simply "INC" (Indicator of Noncompliance).

Since each Brazilian State manifests proper characteristics of infrastructure and human resources, we chose to work with an indicator originated from the analysis of the time series of demands, adjusted to minimize the demographic distortions and associated with the standard deviation σ calculated on all kinds of customer services. The Greek letter σ (sigma) is used in statistics to indicate how far a given process deviates from its goal. Thus, the higher the sigma value, the smaller the deviation.

Sigma techniques are applicable both in production of consumer goods and services production for continuous improvement of processes. The Six Sigma

Table 1. INC at Ministry of Work and Employment – Brazil for Amapá (AP) and São Paulo (SP) States since October 2011 until February 2012.

State/Type	10/11	11/11	12/11	01/12	02/12
AP*Network*	2,73	1,82	4,55	0,30	0,61
AP*Hardware*	0,92	1,51	2,77	2,18	2,61
AP*Software*	0,97	0,76	1,46	3,13	3,68
AP*Application*	0,67	0,83	4,00	3,50	1,00
SP*Network*	3,70	2,04	2,23	1,71	0,33
SP*Hardware*	1,26	1,22	4,21	2,57	0,73
SP*Software*	1,27	0,62	1,88	3,37	2,87
SP*Application*	1,93	2,41	2,41	1,81	1,45

framework, for instance, exalts the total satisfaction of the customer and excellent quantitative results in production, cost and profit, human resources and services [13], although there is no model for effectively guiding the implementation of Six Sigma programs [3]. In a highly competitive global scenario, these techniques are focused on globalization and its demands for standardization and quality. In this context, Campos understands sigma as a symbol designating the "distribution or dispersion around the average of a process or procedure" [2].

Perez Wilson defines Six Sigma as "an optimized level of performance that approaches zero defect in a process of making a product, service or transaction. It indicates the obtaining and maintaining of a high level of performance" [12]. Anyway, the use of a sigma technique seeks to reduce defects, errors or failures, and, as such, constitutes a management framework. The higher the sigma value, the less will be found procedural or productive flaws. In other words, sigma will measure the degree to which a particular process is able to operate without failure, craving the ideal state translated by the notion of *zero defects*, developed by Philip Crosby [5]. In general sense, sigma approaches must be scalable, i. e., they should be related to achievable goals accordingly the available resources, so that quality is incremental as far as the process improvements are implemented according to a planning of investments.

The approach of using sigma techniques is to decrease the variability of production processes, improving quality, reducing costs and deficiencies. The determination of initial levels of variability serves as a reference from which that variability shall be reduced by processual implementations of continuous improvement. In terms of customer services, sigma can express how far the service is from their quality goal. Normally, it is considered that 1 sigma represents 68 % of services which were completed with an acceptable margin of error of classification. As the proposed technique strives to increase the rigor of the search for quality, quantitative noncompliance is a function of an overgrowth in demands of a certain type measured with respect to the so-called "σ-range " (Figures 1 and 2). Quantities of demands out of the σ-range generate indications of noncompliance, starting from the premise that high amounts can be associated with misclassification. The σ generated by the sample is given by the time series,

$$\sigma = \sqrt{\frac{1}{4n-1}\left[\sum_{j=1}^{4}\left(\sum_{i=1}^{n} x_i\right)_j - \bar{x}\right]^2}, \tag{1}$$

where j denotes the nature of the calls, n is the length of time series (in months), $4n$ is the sample size, x_i are the i registered values of the indicator, and $\bar{x}$ is the average value of the indicator along the series. Reducing the *bias* by differences in demands among the States, the indicator of a given type j, in month i, in State e was defined by dividing the number of demands by the total number of demands at the i chosen month in all kinds j, in all States and by 10 requestors, i.e.,

$$x_{(i)je} = \frac{a_{(i)je}}{\sum_{e=1}^{28}\left(\sum_{j=1}^{4} a_{(i)j}\right)_e /10}. \tag{2}$$

By whatever manner, there is no quality control of support services in IT produced at the Ministry of Work and Employment. The number of wrongly classified calls is large due to lack of specialized technical professionals available in the Regional Superintendencies, so that it is just expected highest correlation between high value of the indicator defined by the managers board and taxonomic noncompliance. Thus, the delay time to closing calls has greatly exceeded the expected average, causing customer dissatisfaction, increased costs with displacement of technical teams and wearing of management.

A supply of IT support services subject to fluctuations in quality of attendance may be statistically well modeled with floating standard deviation. We assume that we need to establish a minimum acceptable standard deviation as a quantitative basis to initialize real quality, starting from this limit to achieve incremental improvements. So, the idea is to find the maximum range of fluctuation of the standard deviation. This is particularly advantageous when there is no wide time series, so that we try to compensate changes in the standard deviation resulting from the size of the series assuming the standard deviation variability. In other words, since there is no well-established control of the failures of attendance, featuring an erratic character in the dispersion of the flaws, the best way is to operate on the historical series and try to establish a pattern of variation of the standard deviation.

For an accurate analytical understanding, if we had a continuous sum, the expression of the standard deviation would be

$$\sigma = \sqrt{\frac{1}{4n-1}\left[\left(\int_{i=1;j=1}^{n;4} x_{ij}\,dx_{ij}\right) - \bar{x}\right]^2}, \tag{3}$$

from which we have

$$\sigma' = \frac{2}{4n-1}\left[\left(\int_{i=1;j=1}^{n;4} x_{ij}\,dx_{ij}\right) - \bar{x}\right]\frac{x_{ij}}{2}\left\{\frac{1}{4n-1}\left[\left(\int_{i=1;j=1}^{n;4} x_{ij}\,dx_{ij}\right) - \bar{x}\right]^2\right\}^{-1/2};$$

$$\sigma' = \frac{\frac{x_{ij}}{4n-1}\left[\left(\int_{i=1;j=1}^{n;4} x_{ij}\,dx_{ij}\right) - \bar{x}\right]}{\left\{\frac{1}{4n-1}\left[\left(\int_{i=1;j=1}^{n;4} x_{ij}\,dx_{ij}\right) - \bar{x}\right]^2\right\}^{1/2}};$$

$$\sigma' = \frac{\frac{x_{ij}}{4n-1}\left[\left(\int_{i=1;j=1}^{n;4} x_{ij}\,dx_{ij}\right) - \bar{x}\right]}{\left(\frac{1}{4n-1}\right)^{1/2}\left[\left(\int_{i=1;j=1}^{n;4} x_{ij}\,dx_{ij}\right) - \bar{x}\right]};$$

$$\sigma' = \frac{\frac{x_{ij}}{4n-1}}{\left(\frac{1}{4n-1}\right)^{1/2}} = \frac{x_{ij}}{4n-1}(4n-1)^{1/2} = \frac{x_{ij}}{\sqrt{4n-1}}. \tag{4}$$

We then establish that the σ-range is

$$\underline{\overline{\sigma}} = \bar{x} \pm \frac{x_{ij}}{\sqrt{4n-1}}. \tag{5}$$

4 Results

We calculate the values of the INC (Table 1) of all types, in all months studied, for each State. Figures 1 and 2 show the evolution of σ related to the INC for support services scenarios in Amapá and São Paulo. The curves map Equation 5 and were obtained by smoothing the evolution of the standard deviations, mathematically assuming that there would be a continuous variation of demands. The maximum amplitude of the standard deviation was 2.25 at São Paulo and 2.33 at Amapá against 1.29 at Brazil as a whole. Amapá state had its maximum in network demands, while São Paulo in hardware demands. The highest maximum amplitude of the standard deviation shall be taken as the starting point for both the development of a generic SLA (compliance for hardware, software, network and application) and a incremental sigma quality program to be developed further. Although the available data, organized on a per calendar-month series, is not so extensive in time, the consideration of a variable standard deviation previously establishes a floating pattern representative of the uncertainties inherent to IT services; this is so because they are in process of undergoing improvements from the "flooring" of quality to which we refer with the aid of Equation 5.

Clearly, the scenarios are distinct in accordance with local realities. The σ-range of Amapá proved to be different from São Paulo. This geographic differentiation points to the inadequacy of noncompliance overall accreditation to a whole package of services without accurate quantitative and qualitative criteria, and more: it shows that hard accreditation trivializes the work of the professional of quality, going in the opposite hand of the goals of IT Governance. Obviously, other considerations about quality can and should be made based on verified evidence.

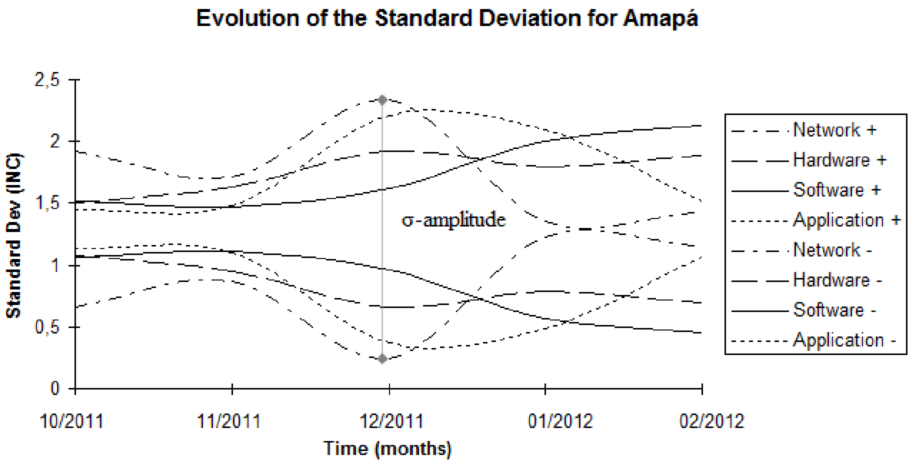

Fig. 1. Standard deviation of INC for Amapá, since October 2011 until Frebuary 2012

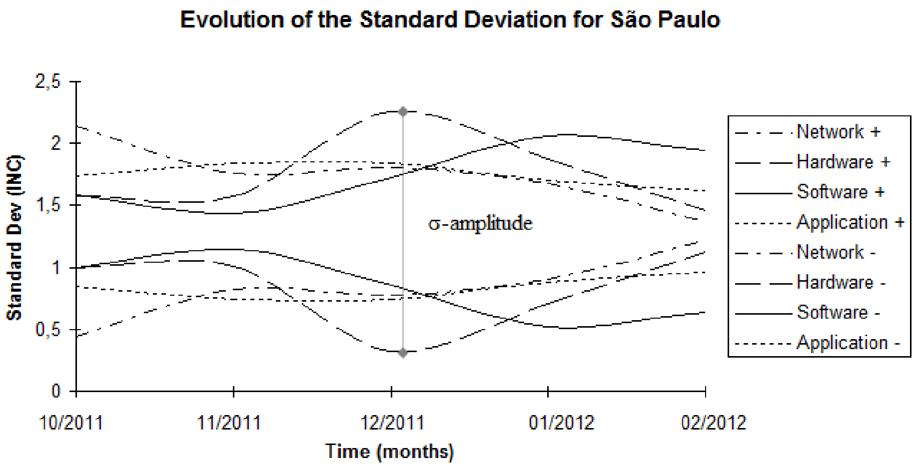

Fig. 2. Standard deviation of INC for São Paulo, since October 2011 until Frebuary 2012

5 Conclusion

This article presented a technique for initial measurement of noncompliances in IT support services based on the concept of sigma evaluation and considering Brazilian geographical variety. The proposal technique can be applied in all organizations with low maturity level of IT support services. The technique was applied only to noncompliances by misclassification of support services at Ministry of Work and Employment – Brazil, assuming the need for quality control with the introduction of an abstract monitoring zone called σ-range over the proposed Indicator of Noncompliance (INC). By establishing this control range, the technique has defined a quality "flooring" determined from the consideration of a floating standard deviation on INC as a preliminary approach to realistic quality programs mainly in government institutions. The technique was conceived having in mind the reduction of technicians travel costs and environmental impact of unnecessary air traffic, but it may be considered as an option to analyze other features such as human resources, time of attendance, etc..

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Education Mediated by Technology: Strategy to Spread High School Learning in Piauí State, Brazil

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Abstract. Brazil is a country of continental dimensions with huge need to provide basic education to its citizens, in particular those living in locations away from major centers. Among its 27 States, Piaui, located in the Northeastern region, has historically been considered one of the poorest of the Federation, but has now stood out for his efforts to resolve the educational problems.This work deals with a project of distance education based on last-generation technology, deployed in the State of Piauí in northeastern Brazil, in the year 2011. The difficulties of locomotion, truancy and the shortage of qualified teachers are some of the obstacles overcome by this pioneer project, that here is approached as a case study. Despite recent, this project has already got its first positive results.

Keywords: Distance learning, quality in education, developing countries.

1 Introduction

Located in the northeastern region of Brazil, the Piauí State has as its capital the city of Teresina, the most populous one. Is the third largest State in the region and the tenthin the country, with a land area of 251,529 km^2, corresponding to 2.9% of the national territory. Borders five other Brazilian States: Maranhão, Ceará, Pernambuco, Bahia and Tocantins.According to itsEconomic and Social Research Center– CEPRO [1], the gross domestic product (GDP), which is the sum of all goods and services produced in the State, had in 2010 a total of about 11 billion US dollars, the highest value obtained by the State up to now.

According to the Brazilian Institute of Geography and Statistics – IBGE [2], the State of has a population of about 3 million people, 1 million living in the rural area and 2 million urban areas. In 2010, 829,143 peopleat school age between four and seventeen years old. Enrolled in high school, there were a total of 162,027 inhabitants, of whom 140,481 were students at public schools.

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The miss of high school regular offering occurs, mainly, due to the lack of qualified professionals in the poorest and of difficult access regions situated in the rural areasof the state. The geographical featuresand the insufficient means of transportation available to the residents of communities with low population density are obstacles to access schools that already offer high school.

These problems require, therefore, actions that enable the service to the student regardless of the type of access to his municipality or community, in respect to the Federal Constitution, item II of Art. 208, which guarantees as a duty of the State "the progressive universalization of free education" and, in Art. 211, paragraph 3"the States and the Federal District will act primarily in elementary and high schools" and 4 "in the organization of their education systems, the States and the municipalities shall define ways of cooperation, so as to ensure the universalization of compulsory education".

To meet this challenge, the Government of Piauí, through the Secretary of State for Education, performs the deployment of high school attendance mediated by technologies with the firm commitment to ensure decent social conditions for these young people, providing them with an education that allows the continuation of the studies, the construction and reconstruction of knowledge for the exercise of citizenship.

It is valid to add to these considerations the information given by the Brazilian Ministry of Education, thatlacks in the country 235,000teachers in high school and so 20% of youthsfrom 15 to 17 years old represent a repressed demand for this kind of educations.

2 Distance Education

Modern needs forced education to pass by transformations in its design in the last thirty years. These changes have brought new ideas, especially when it is focused on universalization of knowledge. A country of continental dimensions such as Brazil, and structural human and economic differences among regions must see in education the more consistent way to searchfor equality and social inclusion. Such education can be achieved through traditional or distance solutions, what historically led to a strong discussion.

However, given the evolution of distance education, today is not more relevant to discuss what is the best way, if distance or face-to-face, but rather provide the structure, models and resources used to achieve the common purpose of obtaining knowledge. As the focus of thispaper isdistance education (DE), and in particular by differences and regional needs that hampers access to education of the majority of the population, DE comes to fulfill the role of encouraging and giving access to a large portion of the Brazilian population that want to continue and improve his studies. Then, DE can be seen as a wayof universalization of knowledge in the country and in the world.

For [3], distance education is a technological system of two-way communication, which can be massive and replacing the personal interaction in the classroomamong teacher and students, as a means of teaching, for systematic action of several joint teaching resources and support for an organization and tutoring that provide the independent and flexible learning to students.

For that DE arrived at a level of massive education,it was required the insertion of a lot of technology in this process.The evolution of communication technologies was responsible for the maturation of several models. According to [4], it is possible to see periods and features of models used in the course of time, thus existing five generations of DE activities, as shown in Figure 1.

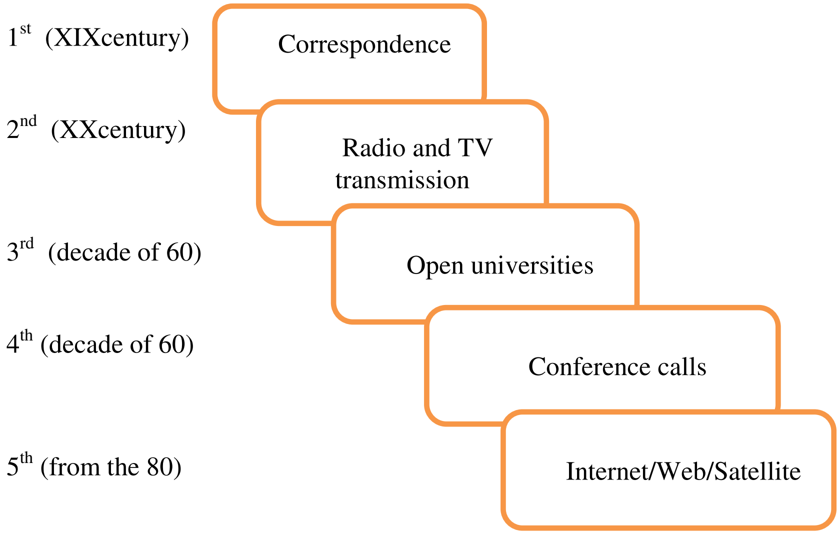

Fig. 1. Five generations of distance education Source: adapted from [4]

Table 1. Evolution of DE enrolments in graduate institutions in Brazil: 2009 – 2011

Years	Institutions	Enrolments
2009	128	528.320
2010	198	2.261.921
2011	181	3.589.373

The case study presented in this article is concerned with the 5th generation of DE, in whichthe evolution of technology provides the use of the Internet and computer networks enabling the convergence of text, audio and video into a single communication platform, integrating the advantages and earlier-generation technologies, and seeking to overcome the geographical barriers and communication. Features the use of the internet, virtual learning environments, multidirectional audio and video transmission, videoconferencing, etc. and all this without giving upthe advances provided by the previous generations, building a model with wide possibilities of learning.

This last generation, that makes an accumulation of experience of the last decades on DE, with itssafety and confidence in the model, has won followers around the world, including Brazil, where a State such Piauí is getting clear benefits with these solutions for the education problems. Table 1 shows the evolution of graduate DE enrolments in Brazil in recent years.

3 Methodology

In recent decades has occurred a considerable expansion in the use of qualitative methods in educational research and in studies related to business management. This is explained because many phenomena can only be understood in the contexts in which they occur and which they are part, and must be analyzed in an integrated perspective. For this integration to exist, the researcher must go into the scenery of the facts to observe the phenomenon being studied from the viewpoint of the people involved, collecting and analyzing data in different ways. The most important ways of acquiring data in qualitative research are documentary research and case study.

According to [6], the case study has become the preferred strategy when researchers seek to answer the questions "how" and "why" certain phenomena occur when there is little possibility of control over the events studied and when the focus of interest is on current phenomena, which can only be analyzed within some context of real life.To [7], the case study consists of a detailed investigation, with data collected over a period of time, of one or more organizations, or groups within organizations, to provide an analysis of the context and of the processes involved in the phenomenon under study. According to this author, the case study has been widely used in the field of organizational behaviour.

The qualitative research, more specifically the case study, encourages the engagement of the researcher with the daily life of organizations, providing a deep and integrated understanding of their realities. According to[6], when adopting an exploratory and descriptive approach, the researcher must be aware of their findings, even though starting from some theoretical scheme, keeping alert to new elements or dimensions that may arise in the course of thework.In this respect thecase study was planned to better understand how new technologies can assist in the process of universalization of education in one of the poorest States of the Brazilian Federation.

4 Results and Discussions

The project of implementing High School Attendance with Technological Mediation in the Piauí State was the administrative-pedagogical alternative to meetthe necessity of students concluding primary school in rural communities where there is no high school or the demand is higher than the supply.

The project offers high school with differentiated, innovative methodology, implementation of multimedia communication services network (data, voice and image) and autonomy to meet the 224 municipalities in 11 development areas of the State.

For that, it was necessary to establish a system of presential support poles,or points of presence, in Piaui State. [8] definespresential supportpole as an structure for the decentralized execution of the didatic-managerial functions of the course, *consortium*, net or system of Distance Education, in general organized with the participation of several institutions, and also with the support of municipal and state governments.

There were implemented 300 points of presence, whit the capacity of receiving up to 27,000 students,an average of 30 students per class, for high school and adult education, in three shifts, through a modern telecommunication platform. This platform to offer a modulatedserial instruction program through teleconferencing solution, including simultaneous access to broadband Internet and multidisciplinary team allocation to support the pedagogical coordination in the deployment and operation of the project. The technology used includes interactive digital TV over IP, through satellite in VSAT (Very Small Aperture Terminal) platform, as shown in Figure 2.

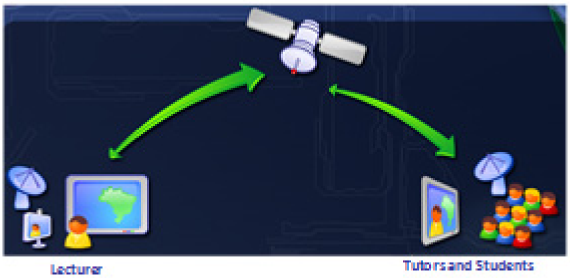

Fig. 2. Interactive digital TV over IP Source: [1]

The rural communities of the participating municipalities are provided with a network of multimedia communication services (data, voice and image) through a modern telecommunication platform including concurrent access to broadband Internet, with appropriate physical facilities.

The methodology is deployed through live classes, televised, uttered by a professor lecturer, from astudio located at TV Antares, in Teresina, allowing the student to attend these lectures at the school classroom in his community.

Under the guidance of a local teacher, a tutor called attendance teacher, present at each remote classroom, the student may interact with the professor lecturer, present in the broadcast studio, by positioning himself in front of a webcam, which will transmit his image, voice and question, resulting in an effective dialogue, in real time, ensuring the complete and interactive communication among the participants of the teaching and learning process.

This project responds to the dichotomy **CHALLENGE = OPPORTUNITY**, with the following characteristics:

- To overcome severe budget and infrastructure limitations;

- To overcome the shortage of schools and teachers;
- The use of convergent technologies for optimization of the human and financial resources available;
- To promote the vocational qualification of young people and students from underprivileged regions.

The following are illustrative figures of the implementation of the project, provided by the authors.

Fig. 3. Broadcast studio in Teresina

Fig. 4. Example of a school in Vila Nova do Piauí, a town about 350 miles away from the capital

The described education project has been implement at Piauí State and is running with its first group of students. So, results on effective learning are not yet available. However, it is expected that shall be reached advantage as good as the ones got in a similar project held inAmazonas State, shown in Table 2.

Fig. 5. Reception equipments at the remote classrooms

Table 2. Results of deproject in Amazonas State

Item	Before project	After project
Approvals	60,4%	77,5%
Disapprovals	12,8%	6,5%
Truancy	26,8%	16,0%

Source: State Government of Amazonas

5 Conclusions

This article demonstrates the practical implementation, with real results, of a distance learning project using satellite transmission, covering remote accessed regions, local tutoring, resource optimization and search for excellence in pedagogical process using the best communicators as lecturer teachers, and interactivity with the remote rooms, as stated in the fifth generation of the distance learning processes.

The results prove the effectiveness of the used system in poor,spredand with disabilities regions, typical of countries with large territorial extension, as in the case of Brazil, particularly in the State of Piauí in the Northeast region. It is expected to have contributed for the dissemination of an experience of great value in education, illustrating its applicability in similar situations.

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Sustainable Initiatives in Developing Countries

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Abstract. The objective of this work is to present the Production Engineering main concepts that have been orienting the establishment of popular housing programs in Brazil, as a way of reducing its housing deficit and helping boost the social upgrading of the less favored classes. In this presentation are included the building processes presently used, which can guarantee the construction of social houses in less time, following the so called “fast construction” process and the new technologies that make it possible. The civil enterprises concepts on popular housing, most specifically those involving aspects of environmental and sociological sustainability, are also included.

Keywords: popular residential housing, “fast construction”, building method, environmental comfort, sustainability, robust house.

1 Introduction

Brazilian economy, its market free and exporting, reached in 2010, nominal GNP of approximately 2,5, according to IBGE (Brazilian Institute for Geography and Statistics), and this gives Brazil’s the seventh place in world’s economy, behind only the United States (14,53), China (5,88), Japan (5,46), Germany (3,29), France (2,56) and the United Kingdom (2,25) [6]. The same article suggests that in 2011 Brazil might already have supplanted the United Kingdom’s GNP, which would upgrade it to the sixth larger word’s economy in 2012 [1; 2; 4].

Consistent with the data mentioned above, as the GNP indicates wealth generated by the country, the Brazilian panorama is optimistic as far as the evolution of its economy for the next ten years. Nevertheless, if Brazil’s GNP is the world’s seventh, quite on the other hand, the per capita GNP is way down to the forty-seventh position, the amount of US$ 9,390 per inhabitant in 2010, again according to IBGE data, released in 2011.

In order to properly evaluate wealth distribution in Brazil at the present time, two sociological parameters are considered below: the Human Development Index – HDI and the Gini Coefficient. According to the UNDP – United Nations Development Program, data released November 2, 2011, Brazil’s HDI for the year mentioned was 0.718, which places the Country at eighty-fourth place in the world, and eleventh in Latin America, behind Chile (0,805), Argentina (0,797), Uruguay (0,783), Cuba

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(0,776), Mexico (0,770), Panama (0,768), Costa Rica (0,744), Venezuela (0,735), Peru (0,725) and Equator (0,720).

The other parameter that describes social inequalities in Brazil is the Gini Coefficient, which, at its last release in 2009, referring to year 2008, attributed to Brazil value 0.544. It should be remembered that this coefficient varies from zero (all population has the same income) to one (only one person has the country's total income). Therefore, it becomes visible that in Brazil there is high income concentration. For comparison, we show value and reference year for a few countries: Mexico 0.479 (2006), United States 0.450 (2007), China 0.470 (2007), France 0.327 (2008), Portugal 0.385 (2008) and Norway 0.250 (2008). Of course these countries have better wealth distribution than Brazil. It is therefore inferable that Brazil, although a powerful generator of wealth, distributes poorly its wealth among its society [3; 5].

The aim of this paper is to present the way Production Engineering perceives Brazil's housing scenario. It will focus specifically the popular housing construction programs and the technological advances of the so called 'fast construction", which has experienced consistent development. This has led to an optimistic expectation of diminishing the Brazilian housing deficit for low income families.

2 Methodology

The research was based on technical and economic documents related to the one-family residence projects implanted by the company MEGASCI –*Sistema Construtivo Industrializado*, researched by the authors. MEGASCI (www.megasci.com.br), with headquarters in São Paulo, has gained recognition for technologic innovations brought up into the construction of housing projects in concrete. Records on calculations, drawings, building methods and budgets were examined during the last four years and thus a thorough view of these technologic innovations was made possible. They are characteristic of the "fast construction", as it is understood today in Brazil.

3 Results and Discussion

Brazil's Present Day Housing Scenario

In several opinion polls about Brazilians' most desired goods [see http://www.correiocidadania.co.br/content/view/3560/91], for all levels of income, home ownership is number one, especially for wage earning workers who have no other way to buy a house, other than (federal, state or municipal) government sponsored programs.

The 2010 IBGE's Census showed that 11.4 million Brazilian (6% of population) live in below normal level conglomerates, like favelas (slums), *palafitas* (houses on stilts) and *mocambos* (miserable dwellings, formerly, refuges of runaway slaves) and other kinds of social assemblages, all characterized by the poverty of its people. It should be noted that in São Paulo's metropolitan area there are 2.1 million dwellers in such conditions. The state capital which its metropolitan area shows the worst rate of slum dwellers is Belem, with 51% of its inhabitants living in slums.

Housing Programs and Social Upgrading

As far as the Brazilian Federal Government is concerned, several housing programs were offered to the poorest social levels, families earning 3 to 5 minimum wages per month (US$ 950.00/month) in order to diminish the country's housing deficit. Among the various federal housing programs, the BNH – National Bank of Housing, formed during the military regime in 1964 and extinguished in 1986, and the *Minha Casa Minha Vida* (My home, my life), presently in progress, and with promising perspectives. While the National Housing Plan, conducted by BNH focused only in the construction of popular dwellings, *Minha Casa, Minha Vida* was devised to promote social upgrading of families most in need, equipping housing nuclei with sanitary infrastructure (water and sewage), transportation, social addenda (schools, daycare centers for babies and young children, health centers, recreation clubs, etc.), so that when occupying a new dwelling, a family is automatically inserted in the area's social context.

It should be emphasized that *Minha Casa, Minha Vida* is offered through agreements and partnerships of the federal government with state and municipal governments and they act jointly in the installation of these housing nuclei: usually the federal government is responsible for management and financial resources, to the state is left investments on urban infrastructure and the municipality contributes with the area and future means of collective transportation.

New Technologies and "Fast Construction" in Brazil

The main technological advancements that allowed Brazil, from year 2000 on, to install in a fast and efficient manner popular housing nuclei of good quality were:

1. Metallic modules with the house installations inside: potable water, sewage, electricity; it allows the finishing of walls already with these modules inside.

2. Ad mixtures to control concrete density in order to obtain different degrees of air entrained concrete, which allow concrete walls and roof to keep thermal comfort inside the houses.

3 Ad mixtures to control concrete fluidity, for easier use, increased construction speed e better structure quality.

Apart from these technological advances at civil construction, it should be mentioned that both government and private companies have intensified training of the work force preparing professionals to work with industrialized building systems.

A Proposal for 'Robust House' in the Context of Popular Housing

Consequently, it is proposed as a promising alternative for the residential industrial construction of dwellings for low income population, the 'robust house', an idea based on the following social and economic building concepts:

1 Concrete prepared of Portland cement as the sole building material for the structure, which comprises the foundation over a radier plate, walls of concrete with mechanical modules already installed inside, and the concrete roof, with special added products to provide thermal comfort inside.

2 One store residence, area of 50 m^2, with multi-use living room, two bedrooms, one bathroom, kitchen and porch.

3 Sale price from 20 to 25 thousand US dollars.

4 Plots of land from 70 to 90 m^2., backyard with barbecue installation, an important Brazilian social custom, which often includes the presence of relatives and neighbors.

5 Fences separating the residences to protect the family's privacy, another important item in Brazilian culture.

6 Robust houses are built inside a housing nucleus with social facilities: school, daycare center for babies and young children, recreation club, medical center, etc.

7 Infrastructure with potable water supply, sewage system, electricity, flammable gas for cooking, paved streets, etc.

8 Reutilization of all rubble from construction, at all phases.

9 Housing projects with solar energy absorber devices, reutilization of water in dwellings, retention and utilization of rain water and other items necessary to environmental sustainability.

It's reasonable to believe that, provided the above items are fulfilled, families living in a popular housing nucleus like this will be effectively upgraded and inserted into the Brazilian society.

The final deduction, after careful analysis of the technical documentation, and visits to the Housing Nuclei built by the above mentioned company, is that the "fast construction" process has been consolidated as a powerful social and technical instrument for the implantation of dwellings specially made for low income families. At the same time, this complete set of technologic innovations of the building methods in use today may and will be progressively amplified, adopting future ideas and procedures that will maintain the same quality of the residences, but at a lower cost and smaller construction time.

4 Final Remarks

This analysis of the implanted projects led us to reach the following conclusions:

1. The Federal Government sponsored program so-called "*Minha Casa, Minha Vida*" – My House, My Life - has been showing remarkable results, mainly because in it the three levels of government (Federal, State and Municipality) are involved and aiming at the same objective, that is, to reduce the dwellings deficit in the country by building houses integrated to Housing Nuclei, which allow for effective social integration of low income families.

2. The technologic innovations herewith described refer to concrete as the building material that made possible a new construction process called Fast Construction,

in which the construction speed is an important factor to reduce the dwellings deficit in Brazil.

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Prioritization of Research Proposals Using the Analytic Hierarchy Process – AHP

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Abstract. This research is a prospective analysis of prioritizing research proposals using pre-established criteria and applying the Analytic Hierarchy Process-AHP. The prioritized projects should ensure the competitive advantage of the organization. For this analysis, criteria which take into account other factors, which are not purely technical, were applied. The guiding hypothesis of this study was that it is possible to maintain a competitive portfolio of research proposals, from the analysis of pre-established criteria, using the methodology of the Analytic Hierarchy Process, giving priority to innovation and technology transfer. A key finding was the importance of retrieving research projects' history in the company, and stating gaps to be controlled in future analysis. Six ongoing projects were analyzed by 17 interviewed researchers and scores were given. Results obtained using the multicriteria analysis were similar to that previously applied by the selection committee, validating the hypothesis. We concluded that AHP may assist in the identification and prioritization criteria for project portfolio management.

Keywords: multicriteria analysis, research proposals selection, project portfolio.

1 Introduction

In the globalized world and today's dynamic, it is essential for organizations to maintain their competitive edge. The essence of this differential is aligned to updated strategies, contributing to the achievement of organizational goals. Without this strategic planning any further action may lead to failure. The connection between strategy and the selection and implementation of initiatives is through the funding of proposals and the project portfolio management is responsible for this alignment [1]. According to the Project Management Institute, portfolio management is the

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collection and management of projects or programs that are grouped together to facilitate the achievement of the strategic objectives of the organization. Therefore, when managing a portfolio, the first premise is that it should be aligned with the organization's strategies. In order to approve the proposals a main approach is that they should be, firstly, be in accordance to the organizations' mission, goals and strategic [6].

Current literature describes various types of problems related to portfolio management, such as proposals without proper strategic alignment, high demand for funding, presenting decision-making problems, and without reliable information. All these issues are usually responsible for poor performance of the portfolio, as the projects either have low impact or present failures, above the acceptable, in their development [1; 4; 6]. One way to prevent this to happen within the organization is working effectively in the management of the portfolio in all its stages.

The preliminary analysis of the proposals that will be part of the portfolio is essential to the efficiency of the portfolio management. Therefore, classification and selection of these proposals must be a careful process, adopting clear pre-established criteria, which have the supervision of a senior manager. The authors [1] warn that determining the strategic focus of the portfolio should be conducted in a senior management levels because it involves the strategic goals of the institution.

Many organizations organize their portfolio subjectively, not adopting specific criteria or methodologies in selecting their proposals. The decision in which proposal should be funded and developed is still tied to an outsider/insider reviewer analysis, and arbitrary choice, according to the reviewer viewpoint. This exposes the project to risk, and maximizes the value assignment sometimes presenting no significant differences between the proposals, leading to difficulties in selecting the best one [6]. This subjective assessment, based on the expertise of the reviewers/evaluators is somehow essential in the evaluation process. When proposals are selected by the same criteria, using mathematical and methodological rigor it promotes more confidence to the decision makers [3].

Nowadays, there are several tools that work with the classification, selection and prioritization of proposals. One of them, developed in the 1970s, is the Analytic Hierarchy Process (AHP), a mathematical model to support decision making [9]. AHP is a method that is characterized by the ability to analyze a problem and propose a decision-making through the construction of hierarchical levels. The problem is analyzed by pre-established criteria. The criteria are decomposed into sub-criteria up to a certain level. These criteria are organized into a hierarchy descending where the ultimate goals should be at the top, followed by their sub-goals, immediately below, and, finally, the various possible outcomes or alternatives are selected. The scenarios determine the likelihood of achieving the goals. The AHP usually run from the general to the more particular and concrete goal [2; 5].

The objective of this study was to propose a methodology for prioritization and selection of proposals in a company's Research, Development and Innovation (RD & I) using the analytic hierarchy process - AHP.

2 Methodology

In this study, the criteria were selected with the application of questionnaires which were organized following the guidelines of the AHP. Five questionnaires were distributed to members of the Embrapa Information Technology Headquarters, and Internal secretary of the Technical Committee. The criteria were listed for the purpose of assisting in the evaluation of proposals to be prioritized.

The questionnaire consisted of 8 questions (yes or no options), and the evaluators could choose what they consider relevant in making a decision to prioritize research proposals. They could also add any other criteria that they found beneficial. One evaluator added four additional criteria. With that, the number of criteria was adjusted to the theory of AHP. The author [9] says that must be established between 3-7 criteria, not exceeding the number 9. The total number of criteria listed was in a total of 6 and 15 sub-criteria. The alternatives were the 6 proposals. Figure 1 shows the division of each criterion into sub-criteria in level 1 and 2, respectively.

Goal	Level 1	Level 2
Prioritizing criteria for selecting research projects	Adaptation to PDE/PDU[1]	Aligned to the organization mission Aligned to the organization strategic
	Creativity	New idea Process improvement
	Technical aspects	Team Risk Technical quality Results expected
	Budget	Organization funding Other sources funding
	Possibility of development	Product Service
	Possibility of technology transfer	Contract/patent Spin off Public knowledge

[1] Organization Strategic Programs.

Fig. 1. Scheme of the goal and the two levels of criteria adopted in the prioritization process of research projects

Pairwise comparisons were made between each pair of factors at a given level of the hierarchy in regards to their contribution to the factor at the immediately preceding level. These pairwise comparisons yield a reciprocal (*n, n*) matrix A, where

$a_{ii} = 1$ (diagonal elements) and $a_{ji} = 1/a_{ij}$. Suppose that only the first column of matrix A is provided to state the relative importance of factors *2, 3, . . . , n* with respect to factor 1. If the judgments were completely consistent, then the remaining columns in the matrix would be completely determined by the transitivity of the relative importance of the factors. However, there would be no consistency except for that created by setting $a_{ji} = 1/a_{ij}$. Therefore, the comparison needs to be repeated for each column of the matrix; specifically, independent judgments must be made for each pair. A is consistent if and only if $\lambda max = n$. However, the inequality of $\lambda max > n$ always exists; therefore, the average of the remaining eigenvalues can be used as a "consistency index" (CI; Eq. 1), which is the difference between λmax and n divided by the normalizing factor $(n - 1)$.

$$CI = (\lambda max - n)/(n - 1) \tag{1}$$

The CI of the studied problem is compared with the average random index (RI) obtained from associated random matrices of order n to measure the error due to inconsistency [9]. A consistency ratio (CR = CI/RI) with a value ≤ 0.1 should be maintained for the matrix to be consistent; otherwise, the pairwise comparisons should be revised. The homogeneity of factors within each group, a small number of factors in the group, and a better understanding of the decision problem would improve the consistency index.

After selecting the criteria, evaluators were interviewed, and then gave the scores to the 6 research projects and the calculation of the collected data was done in real-time using the online web based software [7].

3 Results and Discussion

Data from the weight given by each evaluator were organized in tables containing the criteria for the 6 projects. Mean values and standard deviation of the values were calculated for each criterion, as seen in Table 1.

Table 1. Proportional weight of the criteria adopted by the projects' evaluators (%)

Criteria	**Project**						**SD**
	A	**B**	**C**	**D**	**E**	**F**	
Adaptation to PDE/PDU[1]	29	28	30	26	29	31	2
Technical aspects	18	18	19	17	18	18	1
Creativity	11	10	12	13	11	11	1
Budget	8	7	8	8	8	9	1
Possibility of technology transfer	14	18	13	16	15	14	2
Possibility of development	19	20	18	19	19	17	1

[1] Organization Strategic Programs; SD = Standard deviation.

Total mean score of the weights were calculated and final values are presented in Table 2. The results were ranked and finally compared to the real score the research projects obtained during their previous evaluation by the research committee. Results were similar to those previously obtained, indicating that the methodology using multicriteria analysis is feasible to be used.

Table 2. Comparison of the total scores of each research project considering all criteria and the general classification

Project	Average of score	Classification using AHP	Classification by Embrapa selecting committee
A	16	4º	Rejected
B	20	1º	Approved
C	17	3º	Approved
D	14	5º	Rejected
E	14	5º	Rejected
F	19	2º	Approved

The success of project portfolio management in an RD & I organization is directly related to the adaptation to organizational strategies and innovation management. In the present study, two methods have been proposed to support the management of a portfolio of Institution RD&I proposals. This analysis was based on the retrospective aspect, as the proposals results were known. This knowledge based on specific criteria was necessary to understand the gaps in research and planning for the future of research in the organization.

The use AHP tool to assist in the prioritization criteria for proposals' portfolio management was successful. The AHP is a decision support methodology, which establishes the construction of a hierarchical structure and value judgment for decision making [3; 8]. This methodology does not eliminate the figure of the selecting committee, but it facilitates its performance, using the knowledge for the individual pairwise comparison of the criteria involved in the analysis.

The application of AHP in evaluating 6 projects enabled the prioritization of a project over another, based on technical criteria, considering both the objective and subjective views of these criteria, allowing a greater likelihood of success in project selection. To review and project prioritization, the tool proved to be adequate due to its ability to adapt to different situations that may occur in the proposals evaluation. The application of the tool in a larger set of projects with more evaluators should be considered as a continuation of this work.

4 Final Remarks

The success of project portfolio management in an RD & I organization is directly related to significant aspects, such as an adaptation to organizational strategies. We used the AHP technique to assist in the prioritization of research proposals within a project portfolio. The AHP is a decision support methodology, which establishes the construction of a hierarchical structure and value judgment for decision making. This methodology does not eliminate the figure of the reviewer, but it facilitates their performance, using his knowledge for the individual pairwise comparison of the criteria involved in the analysis.

The application of AHP in evaluating the proposals enabled the prioritization of a proposal over another, based on technical criteria. The tool proved to be adequate due to its ability to adapt to different situations that may occur in the evaluation process.

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Sustainability Issues in Brazilian Housing Construction Industry: The Role of Workers' Education

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Abstract. Brazilian housing industry is a sector that employs a large number of workers without specific technical skill or training. This contributes to the increase in waste of materials due to the limited use of new technologies. The workers low education level interferes in an effort to enhance and improve the sustainability indices in Brazil, in this business chain, which grew up about 4% per year, in the last two years. This study aimed to analyze the issues related to the sustainability of Brazilian housing industry. We compared the data from developed and developing countries, and results indicated that the amount of waste generated by residential constructions is positively correlated to illiteracy. Data on overall waste range from 10 to 30%, depending on the region, and most of it is related to lack of labor training. Improvements in this sector are needed in order to meet the sustainability demand.

Keywords: construction supply chain, education, professional training.

1 Introduction

The construction supply chain represents nearly 9% of Brazil's GDP, and it increased 4% from 2010 to 2011. The construction industry is highly demanding of labor and medium size retail businesses, and it involves a large number of small contractors. It is a growing sector as the national statistics data show an increase of 2.7 million new homes between 2009 and 2011 [1; 11]. The sustainability concepts within the housing construction industry, however, bring up some issues primarily related to the large amounts of wastes generated during the building process. There are also other issues, amongst them we can highlight the reduction in permeability of the soil, changing in drainage methods, which can cause flooding and reduce groundwater reserves; the use of illegal wood, and the improper disposal of effluents [1].

This is a relatively informal business sector, which represents a significant challenge for achieving sustainability within the process as not all steps are properly traced. Probably one of the most influential inhibitions of reducing of wastes and improving sustainability in this industry is the poor training of human resources. Dealing with aspects of sustainability it requires proper understanding of construction

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management and the use of different types of materials and components in the various stages of operation [21; 22]. The lack of innovation in products and processes, in the supply chain, make things more difficult in achieving sustainability in this sector, and it involves designers, manufacturers, facility managers and consumers who seek a more sustainable building. May we emphasize that residential construction industry is probably one of the Brazilian industries that developed less, when compared to other industrial sectors in the last years.

Although facing this scenario, there has been some progress regarding primary education of Brazilian professionals involved in construction, in recent years. According to data from the Annual Social Information of the Ministry of Labor and Employment (RAIS) the percentage of illiterates in the construction sector decreased by 60% in 9 years, from nearly 30 thousand workers (in a total of 1 million workers) in 2000 to approximately 23 thousand (in a total of 2 million in 2009). Despite the lack of official statistical data, organizations related to the Brazilian construction industry indicate that the improvement in education contributes to improve labor quality of life as it reduces the amount of accidents increases work efficiency and provides the reduction in waste and losses, in the construction sites [4].

This study aimed to analyze the issues related to the Brazilian residential construction industry, mainly those associated to the training of workers in order to minimize losses in the construction process.

2 Methodology

An extensive literature review was done on the field of residential construction industry. Data were collected from previous studies including the various phases of the construction process [1; 8; 11; 12; 19; 24].

The following questions were unfolded:

1. Is the lack of basic education a factor for increasing waste, hence the lack of sustainability in the construction process? And,
2. Does the investment in basic education (formal or technical training) improve this scenario?

We studied data from the organizations affiliated to the construction sectors [1; 8; 19; 24], and information on illiteracy (mean value from 2003-2010) were searched on regular education at governmental database, and the World Bank Report [12; 27]. GDP (% of the construction industry) data from the studied countries were obtained from [27].

As innovative initiatives are stated as an instrument of waste reduction, and it impact positively in the sustainable construction process, the following innovations used in the residential buildings were selected: 1- the use of new materials (cardboard, drywall), 2- the use of alternative source of energy (solar energy), 3- the adoption of water use reduction devices, 4- the adoption of fluorescent or LED bulb lamps in the project, and 5- broader structure of the sector supply chain. Scores were given from 0 to 2 (0= none innovation is adopted; 1= 1 to 3 innovations are adopted; 2= all five innovations are adopted) according to the degree of adoption of the initiatives by the different countries, from 1 to 5. A table was built comparing the data from the countries Brazil, Spain, United Kingdom, Portugal, Turkey, China and Japan. Pearson's correlation was applied to the values in order to determine the relationship between the percentage of residential construction waste, and the country' GDP, illiteracy (%), and the level of adoption of innovation in residential buildings.

3 Results and Discussion

3.1 Waste in the Construction Process

Generating waste is one of the main issues in the Brazilian construction industry; it consists, not just by rejected materials at the construction site, but also by losses during the building process. Wastes are inevitable when they happen by natural accidents. Losses during construction can be classified according to their control (avoidable and unavoidable) according to their nature (overproduction; substitution; waiting for, transportation, processing, inventory, the production of defective products, and others such as theft, vandalism, and accidents), to their origin in the production process, and, finally, to the processes that precede the manufacturing of materials, such as the development of human resources, design, procurement and planning [5; 9].

It is known that one of the main sources of wastage in construction today is the lack of planning on recruiting skilled labor. This lead construction engineers to increase the number of workers in order to avoid the risk of the work stops due to lack of staff [4]. Nevertheless, losses of material are positively related to waste in materials. They can be seen as unnecessary consumption of material, which results in excessive waste production as it involves future availability of materials, power demand in producing these materials, and it is related to losses in material transportation [2; 3; 13].

More recently, the construction waste was studied on the national level, where 85 worksites were surveyed from 75 construction companies in 12 Brazilian states, assessing consumption and losses related to 18 different types of materials and services. The research found a wide range of performance amongst the companies, from minimum losses (2.5%), which are similar to the best international rates, to an alarming amount of waste (133%), probably due to many mistakes committed during the construction process. There was also noted that there were differences within the same company and from one service to another. The study showed that, on average, the waste is near 10%, although it was believed to be near 30% [2]. Similar study carried out in the Northeastern of Brazil indicated that the loss ratio of construction material were mostly on sand (72%), gravel (17%), cement (18%), and concrete and steels around 11% [15; 23]. Amongst the reasons attributed to these losses there are poor transportation of material, lack of adequate equipment in the construction site, improper use of machinery to produce concrete and lack of a standardized method for receiving, controlling, storing, and transporting materials.

This information is quite different from that of developed countries. In the UK, a study was conducted with architects and contractors with the purpose of pointing attitudes to waste minimization, revealed that although many are the causes of wastes during the construction; the designer has a key role in the prevention and waste minimization [17]. The study divides into two parts to be analyzed during the first and second stage of the project (the project and the building). Although the study does not disclose the percentage or proportion of each stage of the total loss or wastage in construction, it reveals that the major source of waste is in the design stage, and it happens mostly related to the last-minute changes due to customer requests, followed by the lack in detailing and specifications. Regarding the stage of construction, where there is the action of the least skilled workers, the leading causes of wastage presented were the remnants cuttings, materials and products used, misapplication of materials, and improper storage methods [18; 17].

When comparing the data from different countries, the waste generated during the residential building was found to be positively correlated to the percentage of illiteracy (0.761), while it was inversely correlated to both GDP (-0.240) and the use of innovation during the construction (-0.767) as seen in Table 1.

Table 1. Comparison between the percentage of waste generated in residential constructions, GDP, illiteracy and adoption of innovation in construction, in developed and developing countries

Country	GDP (%)	Waste (%)	Illiteracy (%)*	Use of innovation (%; 0, 1, 2)
Brazil	4.0	10.0	11.0	0
Spain	7.0	3.0	2.0	1
United Kingdom	7.0	2.0	1.0	2
Portugal	5.5	3.0	5.0	1
Turkey	5.0	5.0	13.0	0
China	12.0	NA	9.0	0
Japan	9.0	NA	1.0	2
Pearson coefficient	-0.240	1	0.761	-0.767

* Mean values from 2003 – 2010.

A study on the levels of use of sustainability indicators between Brazilian, Portuguese and American construction industries pointed out that Portugal has more detailed set of disclosure of social, economic and environmental statistics than the other two countries [22]. Another approach is that social responsibility may also be seen inside the sustainability principles and conceptualizes as the willingness of a company to contribute to a better society and a cleaner environment [21; 6]. Brazilian companies should disclose their information on their websites about sustainability and emphasize the importance given to this issue as done in other countries.

Several methodologies were found for identifying the systematic approach for dealing with potential adverse environmental impacts at the construction stage. Some are presented as an assessment tool, to measure the environmental performance of construction activities, and it covers various categories of environmental aspects such as atmospheric emissions; water emissions; waste generation; soil alteration; resource consumption; local issues; transport issues; effects on biodiversity; and incidents, accidents and potential emergency situations [25]. In any case, the main environmental focus regarding this issue should be the prevention and reduction of construction waste generation during the residential construction [7].

3.2 How May the Worker' Education Change the Process?

There was a significant development of the Brazilian construction industries since the 90s, although there was a significant delay when compared with other industries. Facing the new demands of environmental and social responsibility the industry could not ignore the investment in proper training in order to educate their hand labor. Therefore, qualify with these new challenges, means more than just to learn production processes of construction, but also to understand the whole process, and the impact that certain actions or lack of them affect both nature and society [16]. Brazil has near 100 thousand legal construction companies employing around 2 million legal workers, including masons, carpenters, technicians, engineers, and architects. There is also a large number of informal workers, which according to [8] is about 4 million.

Brazil still lives in a profound social inequality, which can be assessed by the level of functional illiteracy (citizens with less than 4 years of formal studies) representing a total of 29% of Brazilians [12]. The illiterates citizens, who cannot read or write a coherent message in Portuguese reaches 13% of the total population of persons 15 years or older, affecting the number of workers in various activities [11]. According to the Brazilian Chamber of Construction Industry, in 2009, the relative percentage of jobs in the construction business was 7%, *i.e.* from 96 million employed Brazilians, more than 6 million were related to the construction industry [12]. In this scenario, there is the proposed federal government construction program so-called "Construction for Citizenship" which had amongst the goals, to reduce illiteracy of construction workers in their own work area, the construction sites. In doing this, it induces the necessary conditions for the professionalization action and full citizenship of this worker [25; 20].

Much of the current construction workers develop their skills by observing experienced colleagues, and they learn by repetition. As the process of repetition does not necessarily always reproduce right actions, sometimes it brings the use of poor practices. Although the construction industry fulfill a social responsibility when it employs less educated labor, it generates low productivity, waste and rework, and high rates of accidents when employing low skilled workers. There is an effect of education on the onset of labor accidents [23; 25]. The authors report that 60% of the victims had between 1 to 4 years in school, and 36% had 5-9 years in primary education. In this study, only 4% of the workers had more than 10 years of education.

It was also noted that 44% of workers had 5-9 years of study and, from this amount, only 24% had some accident at work. From the number of workers (55%) with 1 to 4 years of formal education, only 32 % of them have suffered some accident at work. This means that as the time in school increased the accidents in the work was reduced. This is the main challenge Brazilian residential construction activity has to face when meeting the demand of 28 million housing units by 2023, planned by the National Housing Plan [20].

Illiteracy was found to be positively correlated to the waste generation (Table 1) while the increase in the use of innovation decreases the amount waste (correlation of -0.767). However, the use of innovative techniques can only be applied appropriately if the workers have a certain level of education and training. One key aspect of the improvement in the construction industry is the investment in education and training of workers. Less educated workers without being able to use innovative tools may hinder their potential in producing work of quality [2]. The deficiency in reliable information is also a key factor in understanding this issue. Most construction companies do not give their actual numbers which makes it difficult for collecting data.

In order to improve Brazilian context in the Human Development Index (HDI) the government should invest in infrastructure, sanitation and housing at annual rates of 21.4%. The cities spend more than 50% of world energy sources with all its complexities [14]. The construction sector consumes 40% of the natural resources, 40% of energy and generates 40% of waste [2; 16]. Therefore, to achieve sustainability, several practices need to be adopted by the construction industry.

4 Final Remarks

The concepts of sustainable residential construction are focused on processes that favored the use of natural factors such as natural light, heat, ventilation, among others, which were abandoned with the advent of electricity and artificial heating and cooling. These concepts need to be concentrated on the lifecycle of the project, and the process of reuse of material, besides minimizing wastes in the residential construction cycle.

Several issues are involved in the Brazilian residential construction industry which may affect the sustainability of the construction process. Amongst them, there are the proper regulation, and workers education and training. Implementing appropriate actions related to those two items would increase today's incipient applications of sustainability principles in this industry in most developing countries.

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An Innovative Way to Add Value to Organizations: People Relationship Modeling

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Abstract. Communications agencies are private organizations that have a fundamental role in marketing and communication markets. Following this perspective, this study, with the support of Social Network Analysis tools, the structure of an agency will be modeled with the purpose of identifying the most important actors and its relationships, and show its interdependence with the workflow of the production chain. To achieve compatible results with the organization goals, it is important that their areas or teams relate with one another so as to optimize their production processes. With support of the Ucinet® software and its integrated module NetDraw®, this paper describes through a case study, how to implement this innovative approach and follow the evolution of the network in order to improve their operational performance. The results pointed out an increase in productivity after the analysis and change in the organization's internal communication.

Keywords: Social network analysis, Process innovation, Organizational structure.

1 Introduction

According to the Brazilian Association of Advertising Agencies (ABAP), Brazil is the sixth advertising market worldwide [1]. According to data from the Brazilian Institute of Public Opinion and Statistics (IBOPE), the activities directly related to advertising in 2011 generated R$ 88.32 billion in revenues and represented 2.13% of the Brazilian Gross Domestic Product (GDP) [2]. The Brazilian Geography and Statistics Institute (IBGE) disclosed that the Brazilian GDP in 2011 was R$ 4.15 trillion [3]. The communication chain is basically made up of four groups of actors: the advertiser, the communication agency, the media vehicles and the market, which here includes the consumer public. According to Corrêa [4], each group has its share of responsibility and contribution toward making the communication process a success, as can be seen in figure 1.

According to Corrêa [4], the communication chain is dynamic and has a direction of motion that represents a process aimed at reaching the market efficiently. This motion is also made up of a feedback, which has as result a cycle that keeps the chain always adjusted to the reality. The role of the communication agency is to develop communication campaigns, which can be in the form of: advertising; promotion;

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public relations; direct marketing and events. Its main objective is to take the client's message to the desired public [5].

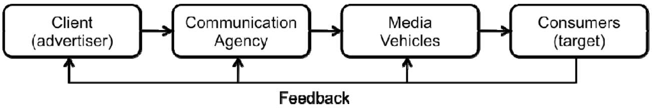

Fig. 1. Communication chain (Source: Adapted from Corrêa [4])

The development of communication products/services, especially in scale, involves work teams with different professional profiles that work simultaneously and create mutual interferences during practically all stages of a job, which must be managed and coordinated over time. Formal tools and techniques are required to assure that the job will attain its objectives and is completed in time and within the budget. However, the network analysis approach can be applied to contribute toward management of the production chain of communication agencies to provide a more efficient environment for leaders to understand and add value to their companies [6].

According to Cross and Thomas [7], the social network analysis approach can drastically improve performance in the vital areas of an organization. This perspective allows leaders to identify key points of collaboration and weak points in their organizations so as to control critical points related to value creation. A network is made up of nodes and links interconnecting the nodes. The nodes can be called actors, who may represent individuals or organizations, while the links represent the relationships between them.

According to Granovetter [8], the concepts used in the intra-organizational networks are related directly with analysis of interpersonal networks, even because they were originally conceived in a context of how relations between people occur. Processes analysis in interpersonal networks provides the best view of how the relations between micro and macro interactions occur. One way or another, it is through these networks that the interaction in small scale is converted into large-scale standards, and these, in turn, feedback the small groups.

The networks help people to attain to an objective that they cannot attain alone. In this wise, all will benefit from the network. However, they must also collaborate to ensure it remains healthy and productive [10].

According to Cross and Thomas [7], leaders who notice how networks work will be able to increase the organization's competitive advantages, producing differentiated results like increase in income, efficacy, cost reduction and even innovative solutions. According to Cross *et al.* [10], it is important to find ways to help people become better connected, thus the organization will be able to obtain the real benefits of its expertise more efficiently.

According to Corrêa [4], the essential departments for an agency to exist and operate include: administrative; attendance; planning; media; creative and production. In this configuration, the administrative department covers the following areas: management, financial, accounting, legal, human resources, purchases, stock control, office services and information technology.

For agencies to obtain results compatible with their goals, it is important for their areas to relate with one another so as to optimize their production processes. On understanding how knowledge flows through the various borders of an organization, it is possible to obtain an understanding of how the management should direct its efforts to promote collaboration, which will have a strategic return for the organization [10].

Currently, internal communication really appears as a function of the company at the same level as production, financial administration or personnel management [11]. According to Kotler [12], the management models adopted by organizations directly influences the communication model. The participative models are based on broad communications, aiming at sharing information and knowledge, while organizations based on a strong hierarchic structure of control tend to have little communication.

Communication is a “mean” and not an “end” activity, which provides service to other areas of the organization. Communication, both internal and external, gives the organization consistency and organicity. Internal communication integrates all communications that take place in the organizational system, giving support to decisions, grouping networks, objectives, norms, policies, programs, directives, among others. The primordial function of internal communication is to establish the official process through which the organization and its internal public communicate [12].

The communication flow in a business process model can be defined as the level in which the model clearly shows how the communication interactions (e.g., face to face, e-mail, internal memorandums, workflows) occur in a business process [13].

For an internal communication policy to be successful, it must be strategically aligned with the organization’s values and culture, as well as with its operational structure. According to Kotler [12], lack of communication alignment can have as result a drop in the productivity of employees due to the incoherence of messages and, on the other hand, in the external plane, the organization can also lose credibility before other stakeholders (clients, suppliers and investors). Thus reducing its profitability.

The objective of this research is to apply social networks analysis (SNA) to one of the actors responsible for the communication chain: the communication agency, where the network’s internal connectivity characteristics will be surveyed, relating the performance of three specific areas with the number of interactions among its actors.

2 Methodology

The study was conducted in a small agency (under 20 employees). To evaluate the production process in a consistent way, one single type of material was used in the survey: the development of simple printed material. In order to align the production process with the workflow, data collection was performed surveying all interdepartmental interactions during the production of each job, recorded in their internal management system. To conduct the case study, the methodological research approach suggested by Miguel *et al.* [14] was used. Figure 2 shows the internal information flow of the communication agency, considering its departments.

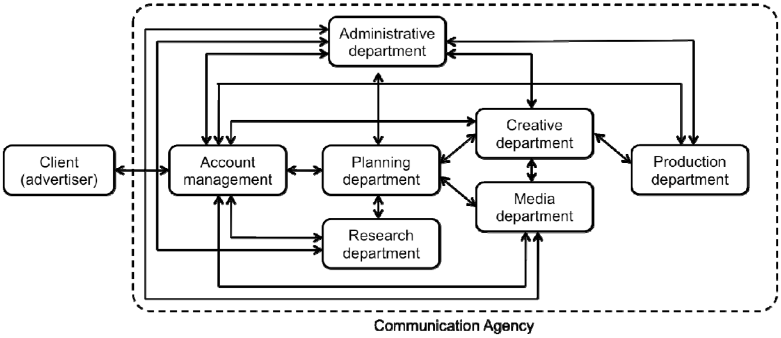

Fig. 2. Communication agency information flow

All jobs with the same technical description were raised, within the range of one month (month 1), totaling 19 jobs. Of all materials developed, 13 were delivered within the estimated time (68.42%) and 6 were delivered out of the estimated time (31.58%). In this analysis, was made an arithmetical mean of the number of interactions of each actor, for the two possible situations: jobs that were delivered on time and jobs that were not delivered on time.

The actors involved in this study are respectively: attendance, creative, production and client (external). In figure 3 it is possible to visualize the production process workflow of printed materials. Based on this workflow is that all data were collected in the survey.

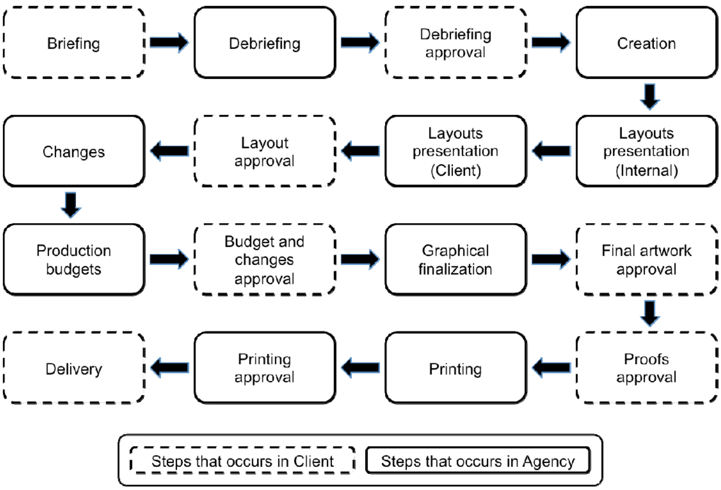

Fig. 3. Printed materials workflow of the communication agency

The aim was to inspect the interactions, identifying the actors and their respective relations. These relations among the actors allowed identification of the relationships weights, and are based on the number of interactions made between one department and another, during the production process. According to Lazzarini [15], to map out the network analyzed, the concept of groups will be used, which is defined as a finite set of actors delimited by conceptual, theoretical or empirical criteria on which the network measurements are based. Understanding the relationship process of actors is crucial to understanding its dynamics and to obtain efficiency in its operational results.

Both the network structure and position of the actors can affect the organization's functioning and its abilities to create value for the company [15]. Connectivity, which is able to interconnect each one of the network's individuals, can be represented by the intensity and frequency of communication among the actors [16].

To evaluate the network studied, two structural indicators were chosen: overall density and Freeman's degree centrality measures [15]. In this research, the degree centrality and density indicators were established using the theory of graphs in the Ucinet® software and its integrated module NetDraw®, which allows the viewing of data in graphical format [17]. According to Coleman *apud* Lazzarini [15], dense networks allow maximum information flow among the actors. The value of the density measurement is obtained from the number of ties observed divided by the maximum number of ties the network can have. The degree centrality indicator evaluates the number of ties that an actor has with other actors of the network. The more centrally positioned in the network, the more capacity will this actor have to access other actors of the network [15].

Based on the obtained indices was possible to relate them with the performance of the evaluated network in order to give information to the management team, and therefore, generate corrective actions in the production chain. After analyzing the first month (month 1) some actions were taken, which generated an improvement in the delivery of the jobs in the following month (month 2).

3 Results and Discussion

The intra-organizational network graph of the agency, shown in Figure 4, was obtained from the data of the actors and their ties in module NetDraw® [17].

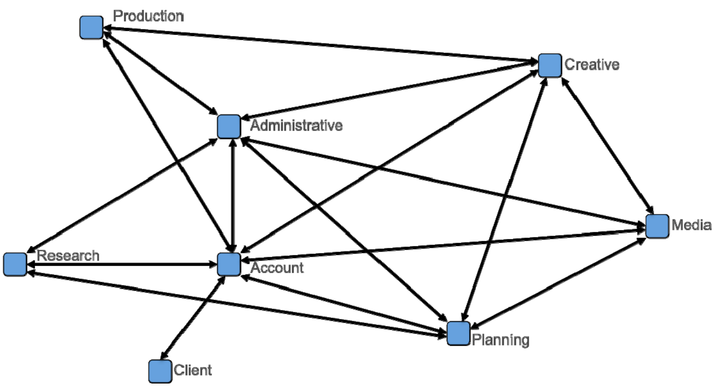

Fig. 4. Network graph obtained using the software Ucinet® and its module NetDraw®

After processing data with the NetDraw® module, two different networks were found: one related to jobs delivered on time and another related to jobs delivered after the deadline. Figure 5 shows the relationships identified according to the number of times that each actor enters in contact with other network actor. The properties of the actors were adjusted and arranged according to their geodesic structure and their links according to their strength. The construction of both networks was done identifying the interactions between the actors of the network in order to present a comparison of the operational response found in both situations.

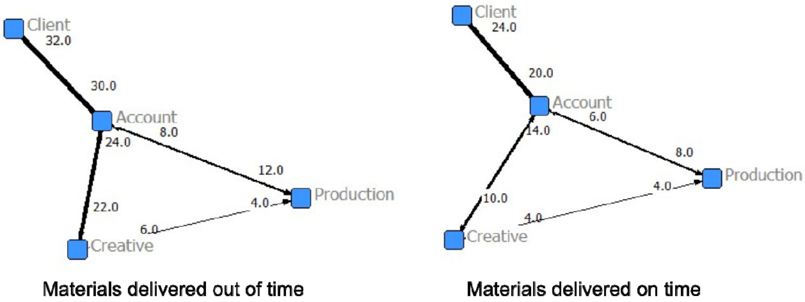

Fig. 5. Networks obtained using data collected in month 1

After processing the data with the module NetDraw®, the weights of relations between the participating actors were processed with the software Ucinet®, so the parameters that describe the networks analyzed were found. Table 1 presents the structural data (Freeman's Degree Centrality Measures and Overall Density) of the evaluated networks. In this way, the key player of this network, in terms of interactions (centrality), is the account management area. It has an input degree of 42.00 and a 40.00 degree output for materials delivered on time, and an input degree of 66.00 and a 62.00 degree output for assignments delivered after the deadline.

Table 1. Structural data of the evaluated networks

Network	Centrality (OutDegree)	Centrality (InDegree)	Density
Materials delivered on time			1.6071
Account	40.00	42.00	
Client	24.00	20.00	
Creative	14.00	18.00	
Production	12.00	10.00	
Materials delivered out of time			2.4643
Account	62.00	66.00	
Client	32.00	30.00	
Creative	28.00	28.00	
Production	16.00	14.00	

This study sought a better understanding of the relation between the actor's relationships and the performance of the production chain. For this purpose, have been found indicators that reflect the network with high density and degree centrality. The actual structure of the network provides a unique view of the client, by the attendance area (account management). Due to this view, which is not shared with other actors, the jobs end up having a high rate of rework and consequently are delivered out of the schedule. Analyzing the density indicator for materials that were delivered out of time is perceived an increase due to the various interdepartmental interactions generated from the rework process.

From the point of view of network resources, internal connectivity should be dense, but not redundant, within the limits of the organization, this analysis is consistent with the citation of Cross and Thomas [7] and Freeman *apud* Lazzarini [15]. This way, due to the optimization of the internal connectivity, organizations can achieve better results in their production processes.

Based on obtained results, the organization management team tried to bring the creation and production departments closer to the client, through face meetings, with the objective of minimize the high degree of centrality of the attendance department, and also reduce the network density index. After this directive, a new survey was made in the following month (month 2) in order to monitor the indexes of the developed jobs. All jobs with the same technical description were raised, totaling 18 jobs. Of all materials developed, 16 were delivered within the estimated time (88.89%) and 2 were delivered out of the estimated time (11.11%). Comparatively, there is a decrease of 64.82% in jobs delivered out of time during month 1 in relation to month 2, and an improvement of 29.92% in jobs delivered on time, which can be seen in Table 2.

Table 2. Indexes of developed jobs

Developed jobs	Month 1	Month 2	Difference
Materials delivered on time	68.42%	88.89%	↑29.92%
Materials delivered out of time	31.58%	11.11%	↓64.82%

The authors Cross *et al.* [10] affirm that social networks, apparently invisible, are fundamental to the performance and execution of business strategy. Thus, the results confirm that, with an appropriate connectivity within the organizations, we can have a significant impact on efficiency and innovation.

4 Conclusions

Through social network analysis techniques it was possible to evaluate how the production chain of a communication agency behaves through its network structure. The results show the necessity of identifying points of knowledge sharing within the organization that have strategic importance. The organization management can better understand how their daily tasks behave, and from that moment, seek better ways to use their social capital to leverage an increase in operational efficiency [7].

To improve individual performance indicators it is necessary to seek, within the network, knowledge of the best techniques and procedures, and through a more efficient internal communication, distribute it to all employees. In this context, it may be more effective to engage in processes that help promote lateral connectivity, so the group can leverage their collective intelligence [6].

So, for this organization to obtain a competitive gain it will be indispensable to improve its internal structures to increase collaboration between actors, reducing borders and bringing people closer together to generate a better knowledge flow.

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Reaching Energetic Sustainability through a Self-oriented Battery Charger, Based on Paraconsistent Annotated Evidential Logic Eτ

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Abstract. The growing demand for simple solutions to the problems faced by people in different situations has led many to an ongoing effort to improve techniques and processes, with a very high tendency to develop self-sustainable devices, aiming to generate reduced environmental impact with optimum results. At this point, there is the supply of electricity on places where this is not available. In these cases, normally the solutions most commonly adopted generate high environmental impact, since working with the burning of fossil fuels, with consequent carbon emissions.

Through the Library and Experimental Research, it was possible to develop the idea which fits within the proposed needs. This article aims to present the idea of a battery charger with solar panel auto-rotatable with working independent of any type of outlet, and provides income support to any charger designed to operate on the grid, with advantage of reduced environmental impact.

Keywords: Sustainability, Energy, Battery Charger, Paraconsistent Annotated Evidential Logic Eτ.

1 Introduction

In modern times, a growing demand for new technologies is largely visible, plus a great effort on improving techniques and manufacturing processes, disposal and power generation, aiming an environmental impact as low as possible, bringing into account the concept of sustainability, and combining maximum output results with minimum losses to the environment.

In contrast to this scenario of great development, cases of very scarce resources are not rare, particularly in locations distant from urban centers, and therefore devoid of many of the advantages offered by them. One of the most important of these resources

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is the electricity, often unavailable because of the distance between distribution networks and the locations itself, or even because the great importance of the local ecosystem, causing the impossibility to build any type of network. [1]

The solutions adopted in these cases, normally results in high environmental impact. Generators and combustion engines, or even gas and kerosene lanterns, offers physical risks to those who handle them, in addition to high greenhouse gas emissions. An interesting method for obtaining energy without burning fossil fuels is through the sunlight. Supply only implies in the cost of equipment (and not the power generation itself), and no carbon is liberated during operation.

One important problem is related to the positioning of the solar panel, which is often fixed and does not have the ability to follow the natural movement of the sun throughout the day. There is an option to circumvent this problem by using a timer-controlled servo, which puts the panel on pre-set positions, but this may not match the actual position of the sun.

By using an agent system, and connecting sensors and actuators to the panel, it is possible to obtain a correct positioning of it. This alternative combined with the use of Eτ logic on the decision-making process by the agent, seeks to provide an optimal performance by positioning the panel in an optimized way. The design of the self-sustainable battery charger now proposed is intended to power small devices of everyday use, by charging batteries that can be used in various applications, thus eliminating the solutions already mentioned and consequently reducing the environmental impact.

2 Paraconsistent Logic

2.1 Historical Background

The Genesis of Paraconsistent Logic, originated in 1910, by the work of logicians N. A. Vasil'év and J. Łukasiewicz. Although contemporaries, they had no personal contact, developing their research independently. In 1948, Jaskowski, encouraged by his professor Łukasiewicz, discovered Discursive Logic, Vasil'év wrote that "similar to what happened with the axioms of Euclidean geometry, some principles of Aristotelian logic could be revisited, among them the principle of contradiction" [5].

Both logicians, Vasil'év and Łukasiewicz, cared more about a possible exception to the principle of Contradiction, but stopped short of building systems that would take out this possibility. Alongside the works of Jaskowski, the Brazilian logician Newton C. A. Da Costa started in 1954 studies that could lead to construction of logical systems that could deal with inconsistencies.

Going beyond the work of Jaskowski, Da Costa has extended its systems for the treatment of very special cases, having been recognized for it as the introducer of Paraconsistent Logic; Abe [4], also a Brazilian logician, set several other applications of Annotated Systems, specially Logic Eτ, establishing the basic study of model of Model Theory and the Theory of Annotated Sets.

2.2 Certainty and Uncertainty Degrees

Founded on the cardinal points, and using the properties of real numbers, is possible to build a mathematical structure with the aim of materializing how to manipulate the mechanical concept of uncertainty, contradiction and paracompleteness, among others, according to figure 1.

Such mechanism will embark, of course, somehow the true and false states treated within the scope of classical logic, with all its consequences. To this end, several concepts are introduced which are considered "intuitive" for the purpose above:

Perfectly defined segment AB: $\mu + \lambda - 1 = 0; 0 \leq \mu, \lambda \leq 1$
Perfectly undefined segment DC: $\mu - \lambda = 0; 0 \leq \mu, \lambda \leq 1$

The constant annotation (μ, λ) that focus on the segment has completely undefined the relationship $\mu - \lambda = 0$, ie $\mu = \lambda$. Thus, the evidence is identical to the positive evidence to the contrary, which shows that the proposition $p_{(\mu, \lambda)}$ expresses a blurring. It varies continuously from the inconsistency (1, 1) until the paracomplete (0, 0).

Since the constant annotation (μ, λ) that focus on the segment has clearly defined the relationship $\mu + \lambda - 1 = 0$, ie $\mu = 1 - \lambda$, or $\lambda = 1 - \mu$. Therefore, in the first case, the favorable evidence is the Boolean complement of contrary evidence and, second, the contrary evidence is the Boolean complement of favorable evidence, which shows that the evidence, both favorable and contrary 'behave' as if classic. It varies continuously from the deceit (0, 1) to the truth (1, 0).

The applications are introduced as follows:

$G_{ic}:[0, 1]\times[0, 1] \rightarrow [0, 1]$, $G_{pa}:[0, 1]\times[0, 1] \rightarrow [-1, 0]$, $G_{ve}:[0, 1]\times[0, 1] \rightarrow [0, 1]$, $G_{fa}:[0, 1]\times[0, 1] \rightarrow [-1, 0]$.

Defined by:
Inconsistency Degree: $G_{ic}(\mu, \lambda) = \mu + \lambda - 1$, since $\mu + \lambda - 1 \geq 0$
Paracompleteness Degree: $G_{pa}(\mu, \lambda) = \mu + \lambda - 1$, since $\mu + \lambda - 1 \leq 0$
Truth Degree: $G_{ve}(\mu, \lambda) = \mu - \lambda$, since $\mu - \lambda \geq 0$
Falsehood Degree: $G_{fa}(\mu, \lambda) = \mu - \lambda$, since $\mu - \lambda \leq 0$

It is seen that the Accuracy Degree "measures" how an annotation (μ, λ) "distances" from the segment perfectly defined and how to "approach" of the state, and the true degree of Falsehood "measures" how an annotation (μ, λ) "distances" from the segment perfectly defined, and how to "approach" the false state.

Similarly, the inconsistency degree "measures" how an annotation (μ, λ) "distances" from the segment undefined and how "close" it is from the inconsistent state, and degree of Paracompleteness "measures" how an annotation (μ, λ) "distances" of the segment undefined, and how "close" it is from paracomplete. Is called G_{in} uncertainty degree (μ, λ) from an entry (μ, λ) to any of the degree of inconsistency or paracompleteness. For example, the maximum degree of uncertainty is in an inconsistent state, ie $G_{ic}(1, 1) = 1$.

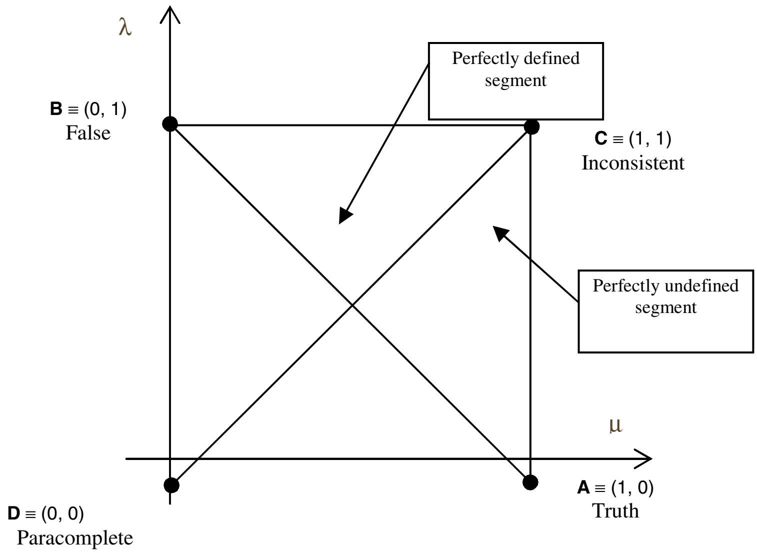

Fig. 1. τ Reticulate [3]

It is called the Certainty Degree G_{ce} (μ, λ) of an annotation (μ, λ) to any of the degrees of truth or falsity.

2.3 Decision States: Extreme and Not-extreme

With the concepts shown above, it is possible to work with "truth-bands" rather than the "truth" as an inflexible concept. Perhaps more well said that truth is a range of certainty with respect to a certain proposition. The values serve as a guide when such a proposition is considered; for example, "true" in order to make a decision positively, and so on. The extreme states are represented by Truth (V), False (F), Inconsistent (⊤) and Paracomplete (⊥); and the not-extreme logical states by the intermediate areas between the states. The areas bounded by not-extreme values depend on each project.

2.4 Applying the Logic Eτ to the Agent System

Starting from the principles shown above, the agent system works based on the readings of a photoresistor, which works as a lightening sensor, attached to the solar panel and providing to the controller board the light values as voltage levels between zero and 5 volts, corresponding to each position. To work with such values by using the Logic Eτ, the agent system uses a "Para-Analyzer" algorithm, developed by Brazilian logician Newton C. A. da Costa, which is able to express the paraconsistent analysis by treating the favorable and contrary evidence degrees, providing a 12-digit binary word where a single active digit, which represents the logical state of the resulting analysis, plus an analog output, represents the certainty and contradiction values.

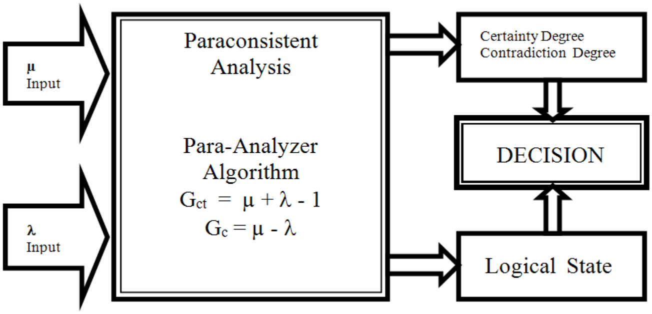

Fig. 2. Schematic of "Para-Analyzer" algorithm [4]

The operation of the algorithm is detailed in Figure 2. In order to obtain from the sensor the input values of favorable and contrary evidence, it was determined experimentally that reading values below 2.5V will represent the contrary evidence, and above it, favorable.

The system works as follows in the activity diagram of figure 3, which shows the steps performed by the software in its operation:

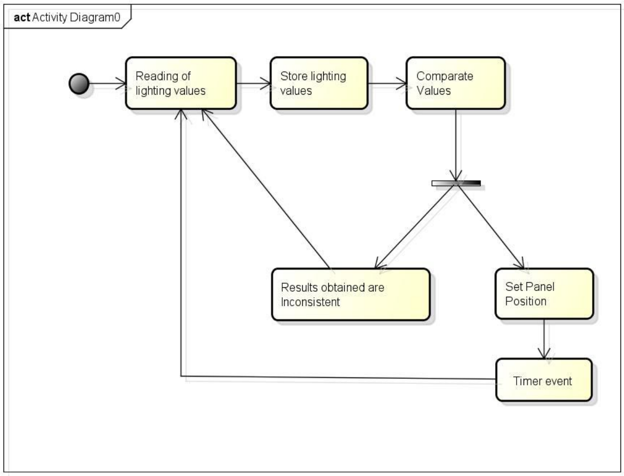

Fig. 3. Activity diagram, showing the work of the Agent system

3 Controller Board and Electronic Circuit

The solar module used is capable of supplying a voltage of 17.5 V with maximum current of 286mA. With relatively small dimensions (338mm x 315mm x 18mm), it provides an effective charge to the battery, optimized by the self-orientation system. For the section of the controller board, responsible for the embedded software, was chosen the Arduino Duemilanove model, based on the ATMEGA168, a simple and versatile microcontroller.

The sensor is positioned next to the solar panel, and provides an idea of the position of the sun to the controller board. As actuator, a low cost servo motor has been chosen, connected mechanically to the solar panel through a pair of tipper gears. An analog regulator provides adjustment of the load current, adapting it to the battery used, a small 12V sealed lead acid (SLA), operating under cyclic charge. A second battery, maintained under continuous charge, provides the energy for operating the positioning system. The use of lead acid type batteries is providential, as most readily available and low cost rechargeable types.

4 Conclusion

In times of a growing technologies and optimized systems, there are still situations of extremely scarce resources, especially in distant places. One of these important resources is the electricity, often not available due to reasons like great distances and importance of local ecosystem. Normally, solutions adopted in these cases are not self-sustainable.

This paper aims to propose a low-environmental impact alternative for powering small devices in places where the electricity is not available. The proposed charger is capable to work without consuming any fuel, thus without release of carbon. The use of Paraconsistent Annotated Evidential Logic Eτ in the decision-making process by agent system, seeks to provide an optimal performance by positioning the panel in an optimized way, extracting maximum performance of a relatively small solar panel.

It is not intended a comparison between the model here proposed with any other similar solutions, based on different systems or even in Classical Logic, since that constitutes object for new iterations, following the present paper on the future.

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Program Inovar-Auto, Initiatives toward Innovation and Competitiveness in the Automotive Sector in Brazil

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Abstract. This paper aims having an understanding of the actual scenario of loss of competitiveness of the Brazilian industrialized goods, in specific of the automotive sector that has been suffered effects since global financial crisis of 2008. The paper is an exploratory research and seeks having overview of the Program "Inovar-Auto", a new regulatory policy for the automotive sector, that became decree number 7819 published in 3rd of October of 2012. With the program, it is observed opportunities and counterpart toward actions of innovation, competitiveness and sustainability of the sector in Brazil.

Keywords: Innovation in developing countries, competitiveness, industry tax benefits.

1 Introduction

The global financial crisis of 2008 has put in evidence the technological and competitive brittleness of the vehicles produced in Brazil. The trade balance of the sector, formerly positive, became adverse as from 2008, which can be observed in the Table 1.

Aware of the situation, authorities decided to introduce the program "Inovar-Auto", a set of policies that create tax reliefs to car manufactures, who decide to invest in the local production and in the development of the whole productive chain [2] [3].

Table 1. Trade Balance – Brazilian Automotive Industry. Adapted from [1]

Period	Trade Balance - Automotive Industry - US$ million		
	IMPORTS	**EXPORTS**	**BALANCE**
2004	4750	8383	3633
2005	6191	11442	5251
2006	7150	12308	5158
2007	10327	13461	3134
2008	16372	14012	-2360
2009	12459	8318	-4141
2010	18247	12843	-5404
2011	24301	16230	-8071

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The main targets of the program are: create favorable conditions of competitiveness to companies produce cleaner and safer vehicles; invest in the local supply chain through suppliers enablement and in product and industrial engineering and incrementing actions of R&D local [2] [3].

2 Objectives

The objective of this paper is to present the opportunities, the challenges and the counterparts deriving of the creation of the program "Inovar-Auto" of the Brazilian federal government, in force to the period between 2013 and 2017.

Besides, having an understanding of the necessary outlays and investments, demanded to suit the goals of the program.

3 Methodology

The methodology applied for this research is exploratory, based in bibliographic review and secondary data collected through the information obtained among the Inovar-Auto decree, ANFAVEA (National Association of Auto-motor Vehicles Producer) and its annual report; OICA (Organization of Motor Vehicle Manufacturers); MDIC (Ministry of Development, Industry and Foreign Trade) constitute the basis for this study.

4 Results and Discussion

Through the analysis of the content of the decree number 7819 published in 3rd of October 2012, shall be deemed to be enabled companies that produce, in the country, motorized vehicles; companies that do not produce, but commercialize in the country such products; companies that have approved investment plan to install factories; or to the ones that are already installed that have approved investment plan to create new plants or industrial projects to produce new models [2] [3].

According to [3], the habilitation to the program shall be requested to MDIC and shall be granted jointly by the Minister of Development, Industry & Foreign Trade and the Minister of Science, Technology and Innovation. Its validity is for a period of 12 months and may be requested the extension to another 12 months, at the end of each period and limited to 31st of December of 2017.

The general conditions to the habilitation are: regularity with respect to federal taxes; commitment of the applicant company to achieve minimum levels of energy efficiency [3].

The specific conditions describes necessary actions for each case of habilitation, like described: companies that produce, in the country, motorized vehicles; companies that do not produce, but commercialize in the country such products; companies that have approved investment plan to install factories; or to the ones that are already installed that have approved investment plan to create new plants or industrial projects to produce new models [3].

Companies that have approved investment plan to install factories or the ones that plan to create complementary or new plants shall observe that the habilitation will be specific and issued to each factory, plant, or industrial project that is intent to be installed. Always, observing the condition that the license is valid for 12 months. In this case, the extension is only permitted to another 12 months, provided that in compliance to the plans of installation and capital expenditure. Finally, the investment plan shall contemplate the technical descriptions of the vehicles to be imported and produced [3].

The habilitation of the brands that do not produce, but commercialize vehicles in the country is conditioned to the company's commitment in comply with the requisites described in the Table 4, Table 5 and Table 6 of this paper.

Automakers that install production plants after 2013 will have to follow the targets related to local production and minimum amount of manufacturing processes; outlays in engineering and R&D; and energy efficiency. The targets are respectively described in Tables 2, 3, 4, 5 and 6. The compliance to the goals of the program that are related to the year 2013 shall be postponed to first calendar-year of the habilitation; the targets for 2014 in the second calendar-year of the homologation, consecutively until 2017 [3].

To the companies that are already installed in Brazil, the main condition to the license shall be subjected through the company's compliance in performing locally, directly or through third parties, the minimum amount of manufacturing activities, infrastructure and engineering, according Table 2 of the processes listed in the Table 3, in at least eighty percent of vehicles manufactured.

Table 2. Minimum amount of manufacturing activities to be locally performed.Adapt from [3]

Period	Vehicles		
	Passenger Cars and Light Commercial	**Trucks**	**Powertrain aggregated in Chassis**
2013	6	8	5
2014	7	9	6
2015	7	9	6
2016	8	10	7
2017	8	10	7

Thereby, the Table 2 represents the number of processes, for each vehicle category, that the company must fulfill in every calendar-year, until 2017. So forth, the Table 3 lists the processes that the company shall select to fulfill the requisits of Table 2.

Table 3. List of manufacturing process required per vehicle category. Adapt from [3]

Processes	Vehicles		
	Passenger Cars and Light Commercial	**Trucks**	**Powertrain aggregated in Chassis**
Stamping	X	X	
Welding	X	X	X
Corrosion treatment and painting	X	X	X
Injection of Thermoplastics	X	X	X
engine manufacturing	X	X	X
Manufacture of gearbox and transmission	X	X	X
Assembly of steering and suspension systems	X	X	X
Assembly of electrical system	X	X	X
Assembly of brake system and axles	X	X	X
Assembly, final check and compliant trials	X	X	X
Laboratory for development and tests of products	X	X	X
Chassis and cabin assemblage		X	X
Monobloc production or chassis assemblage	X		
Final assemblage of cabins with installation of finishing acoustic and thermic items		X	
Body production preponderantly through parts stamping regionally		X	

Additionally, the companies that are already installed in Brazil must meet at least two of the following requisites:

1- Accomplish, locally, minimum outlays in R&D corresponding to the company's revenue, according to the following schedule in Table 4:

Table 4. Minimum outlays in R&D required to fulfill requisites of Inovar-Auto program (based in company's turnover). Adapt from [3]

Period	Outlays in R&D based in company's turnover
	Percentage
2013	0,15%
2014	0,30%
2015	0,50%
2016	0,50%
2017	0,50%

2- Perform, locally, minimum outlays in engineering, industrial technology and capacitation of suppliers that correspond to a percentage of firm revenue, according to the following schedule in Table 5:

Table 5. Outlays in engineering, industrial technology and suppliers enablement required to fulfill requisites of Inovar-Auto program (based in company's turnover). Adapt from [3].

Period	Outlays in engineering based in company's turnover
	Percentage
2013	0,50%
2014	0,75%
2015	1,00%
2016	1,00%
2017	1,00%

Note that the expenditures related to R&D and engineering described in the Table 4 and Table 5 shall be performed either directly; or via a contractor; finally, through universities; institutions of research; companies that has a determined specialization and independent inventors.

3- Adhere to the program of energy efficiency and carbon emission labeling determined by MDIC to be controlled by INMETRO (National Institute of Metrology, Quality and Technology), with a percentage of products according to the schedule in Table 6.

Table 6. Volume of products to be adhered to the program of energy efficiency and carbon emission labeling. Adapt from [3]

Period	Minimum amount of products adhering emission labeling
	Percentage
2013	36%
2014	49%
2015	64%
2016	81%
2017	100%

The adhesion to the program of energy efficiency and carbon emission labeling, the applicant company must fulfill levels of energy efficiency and autonomy expressed in kilometers per liter (Km/L), or in energy consumption expressed in mega-joules per kilometer (MJ/Km). Measurements and instrumentation procedures must be according to the standard ABNT NBR 7024:2010 [3] [4].

In order to fulfill the requisites of the program Inovar-Auto, the applicant company should be able to achieve until 1st of October 2017 levels of energy consumption not higher than the following equation:

$$CE_1 = 1{,}155 + 0{,}000593 \times M_{\text{applicant}}$$

CE1: Energy consumption limit to apply for the program Inovar-Auto.
$M_{\text{applicant}}$: average weight in Kg per gear of the all vehicles sold by the company weighted by the number of vehicles sold in the 12 months prior [3] [4].

The application to the program Inovar-Auto and the compliance to its requisites will ensure a tax relief up to 30%. The benefit will be applied as presumed credit in the IPI (tax over industrial production) and it will be calculated by multiplying the coefficients presented in Table 7 with the values of the expenditures made with strategic supplies and tool-shop, defined in the Table 3.

Table 7. Coefficient applicable over expenditures with strategic supplies and tool-shop [3]

Period	Presumed credit coefficient to be applied
	Coefficient
2013	1,30
2014	1,25
2015	1,15
2016	1,10
2017	1,00

From 1st of January 2017 until 31st of December 2020 the companies will be entitled to have IPI relief of 1% or 2% according to the levels of energy efficiency achieved.

The following equation describes the level of energy efficiency to be achieved until 1st of October 2016, in order to have an IPI relief of 2%, from 1st of January 2017 to 31st of December 2020:

$$CE_1 = 1{,}067 + 0{,}000593 \times M_{\text{applicant}}$$

The next equation describes the level of energy efficiency to be achieved until 1st of October 2016, in order to have an IPI relief of 1%, from 1st of January 2017 to 31st of December 2020:

$$CE_1 = 1{,}111 + 0{,}000593 \times M_{\text{applicant}}$$

5 Conclusion

In summary, with the introduction of the new program, Brazilian authorities uplifted by 30% the IPI of all vehicles commercialized in Brazil. In the other hand, companies that stay in compliance to the Inovar-Auto requisites will be able to have a tax benefit in equal percentage, during the period of the program duration, which means, 1st of January 2013 until 31st of December 2017. From 1st of January of 2017, add up the incentives related to the energy efficiency that can elevate the benefit in 1% or 2%.

However, from 1st of January 2018, the IPI burden will be reduced to prior levels and the only tax incentive, from that, will be granted based in the energy efficiency.

Historically, concerns in Brazil, as well as in other developing countries, have been in how to boost its industry through more innovative and competitive products has been focus of governmental actions in favor of technological development combined to industrial applications. It is in according with [5] [6] [7] [8].

It should be taking into account the Schumpeterian vision that economic growth and trade performance are normally related to activities in industries of technology intensive [5] [9].

The understanding of this research is aligned with [9], ergo, in a country, where the automotive industry is constituted in majority by foreign multi-national companies, the program Inovar-Auto seeks to attack the lack of continuity and long-term commitment due to political and economic issues that has been one of the main obstacles the country to sustain its industrial development.

The results of the new program are still uncertain, once, its requisites create barriers in opposition to the free trade. Nevertheless, the internal market is significant and this can be observed in a surveying from [10] that appoints to investments around USD 33 billion until 2017 to meet the requisites of the new legislation, which, nearly USD 24 billion are the investments in course or forecasted by vehicle manufacturers and USD 9 billion by the system and auto-parts manufacturers.

The condition that stipulates minimum amount of expenditures with R&D and engineering, gives the opportunity to do it directly or through third parties. The initiative indicates a potential problem related to engineering resources, presented in [2]. The indication derives from the fact that the sector revenue and extrapolated revenue to the next years until 2017. The volume increase that is objective of the program and estimations from [1] and [10] appoint to investments in engineering and R&D around USD 14 billion.

Another important issue is energy efficiency, and its definition is according to [12], which means, the rationalization of energy and it is based on the laws of thermodynamics. Energy efficiency includes the set of actions of rationalization, leading to the reduction of energy consumption without loss of quantity or quality of goods and services produced, or the comfort provided by energy systems used. Thus, one can say that energy efficiency is an activity that seeks to optimize the use of energy sources. So, in line with [13], both, energy efficiency as renewable energy are considered the two pillars of sustainable energy policy.

With the implementation of Inovar-Auto, automakers will be entitled to benefits such in the case of achieving energy efficiency levels, for example, vehicles of the new system will have to consume, by 2017, 12% less fuel than current products.

Through the data obtained from [13], the paper concludes that the energy efficiency requisites are still shy and not aligned with the requisites of countries that are integrating the group of the biggest world car markets, who have already adopted mandatory energy efficiency measures for at least three decades.

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Increasing the Sustainability of Pasta Production through a Life Cycle Assessment Approach

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Abstract. Barilla put forth a project to increase the use of cereal sustainable cropping systems. The first part of the project was focused on identifying potential improvements in the most diffused cropping systems for the cultivation of Durum wheat in Italy, while maintaining high levels of quality and food safety standards. Results show that the well-known low input agronomic practices are environmentally friendly and also often economically advantageous. Implementation of dicotyledons into a cereal-only rotation allows a reduction of environmental impacts (- 36% GHG), a reduction of DON risk and an increase in net income for farmers (up to 31%). In the second part Barilla gave to 13 farmers a decision support system (DSS) to help them in reducing production costs and environmental impacts. Results show that the only adoption of DSS contributes in reducing carbon footprint (-10%), and costs for pesticides and fertilizers (- 10%).

Keywords: Life cycle assessment, LCA, Food, Pasta, Durum wheat.

1 Introduction

Considering that many studies revealed that the agricultural phase of food products have a relatively high environmental impacts, a specific study was conducted to determine whether different crop rotations could aid in increasing sustainability of the whole process (Caporali et al., 1992).

As it's shown in the figure 1, Barilla has released its study on the environmental impacts of pasta conducted with the life cycle assessment methodology through the publication of the Environmental Product Declaration (Barilla, 2010).

Durum wheat cultivation is responsible for more than 80% of the ecological footprint and for entirety of the water footprint and it has the same carbon footprint impact of the home cooking phase. Due to this reason, Barilla put forth a specific project aimed to increase widespread use of sustainable cropping systems of durum

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wheat. Analysis was based on a holistic approach, taking into consideration economic, agronomic, food safety and environmental indicators. The project focused on identifying potential improvements of the most diffused cropping systems for the cultivation of Durum wheat, while maintaining high levels of quality and health standards.

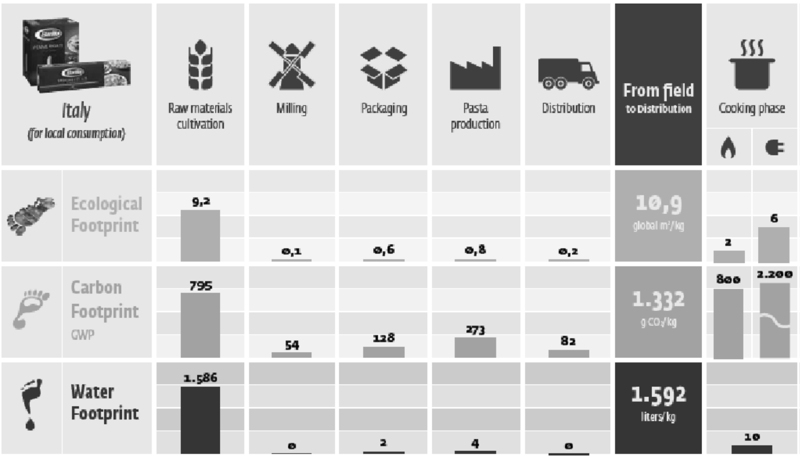

Fig. 1. Ecological, Carbon and Water footprint of Barilla's pasta produced in Italy , (Barilla, 2010)

2 Research Background

Italy was the first cultivation area considered because it is the country where Barilla purchases more than 60% of the durum wheat necessary to its entire pasta production.

The project started in 2010 and it has been developed in different phases.

In the first years the Company put in place theoretical studies on durum wheat cultivation in Italy and the evaluation of environmental impacts and of overall agriculture efficiency through the use of economic, social and environmental sustainability indicators.

In 2010-2011 Barilla analysed a sample of farm to compare real data from farms with optimal values to obtain sustainable productions. The results shows that rotation of durum wheat with dicotyledons is more sustainable than rotations only with cereals and monoculture, and a reduction in production costs is possible with a better efficiency in the use of inputs. The results of this study were published in the *Handbook for sustainable cultivation of quality durum wheat in Italy*, which serves as source of practical suggestions for farmers. Horta S.r.l, one of the partner of this project, has subsequently developed the decision support system (DSS) *granoduro.net*™, a web service that integrates information on weather patterns, soil conditions and varietal characteristics to provide famers decision support related to seeding, weeds control, nitrogen fertilization and information about risk for fungal diseases (yellow and brown rust, septoria, powdery mildew, fusarium head blight and related mycotoxin).

Finally, in 2011-2012 the project was extended to about 15 farms to demonstrate that an accurate planning of crop rotations and the use of a decision support system as granoduro.net could help in being more sustainable, both environmentally and economically. In this part of the project the DSS was given to the farmers to help them following the suggestions of the Handbook for the sustainable cultivation of quality durum wheat in Italy.

The "sustainable durum wheat" project is going on. In 2012-2013 the sample involved in the last crop year will be supplemented with new farms (around 100) situated in initially not considered areas.

3 Methods

With the improvement project in focus, analysis of durum wheat cultivation was performed by identifying the main durum wheat cropping systems. The cropping systems considered were four-year rotations in which the cultivation of different crops was planned. Durum wheat cultivation in Italy was relegated to four main areas: Northern Italy (Lombardy-Veneto area and Emilia Romagna), Central Italy (Tuscany, Umbria and Marche) and Southern Italy (Apulia and Sicily).

Tables 1, 2, 3 and 4 list the crop rotations identified in those four main areas.

Table 1. Crop rotations of the Lombardy-Veneto plain

Crop rotation	Year 1	Year 2	Year 3	Year 4
1*	maize	durum wheat	maize	maize
2	soybean	durum wheat	rapeseed	maize

*most common scenario.

Table 2. Crop rotations of Emilia Romagna

Crop rotation	Year 1	Year 2	Year 3	Year 4
1*	maize	durum wheat	sorghum	soft wheat
2	soybean	durum wheat	maize	soft wheat
3	tomato	durum wheat	maize	soft wheat

*most common scenario.

Table 3. Crop rotations of Central Italy

Crop rotation	Year 1	Year 2	Year 3	Year 4
1*	durum wheat	durum wheat	sorghum	durum wheat
2	proteic pea	durum wheat	proteic pea	durum wheat
3	alfalfa	alfalfa	alfalfa	durum wheat
4	sunflower	durum wheat	rapeseed	durum wheat

*most common scenario.

Table 4. Crop rotations of Southern Italy

Crop rotation	Year 1	Year 2	Year 3	Year 4
1*	durum wheat	durum wheat	durum wheat	durum wheat
2	fodder	durum wheat	fodder	durum wheat

Then, Barilla compared two different durum wheat crop management. The first one consists in farmer's usual crop management with only farmer crop choices and strategies, while in the second one the farmers were supported by the handbook and the DSS *granoduro.net* ™. The test was conducted in 13 farms, located in the most important areal for durum wheat cultivation in Italy. In order to verify the effectiveness and feasibility of the suggested practices, farmers have agreed to cultivate part of their land following the handbook and granoduro.net and part following their routine practices.

3.1 Measures

The indicators used to quantify the different cropping system impacts were divided into environmental indicators (carbon footprint, water footprint and ecological footprint), agronomic indicators (NUE), food safety indicators (DON index) and economic indicators (Net income).

Carbon footprint, also known as "global warming potential" (GWP), expresses the total amount of greenhouse gases (GHG) produced to the system and it's usually expressed in kg of CO2-equivalent. It is regulated at an international level by the documents Greenhouse gas protocol (World Resource Institute, 2010) and PAS 2050 (British Standard Institute, 2011). Concerning the Carbon footprint of products an ISO regulation is under development.

Water footprint measures the water consumption of a system in terms of volume of water evapotranspirated by plants, consumed or polluted. It is regulated by the document "The water footprint assessment manual" (Hoekstra et al, 2011). Data about the water footprint of the main crops cultivated in the world are reported in the database of Mekonnen (2010).

Ecological footprint is a measure of how much biologically productive land and water surface an activity requires to produce all the resources it consumes and to absorb the waste it generates. It is measured in global hectares (gha) and it is regulated by the document "Calculation methodology for the national Footprint accounts" (Ewing et al., 2010).

NUE is the Nitrogen Use Efficiency: it is measured in terms of kg or product per kg of nitrogen given to the crop through fertilization (Rahimizadeh, 2010).

The DON Index expresses the risk of molecules toxic to human health originated by the proliferation of pathogenic fungi Fusarium Head Blight (FHB), producers of secondary metabolites called mycotoxins. These mycotoxins can be present in different quantities of crop yields obtained. It depends on the choices made and on the seasonal cultivation during the crop cycle. The development of these fungi depends on meteorological factors, along with specific factors linked with production unit, such as varietal susceptibility, the rotation of crops and the tillage of soil. DON content in wheat for human consumption is limited by law. The DON index is calculated on a scale of 0 to 9 where 0 is a risk-free condition and 9 is that of highest risk (Ruini et al., 2011). This one is related to law limit. For unprocessed durum wheat the limit is 1750 ppb of deoxynivalenol contamination. High DON risk means high probability to overcome the law limit. Regions of Northern Italy have meteorological conditions more favourable to the onset of DON.

Net Income is the difference between direct costs of cultivation (in field activities and technical tools) and the gross marketable production. This profitability indicator refers to March 2011 quotation for medium quality durum wheat in Italian commodity exchange (280-290 €/ton).

Agricultural practices can influence the environmental, economic and food safety performances of cultivation (Tilman et al, 2002). In particular, this study contemplates the main practices of crop rotation, use of fertilizers, tillage, seeding, and weed and pest management.

4 Results

The study shows that in the Lombardy-Veneto area, where agriculture is considered advanced for a technological and knowledge standpoint, rotation 2 (durum wheat after soybean) performed better than rotation 1 (durum wheat after maize) with regard to all the indicators (Table 5). Aversion of maize as precession for durum wheat allows considerable reduction of the DON risk index.

In Emilia Romagna (Table 6) rotation 1 (cereal based) yielded high DON risk due to maize as precession for durum wheat, while having lowest NUE among the rotations considered. The low efficiency in nitrogen utilization has as consequence higher values of carbon footprint.

In central Italy (table 7) durum wheat cultivation has the lowest environmental impact for rotation 2 (fodder). The net income in such rotation is however lower the rotations 3 and 4. Rotation 1, with 3 years of durum wheat and 1 year of sorghum produced the highest environmental impacts and DON risk with the lowest yield and net income.

In southern Italy (table 8) rotation with four years of durum wheat was the poorest in all indicators.

Table 5. Indicators calculated in the Lombardy-Veneto area

Crop rotation	Yield	Carbon footprint	Water footprint	Ecological footprint	Net Income	NUE	DON risk
	t/ha	t of CO_2-eq/t of d. wheat	t of water/t of d. wheat	global ha/t of d. wheat	€/t of d. wheat	kg of d. wheat/kg of N	-
1	7.0	0.51	315	0.38	155	33.8	7.9
2	7.5	0.42	294	0.36	167	44	1.7

Table 6. Indicators calculated in Emilia Romagna

Crop rotation	Yield (t/ha)	Carbon footprint	Water footprint	Ecological footprint	Net Income	NUE	DON risk
	t/ha	t of CO_2-eq/t of d. wheat	t of water/t of d. wheat	global ha/t of d. wheat	€/t of d. wheat	kg of d. wheat/kg of N	-
1	7.3	0.51	328	0.40	141	32.5	7.9
2	7.5	0.41	315	0.38	157	42.2	2.3
3	7.5	0.36	315	0.38	151	47.1	1.7

Table 7. Indicators calculated in central Italy

Crop rotation	Yield (t/ha)	Carbon footprint	Water footprint	Ecological footprint	Net Income	NUE	DON risk
	t/ha	t of CO_2-eq/t of d. wheat	t of water/t of d. wheat	global ha/t of d. wheat	€/t of d. wheat	kg of d. wheat/kg of N	-
1	3.3	0.67	745	0.73	24.1	28.4	3.9
2	4.3	0.30	478	0.47	99.4	66.7	0
3	5.3	0.43	502	0.49	139	45.3	0
4	5.3	0.34	479	0.47	139	58.5	0

Table 8. Indicators calculated in southern Italy

Crop rotation	Yield (t/ha)	Carbon footprint	Water footprint	Ecological footprint	Net Income	NUE	DON risk
	t/ha	t of CO_2-eq/t of d. wheat	t of water/t of d. wheat	global ha/t of d. wheat	€/t of d. wheat	kg of d. wheat/kg of N	-
1	2.5	0.74	1429	1.11	23.3	32.4	1.1
2	5.0	0.45	694	0.54	133	44.3	0
3	4.2	0.53	874	0.68	112	38.7	0
4	5.0	0.45	694	0.54	133	44.3	0

Then, 13 farms were involved in the study. The cultivation of durum wheat after several crops was tested. Such previous crops were divided into four groups as shown in table 9 (cereals, industrial crops, leguminous, vegetables). A comparison of the durum wheat cultivated after those crops was made.

Table 9. Crops that forego the durum wheat cultivation

Cereal	Industrial crops	Leguminous	Vegetables
Maize	Sunflower	Faba bean	Tomato
Sorghum	Rape seed	Chickpea	
Soft Wheat	Sugar beet	Proteic pea	
Durum Wheat			

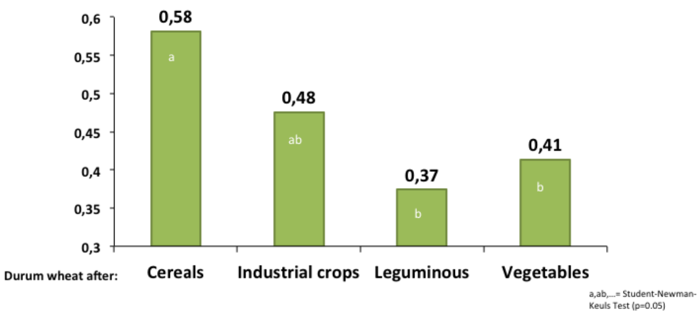

Fig. 2. Carbon Footprint (t CO2/t durum wheat) and previous crop

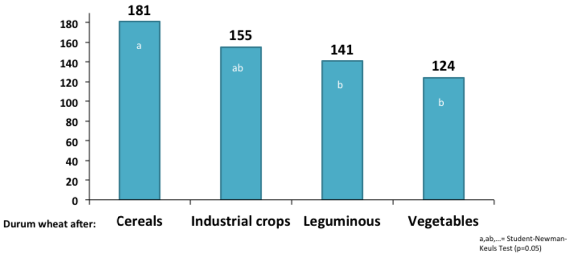

Fig. 3. Production costs (€/ t durum wheat) and previous crop

The results are encouraging. A favourable previous crop contributes in reducing significantly the greenhouse gas emissions (- 36% equivalent to -0,21 t CO2-eq/t grain) compared to an unfavourable one (see fig.2). Concerning the expenses it contribute in reducing significantly production costs (- 31% equivalent to -57€/t) compared to an unfavourable one (fig.3). To finish, as it's shown in fig.4, a favourable previous crop contributes in obtaining a significantly higher yield (+20% equivalent to +1,3 t/ha) compared to an unfavourable one.

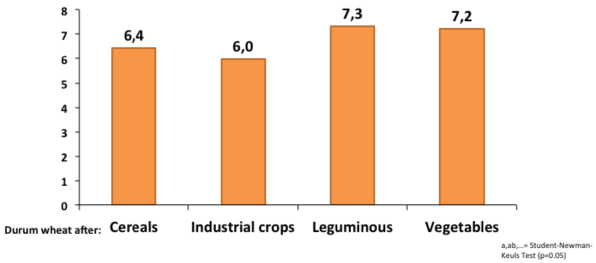

Fig. 4. Yeld (t durum wheat/ha) and previous crop

Previous crops were then divided into three groups (favourable, neutral and unfavourable) according to their influence on durum wheat cultivation (table 10). A comparison was made, for each type of previous crop, between the cultivation of durum wheat with and without the use of the decision support system *granoduro.net*™.

Table 10. Groups of previous crops

Favourable	Faba bean
	Chickpea
	Rape seed
	Proteic pea
	Sugar beet
Neutral	Sunflower
Unfavourable	Maize
	Sorghum
	Wheat

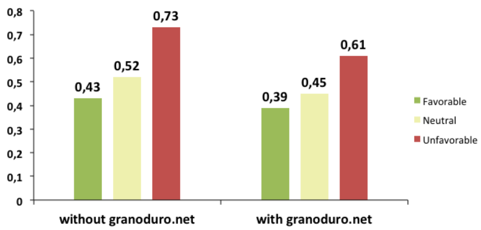

Fig. 5. Carbon footprint (t CO2/ t durum wheat) and granoduro.net

Results show that the use of granoduro.net contribute in reducing carbon footprint (-10%, fig. 5), supply to the reduction of production costs especially in case of favourable or neutral previous crop (- 10%, fig. 6) and contributes in reducing the costs of pesticides and fertilizers management (fig.7).

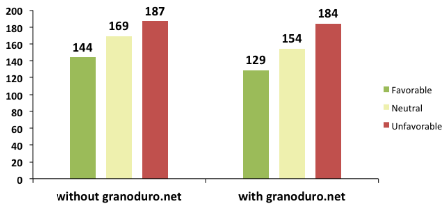

Fig. 6. Production costs (€/ t durum wheat) and granoduro.net

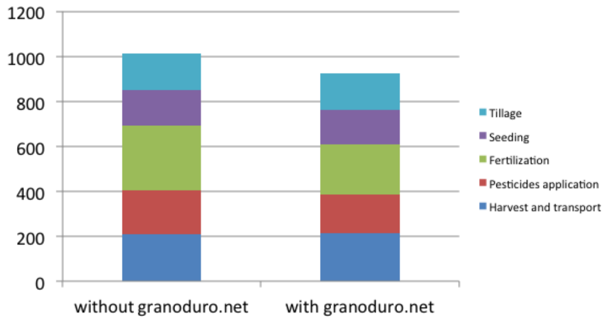

Fig. 7. Production costs (€/ ha) and granoduro.net

To sum up the use of *granoduro.net*™ contribute to a reduction in direct costs of production (- 10% = - 15 €/ton), a reduction in Carbon footprint (- 10% CO2 = - 0,12 ton CO2/ton), an increasing in nitrogen use efficiency and to maintain high yields.

5 Conclusions

The project has demonstrated the importance of an integrated approach to study the sustainability of a cropping system. It's important to bear in mind that agriculture is primarily an economic activity and there's the risk walking the line of counter-productivity when merely focusing on environmental and food safety issues. However, the study shows that environmentally friendly practices are also often economically advantageous because they greatly increase the efficiency of technical tool usage and the yield (+1,3 t/ha). Implementation of dicotyledons into a cereal-only rotation allows a reduction of environmental impacts (-0,21 t CO2-eq/t grain), a reduction of DON risk and an increase in net income, thanks to the reduction of production costs (-57€/t).

The project has also highlighted the importance of technical instruments such as the DSS granuduro.net to help the farmers in their decisions. With this kind of support the agriculture would be less costly (-10%) and at the same time the environmental impacts linked to its activities could be reduced (-10%).

The next steps of the project are to continue the undertaken experimentations and to take “sustainable agriculture” to a large scale by signing in the next years an increasing number of contracts with farmers that encompass sustainable practices.

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Is Healthy Eating Healthy for the Environment? Barilla Center for Food and Nutrition Double Food Pyramid

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Abstract. Barilla Center for Food and Nutrition decided to repropose an updated food pyramid, involving global warming and impacts of food on the environment. It has been made a reclassification of foods that together with their positive impacts on health also included their environmental impacts. These values were overlapped in descending order to obtain an upside-down pyramid that reproposes the same succession of foods. The new "Double Pyramid" shows that foods with higher recommended consumption levels are also those with lower environmental impact, and foods with lower recommended consumption levels are those with higher environmental impact.

Two daily menu were analysed: both balanced from a nutritional point of view, but in the first one the protein is of plant origin, while in the second one it is mainly of animal origin. Vegetarian menu has an environmental impact that is two and a half times lower than the animal protein-based one.

Keywords: Nutrition, ecological footprint, carbon footprint, water footprint.

1 Introduction

It is generally known that proper nutrition is an essential condition to health. This is a natural law that, however, has not received due attention in the last few decades. Indeed, the growing impact of disorders related to overeating serves as testimony of this last observation. Common disorders are: obesity, diabetes and cardiovascular pathologies – in people of all ages, including the younger portion of the population (Must et al., 1999; Burton et al., 1985).

In the 1970s, American physiologist Ancel Keys explained to the world the diet he dubbed "Mediterranean" based on balanced consumption of natural foods (olive oil, fruit, grains, legumes, etc.), thanks to which death rates from heart disease were

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shown to be lower than with saturated fat-rich diets typical of Northern Europe. In 1992, the US Department of Agriculture developed and released the first Food Pyramid which concisely and efficaciously explained how to adopt a nutritionally-balanced diet.

Aimed at commencing nutritional education, at the start of the 1990s the US Department of Agriculture elaborated and disseminated the first “food pyramid”, based on the scientific studies of Ancel Keys. This structure provided a synthetic and efficient explanation on how to adopt balanced nutrition, serving as a general guideline. Since then, there has been an enormous increase of researches related to confirmation of disease prevention through proper nutrition.

During the last years the Food and Agriculture Organization (FAO) together with Biodiversity International, pointed out the importance of “sustainable diets” that recognize the interdependence between food production and consumption, dietary requirements and nutritional recommendations, while at the same time confirming the concept that human beings’ health cannot be disconnected from the health of ecosystems (FAO, 2010).

Despite these studies, public awareness seems to still lag well behind.

This is the first reason that leads the Barilla Center for Food & Nutrition (BCFN) to the re-proposal of the food pyramid, 20 years after its conception. This elaboration of the food pyramid put forth by BCFN has been updated to carefully integrate the latest findings by research. The second reason involves global warming and, more in general, the impact of man’s activities on the environment.

2 Research Background and Results

In recent years, confirmation regarding the importance of proper diet in preventing illness has increased enormously thanks to further laboratory studies and empirical evidence.

However, the same cannot be said about the public awareness, which has grown more slowly. This is the reason why, it was decided to offer once again the Food Pyramid, a familiar and well-established tool in the scientific and nutritional circles. The second reason is less obvious and is connected to the problem of climate change and, more generally, the impact of human activity on the environment (Wackernagel and Rees, 1996).

It has been demonstrated that agriculture and animal farming are among the sources that yield the greatest amounts of greenhouse gasses (beating out transportation) (Foster et al., 2006; Williams, Audsley, and Sanders, 2006). Therefore, as it’s explicitly emphasized and suggested by the paper “Climate Smart Food” – drafted in November 2009 by SIK – the Swedish Institute for Food and Biotechnology, as charged by the mandate of the Presidency of the European Union hold by Sweden – environmental variables must also be taken into account in regards to food and nutritional diet selection (Sonesson, Davis, and Ziegler, 2009). From this standpoint, the various food groups can be evaluated in terms of their environmental impact.

The environmental indicators that have been selected to built BCFN Food Pyramid are: "(i) the Carbon Footprint, which represents greenhouse gas emissions responsible for climate change and is measured in terms of amount of CO2 equivalent; (ii) the Water Footprint (or virtual water content), which quantifies the amount of water resources consumed and how they are consumed; it measures water use in terms of volume and (iii) the Ecological Footprint, which measures the biologically productive land and sea area human activity requires to produce the resources it consumes and to absorb the waste it generates; it is measured in square meters or global hectares" (BCFN, 2010).

The use of the Life Cycle Assessment method places all environmental markers at the same level for the duration of the analysis: in this work, carbon, water and ecological footprint have been studied as key performance indicators of food production chains. The data came from available public studies (Ecoinvent Database; Environmental Product Declaration Database; LCA Food Database; Andersson, 2000; Baroni et al., 2006).

As stated in the BCFN publication (BCFN, 2010, p. 64): "the information is presented grouping foods according to the following categories that reflect the detailed process description: (i) foods derived from agriculture (fruit, vegetables, grains, etc.); (ii) foods derived from cultivation agricultural products (sugar, oil, pasta, etc.); (iii) foods derived from animal husbandry (dairy products, meat, etc.); (iv) foods from fishing; and (v) beverages. For every category examined, the values connected with each environmental indicator are given (…). The results for each of the environmental indicators examined (for both scientific studies and processed data) are expressed as a range of values since a specific value would not be representative of the category as a whole. For example, fruit includes a number of varieties with different cultivation processes and, as a result, a single value for the category "fruit" cannot be given for each indicator".

However, once results have been obtained, a need for both communicational conciseness and clarity imposes a simple method that accounts for all outcomes. This is why the ecological footprint served as base indicator in the construction of the double pyramid. All motivations shall be illustrated in the main BCFN paper, but it can be briefly stated that these essentially depend on the ability to easily convey the environmental impacts linked to food chains. Thereby, analysis of the food pyramid and its categories reveals a wide array of values concerning the environmental impact of each category in terms of Ecological Footprint (Ewing et al., 2010).

Thus, the reclassification of food goes beyond their positive impact on health, encompassing their impact on the environment, as well. These values are overlapped in descending order to obtain an upside-down pyramid that, in good measure, re-proposes the same succession of foods. When this new Environmental Pyramid was brought alongside the Food Pyramid, it created a Food-Environmental Pyramid which called "Double Pyramid of Food and Environment" (BCFN, 2009, 2011, 2012).

It shows that those foods with higher recommended consumption levels are also those with lower environmental impact. Contrarily, those foods with lower recommended consumption levels are also those with higher environmental impact (Fig. 1).

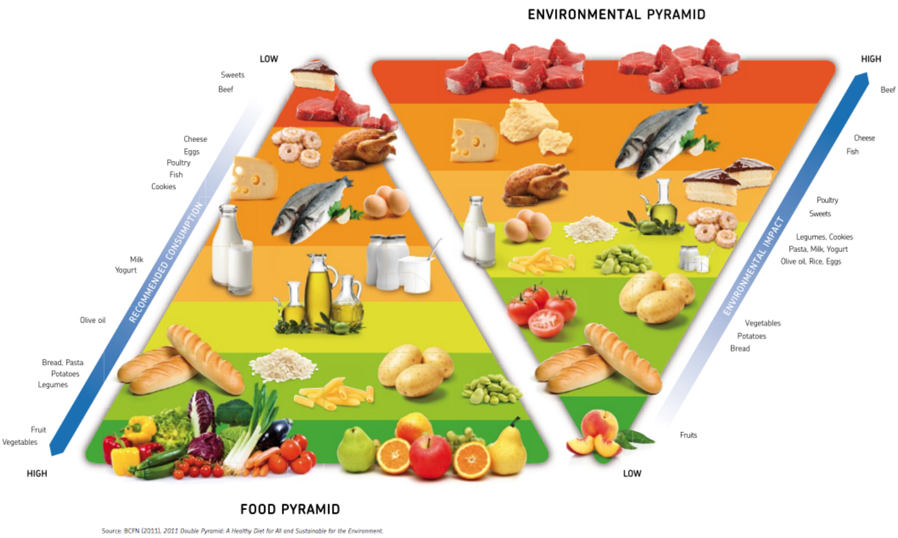

Fig. 1. The Double Pyramid of Food and Environment (Source: BCFN, 2012)

This newly-elaborated version illustrates, in a unified model, the connection between two different but highly-relevant goals: health and environmental protection. In other words, it shows that if the diet suggested in the traditional Food Pyramid is followed, not only do people live better (longer and healthier), but there is a decidedly lower impact – or better, footprint – left on the environment.

All of us, through eating responsibly, can definitely reconcile our personal well-being (personal ecology) with the environment (ecological context).

Applying the model to everyday life and in order to estimate the extent to which the food choices of individuals affect the environmental impact, in terms of Ecological Footprint, two different daily menus were analysed: both are balanced from a nutritional point of view, both in terms of calories and nutrients (proteins, fats and carbohydrates), but in the first one, the protein is of plant origin ("vegetarian menu"), while in the second, it is mainly of animal origin ("animal protein-based menu").

As it is shown in the figure 2, the animal protein-based menu has an environmental impact that is two and a half times higher than the vegetarian one: 41 square global meters compared to 15; that is, a difference of at least 26, which represents a very significant share in the daily impact of an individual. The vegetarian menu has an environmental impact that is two and a half times lower than the meat one.

An additional analysis was based on the calculation of the features for four different weekly menus, all balanced from a nutritional point of view, but with the only difference that their source of protein is from animal or plant origin. The sustainable (or BCFN) menu includes both meat and fish, with a preference for white meat, and provides a balanced consumption of protein both vegetable or animal origin. The meat menu and the meat and fish menu provide more conspicuous consumption of protein of animal origin. Lastly, meat and fish are obviously excluded from the vegetarian menu, and the sources of protein are animal-based (cheese, eggs, etc.), as well as of plant origin (legumes).

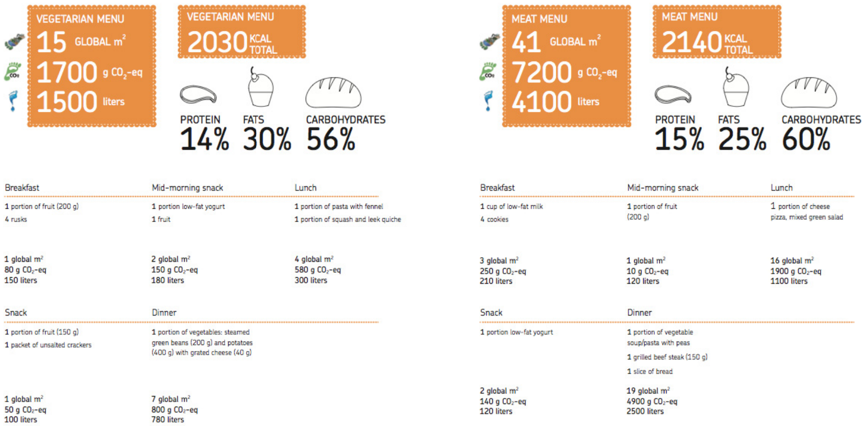

Fig. 2. Comparison between vegetarian and animal protein-based menu (Source: BCFN, 2012)

Regarding environmental impact, the two menus richest in meat and fish have values that are higher compared to the sustainable (BCFN) and to the vegetarian menu. In fact the sustainable and vegetarian menus have a Carbon Footprint respectively of 21 and 19 kg CO_2 eq. per week while the meat menu attains a Carbon Footprint of 32 kg CO_2 eq. per week (Fig. 3).

As it's shown in the figure 4, with a sustainable menu you can save up to 7,000 litre of water per week.

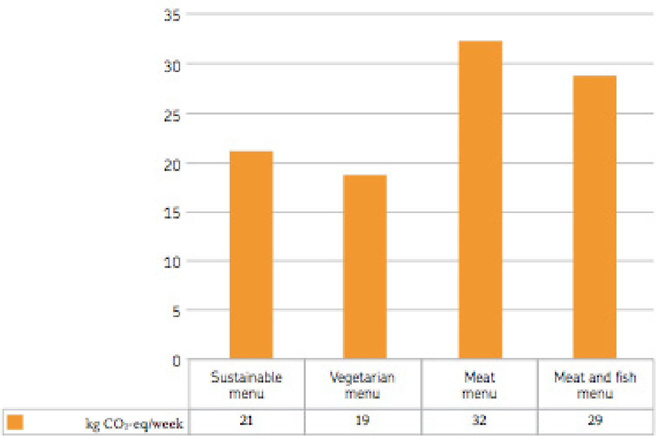

Fig. 3. Carbon footprint of the 4 menu analysed, all nutritionally balanced

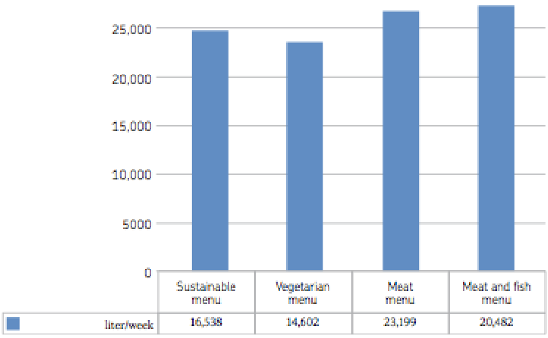

Fig. 4. Water footprint of the 4 menu analysed, all nutritionally balanced

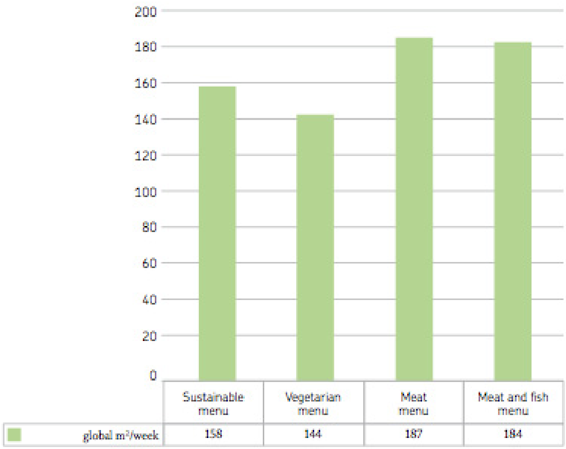

Fig. 5. Ecological footprint of the 4 menu analysed, all nutritionally balanced

To finish, if you chose a sustainable menu, you can have less environmental impacts also in term of ecological footprint (Fig. 4).

In the last version of the Double Pyramid publication (BCFN, 2012) it was pointed out the costs of sustainable diets, and in particular the Mediterranean one. The research question was: "Does sustainable diets cost more?".

As was used for the analysis of environmental subjects, public information sources are also used for this study. In this manner, the prices in Italy for typical diets are estimated, demonstrating that, when they have the same nutritional value, menus rich in protein of animal origin (meat and, especially, fish) have a slightly higher cost (about 10% more). Comparing the outcomes with the results of other research studies conducted in other countries as United States, France, and Great Britain (USDA, 2012; Drewnowski et alt., 2005; Aggarwal, Monsivais, Drewnowski, 2012; Drewnowski, 2004; Drewnowski et alt., 2007; Cade, 1999; WWF, 2011), the situation does not appear to be the same. In fact, in some countries, the sustainable diet is more expensive for families, even if this fact can be at least partially conditioned by the different calculation criteria used (price per protein, price per gram, etc.).

Aside from some sectors for which additional analyses would be desirable, it may be affirmed in any case that the Mediterranean diet is the cheapest, as long as the foods are selected judiciously, preferring those which have a low cost and high nutritional value, such as pasta, legumes, certain types of vegetables, oil, and dried fruit. In particular, low-fat dairy products and eggs are the least expensive source of protein. The creation of a single-course meal based on vegetables enriched with a modest addition of meat may be the best method to provide the proper caloric and nutritional intake at a limited cost.

Therefore, sustainable eating definitely does not necessarily mean spending more money. However, this generally requires an additional effort by families in terms of the time dedicated to the selection and preparation of food.

3 Conclusions

The evidence of true interest that emerges from this new elaboration is the coincidence, in a single food model, of two different objectives that share fundamental importance for man: health and environmental protection. In other words, it has been demonstrated that following a diet put forward by the traditional food-nutrition pyramid not only leads to an improvement in quality of life (longer life-span and enhanced health conditions), but also yields a decisively lower impact, better expressed as Ecological Footprint, on the environment. Indeed, food that should be consumed in greater quantities, for example following the Mediterranean diet, fits into the category that inflicts less environmental impact overall. Vice-versa, foods falling into a recommendation of limited quantity consumption have also the higher impact on the environment. It has been demonstrated, that a vegetarian menu reduced by one third the environmental impacts compared to a animal protein-based menu.

The Double Pyramid model proposes the evaluation of all the choices and eating behaviours, even those which apparently, and at the present time, determine less obvious impacts on the individual or the community, but which can become substantial when measured cumulatively and over time.

With this in mind, the declination of the food and environmental pyramid regarding future generations, beginning with children, leads to some implications briefly mentioned below that can be further analysed and distributed to families and educators.

On the one hand, the dietary habits that are increasingly widespread among large sections of the population are leading to a gradual deterioration of the health of children and a consequent reduction in life expectancy, a fact which reverses an established trend of gradual improvement.

On the other hand, the excessive intake of certain foods - generally the same ones that should be eaten less frequently – determines a significant impact on the environment and the natural resources which, ultimately, can further reduce the quality of life and the overall well-being of future generations.

Therefore, for its positive nutritional and environmental effects, the adoption of a correct food model impacts both directly and indirectly on the future of our children.

This makes it absolutely vital today to start a process of collective responsibility.

At this point, the BCFN's next focus is to promote actual implementation of the sustainable diet, by investigating potential obstacles, which would slow its spread or, in some cases, cause it to be abandoned by those who traditionally used it.

The first variable dealt with is that of price, rightly considered a potential obstacle, especially during the current economic crisis. The studies collected indicate that the situation is still debatable, although it would appear possible to state that the sustainable diet generally does not cost more, especially if its costs are evaluated using more appropriate criteria. The BCFN has found that the Mediterranean diet is, albeit slightly, more sustainable economically. And this cost comparison does not include the "hidden" costs of a poorly balanced diet, in terms of the environment and, especially, of people's health.

Certainly, much more research can be carried out on the topic of economic sustainability, especially if developing countries are included in the analysis (and it is indispensable that this be done) since, in these countries, the lack of resources and infrastructure, along with greater demographic growth, may render less economical that which is easily accessible in industrialized countries. How to make a sustainable diet truly accessible "to all" will be the subject of the BCFN's upcoming publications.

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Towards a Fast Evaluation of Environmental Impacts

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Abstract. Full LCA is a well-known methodology which can help decision-makers to select the product or process that results in the least impact to the environment. However performing a Full LCA is resource and time intensive. Therefore different simplified LCA methods are developed in literature. This paper would develop another simplified LCA tool, driven by the extreme ease of use for all the people that don't know in depth environmental issues or that haven't time / data to deepen these topics. This tool can be very useful to the designers. They should be evaluate environmental impacts of something doesn't exist and it can help them to evaluate rapidly the more "green" product.

Keywords: LCA, Life Cycle Assessment.

1 Introduction

Full LCA is a very well-known methodology in literature. It is developed since 1960s, but only in the last decades it is more considered, due to the increasing environmental consciousness. LCA is really useful, helping decision makers to select products or processes. However performing a full LCA analysis is very problematic, because it is resource and time intensive. Another great problem is represented by data, that can greatly impact the accuracy of the final results. Therefore it is important to weigh availability of data, necessary time to conduct the study and required financial resources against the projected benefits of LCA [1]. To pass these problems different simplified LCA methodologies are developed. The aim of simplifying LCA is to provide essentially the same results as a detailed LCA, followed by a simplified assessment, thus reducing significantly the expenses and time expended. It should still include all relevant aspects, but good explanations can, to some extent, replace resource demanding data collection and treatment. [2]

The aim of this paper is to realize a simplified LCA tool, driven by the extreme ease of use. Before to show it, in Section 2 a state of the art of simplified LCA is reported. The tool is presented in Section 3; finally Section 4 concludes the paper.

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2 State of the Art

Simplified LCA (S-LCA), also known as Streamlined LCA or Screening LCA, emerged as an efficient tool to evaluate the environmental attributes of a product, process, or service's life cycle [3]. The concepts of Screening, Simplified and Streamlined LCA are often mixed as they are all dealing with the attempt to simplify the LCA procedure [4].

In literature there are few definitions in which simplified LCA is as a simplified variety of detailed LCA conducted according to guidelines not in full compliance with the ISO 14040 standards and representative of studies that typically require from 1 to 20 person-days of work [5]. Hunt et al. refer to simplified methods as any measure or procedure taken to reduce the scope, cost, and effort required to conduct the LCA [6].

Goglio and Owende define simplified LCA as a method aimed to the identification of environmental hotspots or processes which the emissions of particular interest occur in the product / process life cycle [7]. In general the simplifying or streamlining can be viewed as a way of “cutting” whilst still meeting the study goal [8].

Nevertheless, the distinction between the Screening, Simplified and Streamlined LCA is not well-defined at all, it is up to the practitioner to define the methodology.

According with Fleischer et. al, data collection is the most time-consuming task in LCA, thus the most costly part is the life cycle inventory [9]. Also Christiansen et al. pointed out that effort should focus on the life cycle inventory analysis, which is typically the most time consuming phase, with the greatest potential for savings [10]. Considering that, there are different strategies for the simplification of the inventory analysis, depending on the goal and scope of the study (the specific application and decision to be supported), the required level of detail (information on single technological processes or aggregated entities), the acceptable level of uncertainty, and the available resources (time, human resources, know-how and budget).

To simplify LCA Rebitzer et al. describe three different types of approaches:

- Qualitative approaches: which are limited to a qualitative identification of the most environmentally critical stages or processes; making only a limited use of quantitative data;
- Semi-quantitative approaches: which are limited to the identification of the most environmentally critical stages or processes, making only a limited use of quantitative data;
- Quantitative approaches : applying numerical data, even though in a limited amount or in a quantity which is lower than that required by traditional LCA, often by restricted modeling of the product system by means of cut-off [11].

Pigosso and Sousa give a classification of the simplified LCA methods and tools identified by a systematic literature review. The authors report 27 simplified LCA methods and tools, many of which are of semi-quantitative approach [12].

The tool shown in this paper uses one of the semi-quantitative approach reported by Pigosso and Sousa: the Eco-Indicator 99. This approach is used by one of the most popular LCA software, SimaPro.

The Eco-indicator of a material or process is a number that indicates the environmental impact of a material or process, based on data from a life cycle assessment. The unit of measure is the Eco-indicator point (Pt), but usually the milli-point (mPt) is adopted and used. The higher the indicator, the greater the environmental impact. The absolute value of the points is not very relevant and the main purpose is to compare relative differences between products or components. The standard Eco-indicator values can be regarded as dimensionless figures. Also, different types of Eco-indicator exist, depending on perspective and weighting. There are three types of perspective (egalitarian, hierarchist and individualist) and 4 types of weighting (average, egalitarian, hierarchist and individualist). Combining them different types of Eco-indicator are obtained and the most relevant are:

- The Hierarchist damage model and normalization with the Average weighting. (H,A)
- The Egalitarian damage model and normalization with the Egalitarian weighting. (E,E)
- The Individualist damage model and normalization with the Individualist weighting. (I,I)

Eco-Indicator 99 (H,A) is considered to be the default version of the methodology while the other perspectives can be used in a robustness analysis.[13]

Therefore Eco-Indicator 99 (H,A) is used in the tool presented in this paper.

In summary, Simplified LCA (S-LCA) is used to reduce cost and time investment in the evaluation of environmental attributes of a product, process or service's life cycle. Many approaches exist in literature and they are classifiable in three categories: qualitative, semi-quantitative and quantitative. In particular Eco-Indicator 99, the methodology chosen, is highlighted.

3 Tool Presentation

In this section the tool is presented and a small example, based on the one in [13], is conducted. The idea of this tool, realized on Microsoft Excel, comes from the need to provide to the designers, not totally conscious of the environmental aspect, a very simple and fast tool to a first environmental analysis, in order to compare the different alternatives.

The file is organized in different spread sheets, grouped in four categories. First one is related to Eco-Indicator 99 (H,A) database, divided in: material, process, energy, transport and end of life. Database is necessary for the subsequent calculations and it gives the possibility to practitioners to access to more information about the indicators. For example, in Fig.1 table about production of ferro metals is reported. All database tables are composed by: the type of material, the value of the Eco-Indicator, the indicator's unit of measure (MSU) and a brief description about the indicator.

Production of ferro metals			
	Indicator	MSU	Description
Cast iron	240	mpt/kg	Casting iron with > 2% carbon compound
Converter steel	94	mpt/kg	Block material containing only primary steel
Electro steel	24	mpt/kg	Block material containing only secondary scrap
Steel	86	mpt/kg	Block material containing 80% primary iron, 20% scrap
Steel high alloy	910	mpt/kg	Block material containing 71% primary iron, 16% Cr, 13% Ni
Steel low alloy	110	mpt/kg	Block material containing 93% primary iron, 5% scrap, 1% alloy metals

Fig. 1. Example of Eco-Indicator 99 database: production of ferro materials

Database is taken from [13].

In the second category the designers can design the flow of product analysed, in order to understand the product life cycle.

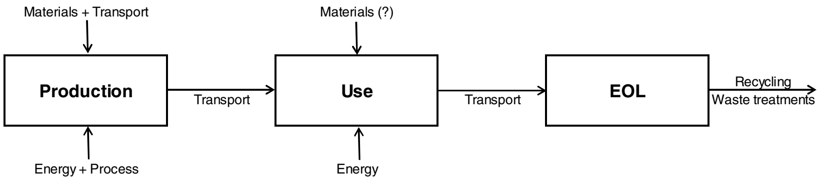

Fig. 2. Flow spread sheet

In the third category calculation is performed. In this category spread sheets are divided as in the database category (material, process, energy, transport and end of life).

Transport	Indicator	MSU	Value	EI
	#N/D	#N/D		0
	#N/D	#N/D		0
	#N/D	#N/D		0
	#N/D	#N/D		0
	#N/D	#N/D		0
	#N/D	#N/D		0
	#N/D	#N/D		0
	#N/D	#N/D		0
	#N/D	#N/D		0
	#N/D	#N/D		0
	#N/D	#N/D		0
	#N/D	#N/D		0
	#N/D	#N/D		0
	#N/D	#N/D		0
	#N/D	#N/D		0

Fig. 3. Example of calculation spread sheet: transport

For example, in Fig.3 spread sheet to evaluate the environmental impact of transport is shown. In the light blue area there is a drop down menu where designers can choose the way of transport among all those in database. Choosing one of these Indicator and Unit of measure (MSU) get a value. Then designers should insert value (in this case usually is tonnes per kilometres). In EI column the calculation is performed, multiplying Value and Indicator.

Finally in the fourth category there is a report spread sheet, that shows a results summary.

Fig. 4 shows it.

	Environmental Impact (mpt)
Production of ferro metals	0
Production of non ferro metals	0
Production of plastic granulate	0
Production of rubber	0
Production of packaging materials	0
Production of chemicals and others	0
Production of building material	0
Total Production	0
	Environmental Impact (mpt)
Processing of metals	0
Processing of plastics	0
Total Process	0
	Environmental Impact (mpt)
Electricity	0
Heat	0
Solar energy	0
Total Energy	0
	Environmental Impact (mpt)
Total Transport	0
	Environmental Impact (mpt)
Recycling of waste	0
Waste treatment - incineration	0
Waste treatment - landfill	0
Waste treatment - municipal waste	0
Waste treatment - household waste	0
Total EOL	0
	Environmental Impact (mpt)
TOTAL	0

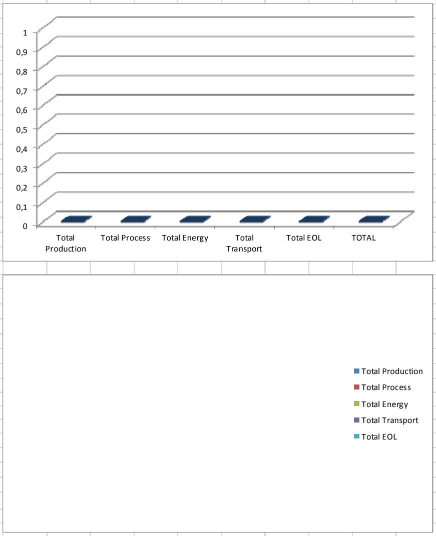

Fig. 4. Report spread sheet

Material, Process, Energy, Transport, EOL and Total environmental impacts are reported. Also a bar and a pie chart are realized to simplify the reading of the results.

To show how tool works, a sample from [13] is taken. The example is a simply analysis of a coffee machine. Some hypothesis are: the coffee machine is used for 5 years, making 5 cups of coffee, twice a day, and keeping it hot for half an hour after brewing. In the Fig. 5 you can see the flow of the coffee machine.

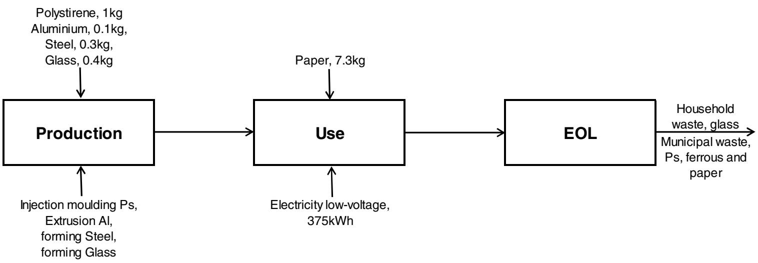

Fig. 5. Coffee machine flow

Materials and processes used to realize the coffee machine are considered, while in the Use phase filter papers and electricity to work the coffee machine are evaluated. Finally in EOL disposal of materials is taken into account.

After completing the flow, it is possible to perform the calculation. For example in Fig. 6 calculation of EOL is shown.

Waste treatment - municipal waste	Indicator	MSU	Value	EI
Municipal waste ECCS steel	-5,9	mpt/kg	0,4	-2,36
Municipal waste PS	2	mpt/kg	1	2
Municipal waste Paper	0,71	mpt/kg	7,3	5,183
	#N/D	#N/D		0
	#N/D	#N/D		0
	#N/D	#N/D		0
	#N/D	#N/D		0
	#N/D	#N/D		0
	#N/D	#N/D		0
	#N/D	#N/D		0
	#N/D	#N/D		0
	#N/D	#N/D		0
Waste treatment - household waste	**Indicator**	**MSU**	**Value**	**EI**
Glass	-6,9	mpt/kg	0,4	-2,76
	#N/D	#N/D		0
	#N/D	#N/D		0

Fig. 6. Example of calculation: EOL

Results are reported in Fig. 7 (only the bar and pie chart are shown).

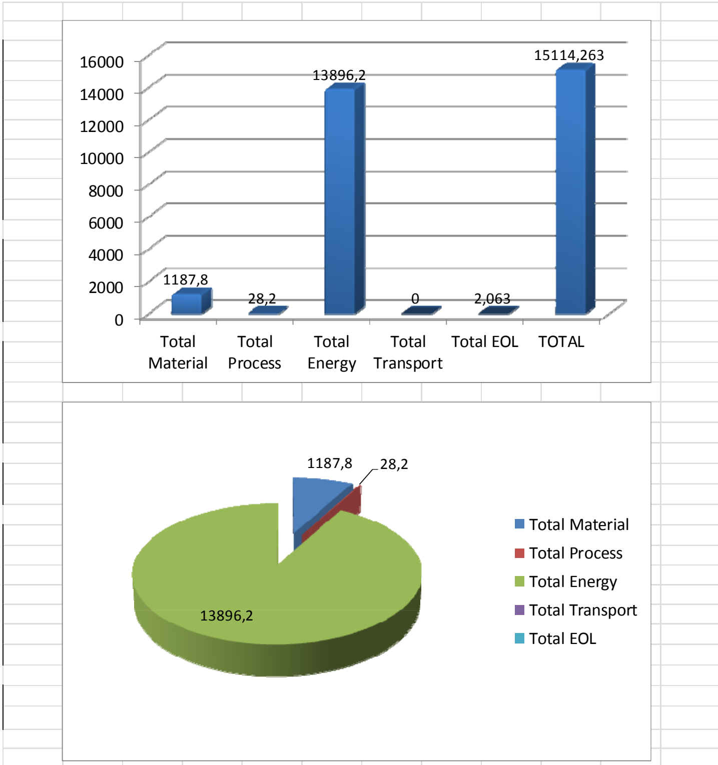

Fig. 7. Coffee machine report

As you can see from the graphs, the energy used is the major environmental impact of the coffee machine, in particular the electricity consumption. If the designers are able to reduce consumption they can significantly improve the sustainability of the product.

In summary a tool is presented. It is based on Eco-Indicator and driven by the extreme ease of use. A small example is used to show how the tool work.

4 Conclusion

In this paper the aim is to realize a tool to evaluate environmental impacts of product / process / service. The tool doesn't perform a full LCA analysis, due to cost and time expensive. It conducts a simplified LCA analysis. Literature is explored and a huge approaches for simplified LCA are found. They are classifiable in three categories: qualitative, semi-quantitative and quantitative approach. For the tool presented in this paper Eco-Indicator methodology is chosen. Then the tool is explained and a small example is used to show how the tool works.

The objective is not to innovate or to revolutionize Life Cycle Assessment, but it is to realize a tool to a fast and simple evaluation of environmental impacts. Simplicity and speed are possible because the tool is based on a well known software (Excel), using one of the most simple S-LCA approach (Eco-Indicator).

Also, this tool could be part of a more general and complete framework about LCO (Life Cycle Optimization).

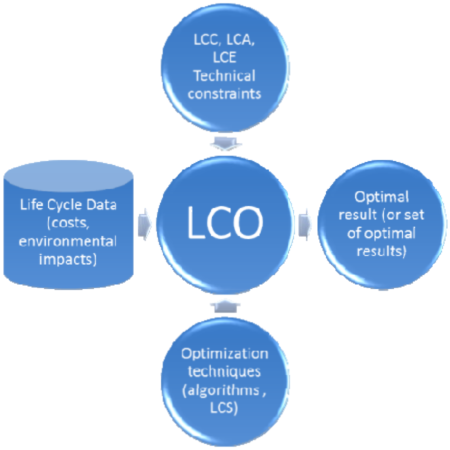

Fig. 8. General framework for Life Cycle Optimization

This framework considers three main elements for making a successful LCO: life cycle data, life cycle methodologies and optimization techniques. The presented tool will have the task of converting life cycle data related to environment (like used material, energy consumptions, etc.) in environmental impact. Future development will be the substitution of Eco-Indicator with something of more understandable like the Carbon Footprint.

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A Concept for Graph-Based LCA Analysis Tool

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Abstract. Life Cycle Assessment is a comprehensive life cycle approach that quantifies ecological and human health impacts of a product or system over its complete life cycle [5]. The existing LCA and environmental assessment tools do not model the relations between different lifecycle factors or different environmental dimensions and focus mostly on the inventory analysis. The main idea of the proposed concept is to develop environmental assessment tools in order to evaluate the environmental performance and deliver a dynamic environmental profile for products, services and processes, by taking into account the various dimensions of environmental impact, as well as the relations between different factors in their lifecycle. Furthermore, this concept proposes a graph-based representation of different lifecycle factors and dimensions in order to facilitate the visual analysis and simulation of the product/service/process lifecycle. Finally, this concept provides a way to model environmental KPIs as a representation to different lifecycle factors and a simulation environment.

Keywords: LCA, KPIs, Graph-based representation, Visual analysis.

1 Introduction

Environmental assessment is a procedure that ensures that the environmental implications of decisions are taken into account before the decisions are made [1]. The leading tool for environmental assessment is life cycle assessment (LCA). LCA is a methodological framework for estimating and assessing the environmental impacts attributable to the life cycle of a product, such as climate change, stratospheric ozone depletion, tropospheric ozone (smog) creation, eutrophication, acidification, toxicological stress on human health and ecosystems, the depletion of resources, water use, land use, and noise—and others[2].

Environmental processes are often very complex and convoluted that makes it difficult to model an LCA. LCA is often data intensive. LCA software further helps to structure the modeled scenario, displaying the process chains and presenting and analyzing the results [3]. Although, software tools were developed to make the processing and calculation of LCAs easier and faster, most of these tools require

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expert knowledge to generate meaningful results and takes huge amount of time to make a full evaluation.

Therefore in this paper, we will present the concept of graph-based representation and analysis of the various relations between different aspects of LCA. With this concept we aim to make the decision process faster and far more intuitive. The graph-based representation of LCA factors will facilitate the capturing of implicit knowledge on the LCA domain as well as the knowledge sharing between different actors of the LCA and beyond.

In section 2 of the paper, we present the necessary scientific background, starting from an overview of the LCA approach, its value and requirements. We then provide some key information concerning the graph theory and the significant benefits of using graphs to represent knowledge, as well as some basic background for employing KPIs in LCA. In section 3, we present the concept overview for the graph-based LCA analysis, showing the dependencies and influences between different lifecycle (LC) indicators, as well as the proposed visualization. In the final section, we conclude our work, demonstrate the expected benefits and describe the various next steps of the approach.

2 Background

The authors in [11] and [12] have performed a literature survey gathering and explaining the major current issues and problems in LCA being addressed in recent LCA research. These issues, such as boundary selection, spatial variation, environment dynamics and data availability are spread among the LCA phases and are classified according to their severity and solution adequacy.

In the next subsections, we present some important background on LCA, graph theory and KPIs in order to provide a better understanding of the proposed approach.

2.1 Life Cycle Assessment

LCA is an internationally recognized approach that evaluates the potential environmental and human health impact associated with products and services throughout their life cycle, beginning with raw material extraction and including transportation, production, use, and end-of-life treatment. LCA is the only tool that can make a full evaluation of all sources and types of impact over the entire life cycle of a product. ISO standards have been developed for LCA providing a framework, terminology and some methodological choices (ISO 14040 2006; ISO 14044 2006).

Among other uses, LCA can identify opportunities to improve the environmental performance of products at various points in their life cycle, inform decision-making, and support marketing and communication efforts. LCA exposes the hot spots and strengths of a product, compared to the alternatives. However, in order to make an appreciable LCA, it is necessary to choose the functional unit properly, determine the system boundaries to cover all important stages of the lifecycle of the product and choose the life cycle impact assessment methodology to calculate the desired environmental impacts important for the company.

The LCA methodology is standardized by a series of ISO standards and includes the following phases:

- Goal and scope definition (ISO 14041) [8]
- Inventory Analysis (ISO 14041) [8]
- Impact Assessment (ISO 14042) [9]
- Interpretation (ISO 14043) [10]

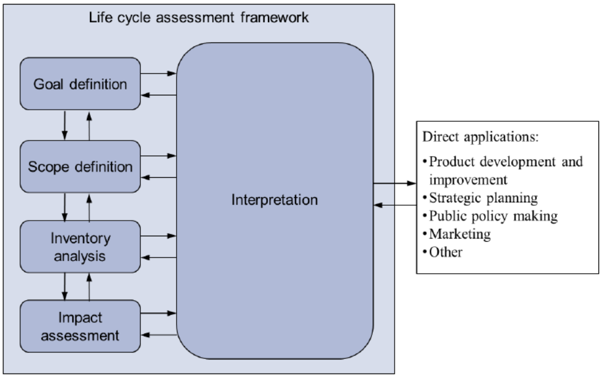

Fig. 1. LCA Methodology (ISO 14040) [7]

2.2 Graphs

Graph theory is a very useful visual representation because the elements of the graph can be defined in such way so that they have a one-to-one correspondence with elements of many kinds of engineering or general real-world systems and situations. A graph is a finite set of dots called vertices connected by links called edges and exist in a variety of forms, from simple graphs where up to one edge can connect two vertices to more much more complicated graphs, such as multigraphs, pseudographs or digraphs. Graph theory has been systematically investigated and widely used because through their graphical representation of real-world systems, it provides a better understanding of many of their properties and relationships whereas the theorems and algorithms of graph theory can allow for an effective representation of their behavioral attributes. [6]

Graphs provide a unique visual way to represent knowledge in various kinds of forms such as facts and constraints. They possess very useful modeling and computational qualities and the knowledge of the mathematical properties of these graphical representations can be used to achieve an augmented overall understanding of a domain and even deduce implicit knowledge that was not known even to human experts. Conceptual graphs in specific provide the formalism for graphical representation that expresses knowledge in a manner that is logically precise, humanly readable and computationally tractable whereas with their graphic representation, they serve as a readable, formal design and specification language. [6]

2.3 KPIs

KPIs are quantifiable metrics that reflect the environmental performance of a business in the context of achieving its wider goals and objectives [4]

Concerning LCA, adequate environmental performance management and reporting can lead to significant benefits for both business and environment perspectives [4]. The environmental performance management and reporting require the consideration of a set of appropriate environmental indicators.

3 Graph-Based LCA

The main idea of the approach is based on the concept of graph based representation of different lifecycle factors which influence a product/service/process during its lifecycle. Factors are defined as the various activities during the lifecycle which influence its environmental performance e.g. farming, manufacturing. They are represented as KPIs which could have mutual dependencies and can influence each other in many different dimensions. These interdependencies are represented as relations between the factors.

In this paper we propose an approach which covers all the phases of the LCA methodology, as shown in Fig.1. Graph-based representation of different LC factors supports the visual interpretation of the different aspects and phases of LCA. For example, using the graphs it is possible to visualize how the change of one factor (KPI) will affect the other. This concept provides the capacity to set up the goal and scope of analysis (e.g. carbon footprint below a threshold), and the system may then find all the possibilities and opportunities in order to achieve that goal. Furthermore, this supports the use of more advanced concepts, such as impact analysis which is specifically based on simulation scenarios and what-if analysis.

3.1 LC Dimensions

Lifecycle factors were mainly being considered until now as one-dimensional, meaning they could have only one aspect of influence corresponding usually to only one type of externality (e.g. carbon footprint). In this case, all the other types of externalities were modeled as completely separate indicators. Other dimensions such as time or location were often being neglected. As a result, it was impossible to model the different cross-dimensional relations and therefore to perform the cross-dimensional analysis.

In our concept we try to solve these issues by introducing the novel concept of dimensions and by proposing the new multi-dimensional definition of the lifecycle factors. Dimensions represent the different aspects of influence on the same factor, corresponding to different types of externalities. In this work, we have identified the following four basic LC dimensions based on different types of influences:

- **Temporal dimension.** E.g. change of one factor will affect the other in a month later.

- **Lifecycle phase.** E.g. one factor affects the other only in Middle-Of-Life phase.
- **Location**. E.g. one factor is related to the other in Germany, but not in Switzerland.
- **Type of externality.** E.g. two factors are related if we consider the CO_2 emission.

These dimensions can be used as filters and overall consist a powerful tool to visualize and analyze different types of influences. This concept is especially helpful for impact assessment of changes concerning different LC factors as well as for cross-dimensional analysis.

3.2 Reference Model of LC KPIs and Their Interdependencies

Employing the graph-based representation of KPI interdependencies, we propose an reference interdependencies model which can be retrieved and/or inferred from the reference lifecycle inventory database or defined by an LCA expert. This concept supports capturing the experts' implicit knowledge about the different LCA processes. The abstract model represents the generic LC KPIs and the relations between them whereas for different cases it is possible to instantiate the abstract model and even to add new and/or override some relations and values of the LC KPIs.

Each KPI is defined by its name, formula and dimensions of the influences. KPIs are calculated based on their formula and LCIs retrieved from the reference database. Relations between KPIs are modeled as functions and it is possible to have multiple relations between the same two KPIs. These relations represent the influences regarding the different dimensions. Every KPI instance can have multiple values which correspond to the dimensions they are analyzed for. The relations between KPIs are defined by specified functions for each dimension, if they exist. It is important to note that if there is temporal dependency between two KPIs, then the relation is the function of *t*, which represents the time. Fig. 2 illustrates the multidimensional representation of a single KPI.

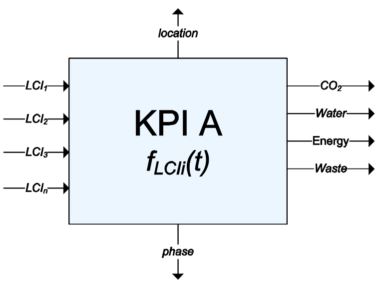

Fig. 2. Multidimensional representation of KPI

Using the graph-based presentation of KPIs interdependencies, unexpected or undesired KPI state changes can be easily detected. In this way, different kinds of analysis are supported and impact assessment can be easily performed. The user can also detect possible risks as well as infer new relations between KPIs which are not explicitly modeled. The elements of the one dimensional graph-based presentation are shown in Fig. 3.

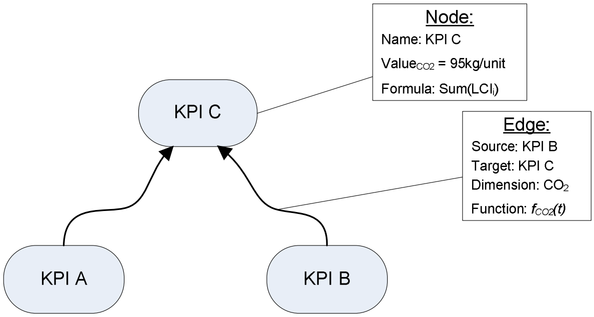

Fig. 3. One-dimensional visual representation of KPI dependencies

In order to implement the interdependencies model, the use of ontologies is recommended since they represent a very powerful concept and suitable for modeling graph-based knowledge. Furthermore, by using the advanced features of ontologies, it is possible to infer new knowledge which in this case would be new relations.

3.3 Visualization

This concept is based on the visual analysis and interpretation of the dependencies and influences between different KPIs. KPIs are represented as nodes (rectangle shape) and the relations between them are represented as arrows. For the representation of the status (or values) of different factors, the traffic light color-scheme is employed. For example, if one KPI surpasses a predefined threshold and thus is critical for the environment, it is colored in red.

This visualization method supports the so called cross-dimensional analysis, since it is possible to filter on different dimensions of lifecycle factors or KPIs which represent them and to visualize multiple dimensions and their mutual influences.

For example, in Fig. 4 we propose a way to visualize the proposed concept and perform the cross-dimensional analysis in the form of a software tool mock-up. The mock-up window is consisted of three main panes: LCA Graph pane, Dimension Filtering pane and the KPI Details pane. The LCA Graph pane visually presents the various dependencies between selected KPIs as well as their statuses. The Dimension filtering pane is consisted of several sliders which represent the different dimensions of the environmental influences. Lastly, the KPI details pane shows the details on the selected KPI such as its value, status, etc. with the capacity to generate reports.

In this example the user has selected to visualize specified KPIs and analyze its impact regarding selected dimensions (location: Germany; externality: CO_2) while observing the details on the overall Environment KPI.

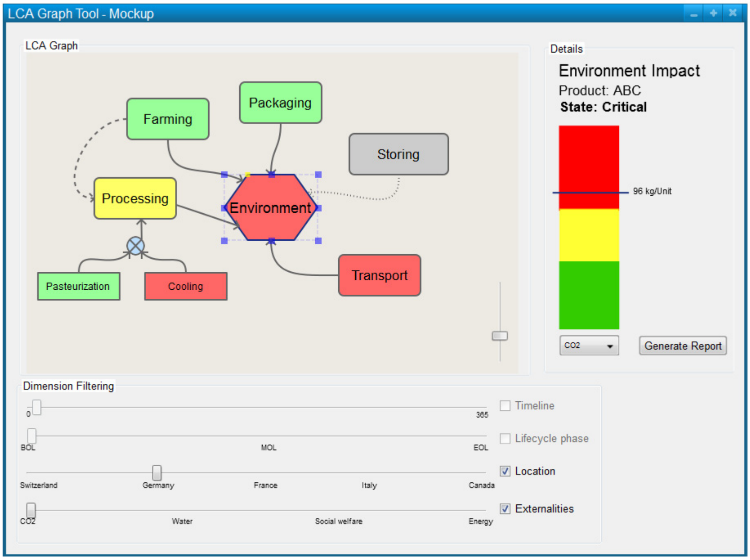

Fig. 4. LCA graph tool mock-up

In simulation mode, it would be possible for the user to change KPI values and visualize the impact on the other dependent KPIs and overall in the environment KPI. Furthermore, this concept supports setting up a goal in form of certain KPI value or value range, and the software should calculate all the possible opportunities and suggest the optimal strategies in order to achieve it. For example, the user can set the maximum value for the overall environmental KPI to be below the critical (red) threshold.

4 Conclusion and Future Work

In this paper we proposed a novel approach for LCA cross-dimensional analysis using a graph-based representation of different lifecycle factors in order to facilitate the visual analysis and simulation of a product/service/process lifecycle. The concept of dimensions was introduced in order to cover different aspects of LC influence, such as time, LC phase, location and type of externality. We presented a graph-based model of LC KPIs interdependencies visualization corresponding to specific LC factors and encapsulating multiple dimensions in order to deliver a dynamic overall environmental profile.

Concerning the expected benefits of the proposed approach, it would be possible for a user to evaluate the overall environmental performance of a product/service/process or even a firm, and through the visualized interdependencies to achieve better information visibility for improved decision support. This new type of analysis, entailing the novel dimensions, the easy customization and flexibility of the model and graph-based visual interpretation could provide much potential for a firm's optimization of environmental activities. The concept could provide new ways for identifying actions for e.g. reducing carbon emissions and significantly reduce the overall time needed for impact analysis.

The next step for this approach would entail the use of ontologies and the creation of a semantic model, since graphs convey the structural relationships of an ontology and possess the formalism to be represented by ontologies. By using the advanced features and specifically the reasoning capabilities of ontologies, it is possible to infer new knowledge by creating connections between data. The most important step would then be the implementation of the model and the application in a case study in order to evaluate its applicability and efficiency. Lastly, it would be significantly beneficial to further elaborate the model by linking the proposed concept for LCA with Life-Cycle Cost (LCC) analysis.

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A Decision Making Process for Sustainability in the Textile Sector

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Abstract. A growing number of textile companies are adopting sustainable principles as a way of distinguishing themselves from their competitors and gaining a competitive advantage. Life Cycle Assessment (LCA) is a predominant methodology for the systematic evaluation of the potential environmental impacts of a product or service system through all stages of its life cycle. However its influence and relevance for decision making is still limited since the important relationships between the economic and environmental performance are not properly addressed. In this paper, a new decision making process, exploiting the LCA methodology and combining economic and environmental aspects, is proposed.

Keywords: Life Cycle Management (LCM), Life Cycle Assessment (LCA), Sustainability, Textile, Decision making process.

1 Introduction

The increasing concern about industrial pollution, waste problem, effects of global warming, and water scarcity has led to the need of approaches, methods, and tools for measuring and reducing the environmental impact of textile products and processes, from fiber sourcing to end product [1]. In particular, the negative impacts associated with this sector can be grouped in four main categories [2]: i) energy use in laundry, in the production of primary materials (especially man-made fibers), and in yarn manufacturing of natural fibers; ii) use of toxic chemicals which may harm human health and the environment; iii) release of chemicals in water – especially in wet pretreatment, dyeing, finishing and laundry; and iv) solid waste arising from yarn manufacturing of natural fibers, making up, and disposal of products at the end of their life.

Despite the awareness of the relevance of this topic for the entire textile industry, the concept of environmental sustainability still must be assessed and transformed into business practices [3].

As argued by Waite [4], a life cycle thinking is one of the approaches that can support companies in making the textile industry more sustainable and less damaging to the environment, while at the same time remaining competitive. To this extent, the

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Life Cycle Assessment (LCA) [5] is one of the analytical methodologies that support the quantitative assessment of the environmental impacts of products, processes and services. Even though life cycle assessments currently available in the textile sector address numerous environmental issues, they do not properly consider the economic impacts of the decisions that, on the contrary, represent the main aim of private sector managers [6]. Hence, there is a need of investigating how LCA can be integrated with other management practices in order to encompass more aspects of the decision-making process.

In this paper, we develop a decision making process based on LCA that incorporates economic analyses, adopting a continuous improvement approach. This process helps the companies operating in the textile industry to measure, monitor and improve their performance in order to achieve, at the same time, economic and environmental advantages, both in the long- and short-term.

The remainder of the paper is organized as follows. Section 2 presents the theoretical background of the paper, focusing on Life Cycle Management (LCM) and LCA. Section 3 describes the development of a decision making process for the textile sector based on LCA, while Section 4 introduces an application to a real case. A discussion of the results precedes the final conclusions (Section 5).

2 Literature Review

Life Cycle Management (LCM) is defined as "an integrated framework of concepts, techniques and procedures to address environmental, economic, technological and social aspects of products and organizations to achieve continuous environmental improvement from a life-cycle perspective" [7], from raw material extraction, through manufacturing, to consumption and finally to ultimate disposal [8].

Within this framework, Life Cycle Assessment (LCA) is one of the most prominent methodology [9] for the systematic evaluation of the potential environmental aspects of a product or service system through all stages of its life cycle. It can assist in [10]: i) identifying opportunities to improve the environmental performance of products at various points in their life cycle; ii) informing decision-makers in industry, government or non-governmental organizations (e.g., for the purposes of strategic planning, priority setting, and product or process design or redesign); iii) selecting relevant indicators of environmental performance; and iv) marketing (e.g., implementing an eco-labeling scheme, making an environmental claim, or producing an environmental product declaration).

Both the public sector and many business associations and industrial companies already use the life-cycle approach in the framework of sustainability. Within the textile sector, several LCA results were contributed from many areas like cotton growing, spinning, weaving and finishing, laundering and integrated life cycles, as analyzed by Nieminen et al. [11]. The key objective of these LCAs is to select the most appropriate strategies for a product or a process to reduce its environmental impacts [12]. Although environmental issues are important, it is crucial to consider in the decision-making process also business strategies and economic consequences, especially when considering private industry applications.

However, since LCA is a decision supporting methodological framework [5] rather than a decision making methodology, economic aspects of the decisions are within the scope of LCA methodology, and are not properly addressed by existing LCA tools. This traditional separation of life cycle environmental assessment from economic analysis has limited the influence and relevance of LCA for decision making, and left uncharacterized the important relationships and trade-offs between the economic and environmental performance [6]. Therefore, LCA results should be handled together with other criteria (e.g., economic aspects) in the decision-making process in order to utilize the outcomes in the final decision context [13].

In order to consider both environmental and economic aspects, a new decision making process based on a LCA approach, integrated with economic consideration, is proposed in this paper.

3 Development of the Process

Through the identification of the critical elements in managing primary and support processes and facility infrastructures, combined with the definition of a set of indicators to measure and control environmental performances, the proposed decision making process aims at supporting a textile firm to: i) evaluate its environmental performance with a dynamic perspective; ii) identify "hotspots", that are activities and/or infrastructures that could be improved or changed in order to reduce environmental impact, save money in the short as well as in the long term; iii) drive investments for sustainability; and iv) increase a sustainable image. The proposed model, depicted in Figure 1, is built on the technical framework for the Life Cycle Assessment methodology that has been standardized by the International Standards Organization [14].

3.1 Goal and Scope Definition

Goal of the project is the integration of a traditional business model with sustainable principles to get environmental, economic and competitive benefits. By making the workplace healthier and working activities safer, also social sustainability can be obtained as a direct consequence. As for the system boundaries, the textile production chain as defined in [15] is addressed, including yarn, fabric and product manufacturing (spinning, weaving, knitting, cutting, making and trimming) as well as finishing processes (desizing, scouring, bleaching, dyeing, printing, printing and finishing).

3.2 Inventory Analysis

Through the support of a panel of experts, from both academia and industry, 14 semi-structured interviews in 6 companies operating in the textile production chain were conducted. Each of the 14 interviews, carried out by two or three researchers, lasted between one and two hours and was recorded and subsequently transcribed.

Informants included the Plant Manager, shop floor supervisors and workers, and representatives from Manufacturing and Quality function. Additionally, direct observation (e.g., plant tours) was also used as data collection method. As result, the main processes and facility features were identified. Both primary and support activities [16] were considered. Then, for each single process/facility feature, inputs (materials, water, and energy), outputs (environmental releases in the form of air emissions, water emissions or solid waste) and resources (including tools and equipment that support the processes execution) were identified and coded. The main result of this phase was a comprehensive textile inventory matrix, containing 152 inputs, 128 outputs and 64 resources.

3.3 Impact Assessment Phase

In accordance with the GRI standards [17] the environmental performance areas were identified, considering an operative as well as a strategic perspective: material consumption, energy consumption, water consumption, and waste production (operative areas); environmental protection expenses and innovation and training (strategic areas). Then, for each area, a set of Key Performance Indicators (KPIs) was proposed. They were used as a basis for a Sustainable Textile Scorecard, that enables managers to clarify their sustainable strategy and translate it into action. A performance target can also be defined for each KPI and used as a reference value to sustain continuous improvement. The strategic performance areas measure the innovation level and the culture for sustainability of the company, while the operative KPIs support the identification of the criticalities, as described in the follows.

Regarding the operative KPIs, a prioritization strategy was then needed to identify the "hotspots", defined as the elements within the system that contribute most to the environmental impact. Consequently the different input/output values should be characterized into a common equivalence unit that can be compared and eventually summed to provide an overall impact. Among the impact categories defined by the ISO standard [14], the Global Warming was considered as the most representative. Hence, the characterization formula proposed by Heijungs et al. [18], and adapted by Forster et al. [19], was selected:

$$EI_s = GWP_s * Q_s \tag{1}$$

where EI_s is the environmental impact associated to substance *s* (input or output), *GWPs* the global warming potential (characterization factor) for substance *s* calculated in terms of carbon dioxide (CO_2) equivalent, and *Qs* the quantity of substance *s*. Then, the operative KPIs can be assessed in terms of CO_2 emissions using the following formula:

$$EI_{KPI_i} = \sum_{s \in S_i} EI_s = \sum_{s \in S_i} GWP_s * Q_s \tag{2}$$

where S_i is the set of the substances that refer to the calculation of KPI_i.

3.4 Interpretation of Results

Based on the results from the Inventory analysis and Impact assessment, a priority list can be then created by ranking the environmental criticality (in terms of CO_2 equivalent), thus identifying the most critical elements (process, input or output). Three different classes of solutions can be identified to decrease the environmental impact: i) facility structures and equipment; ii) organizational solutions; and iii) material supply management and waste disposal, including reuse, recycling and recovery.

Since the aim of this decision making process is to combine environmental and economic benefits, the identified solutions, potentially advantageous to mitigate the environmental impact, are then assessed with financial tools, to evaluate their investment returns and cash flow impact. In particular, the financial analysis must also capture all relevant and significant environmental costs related to the alternatives. Based on the Total Cost Assessment (TCA) method [20], the environmental costs on which the solution has an impact need to be identified and estimated. TCA is similar to traditional capital budgeting techniques except that it attempts to include all costs and benefits associated with each alternative, including environmental expenditures and savings. In accordance with Curkovica and Sroufe [21], four tiers of costs are considered: i) direct costs; ii) hidden costs; iii) contingent liability costs; and iv) less tangible costs. Once all the cost and savings that accompany each solution are identified, financial tools familiar to many businesses for rating each investment are then used to select the best option. By constantly collecting data and calculating the indicators defined in the Impact assessment phase, new critical indicators are identified and new solutions could be proposed by applying a continuous improvement approach.

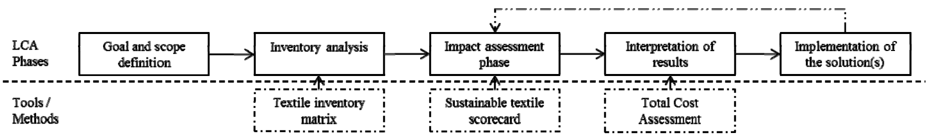

Fig. 1. The decision making process

4 An Empirical Application

In this section the application of the decision making process to an Italian textile company (hereafter referred to as TexCo) is presented. TexCo is specialized in finishing fabrics for a wide range of end uses and markets. The application of the model was limited to hospital cotton bed lines as they represent the most profitable market for the company. Data was collected through semi-structured interviews and several audits performed by the authors and their research groups. The gathered information was then discussed with a panel of experts, who supported the definition of the potential solutions to implement in order to reduce the company's impact on the environment.

Firstly, the processes and facility features associated to the company's business were selected from the comprehensive inventory matrix. For each process/facility feature, inputs, outputs and resources were measured. Afterwards the operative KPIs were assessed in terms of CO_2 emissions. The "Gas Consumption" KPI was recognized as the most critical, since it was responsible for the major contribution to CO_2 emissions. The inputs/outputs/resources, which were directly linked to gas consumption, were "Gas" (Input) and "Singeing machine", "Desizing machine", "Scouring machine", "Mercerizing machine" and "Bleaching machine" (Resources). Consequently, the analysis was focused on five operative processes (Singeing, Desizing, Scouring, Mercerizing and Bleaching) and on one facility feature (Heating System), which were directly connected with the aforementioned input. Since 40% of the total gas consumption was imputable to bleaching process, the solutions proposed were addressed to improve its environmental sustainability. In particular, a panel of experts proposed the introduction of a peracid bleach for the bleaching process. The use of peracetic acid can accelerate the reaction rate and shorten bleaching time at relatively low temperature, which can reduce both the environmental burden and the production cost. Its applicability was tested through laboratory experiments, while its advantages were evaluated through environmental and economic analyses.

Basically, the technical solution under analysis is characterized by a lower operating temperature and, consequently, a lower gas consumption (from 0.125 Nm^3/kg to 0.077 Nm^3/kg). On the contrary, compared to a traditional bleaching process, this solution requires higher quantity of chemical composites (+ 2g/l of TAED, + 0.5 g/l of soda and +2.5 g/l of peroxide). Such technical specifications were directly obtained from the supplier of peracetic acid. No investments in new machines or technologies are required. Considering the four tiers of costs [21], the solution under analysis impacts on direct costs only. The best chemical formulation, characterised by the fulfilment of the required qualitative parameters at the lowest consumption of chemical substances, was defined through more than 30 experimental trials.

The cost analysis revealed savings for the bleaching costs (Table 1). Environmentally, equivalent CO_2 emissions savings of around 40% were gained.

Table 1. Economic and environmental costs and savings

	Additional costs (per kg of fabric)	Savings (per kg of fabric)	Costs or savings/year (*742.500 kg*)
Gas consumption		0,020208 €/kg	
Chemical composites		---	
- Soda	0,00148 €/kg	---	
- Peroxide	0,00925 €/kg	---	
- TAED	0,00400 €/kg	---	
Total	0,01473 €/kg		4.067,4 €

Moreover, additional aspects were analysed to comprehensively quantify the environmental and economic implications of introducing this operational solution. As for cycle time, no significant improvements were registered. Regarding the waste production, the quantity of COD (Chemical Oxygen Demand) in the waste water from the peracid bleaching process decreased by 12% compared to the initial situation.

5 Conclusions

Sustainability is gaining more and more relevance on the manager's agenda since it can positively contribute to the firm's value creation process. The benefits are numerous and range from cost reduction, through risk management and business innovation, to revenue and brand value growth. In the textile sector, several companies are starting to pave the way towards sustainability through a number of different approaches.

In such a context, this paper proposes a decision making process to help textile companies in fulfilling environmental, economic and competitive benefits. The model, which has been built on the LCA methodology, supports the identification of opportunities for preventing pollution and for reducing resource consumption through a systematic analysis. Summarizing, the model provides a management system able to support managers to: i) monitor and evaluate its environmental performances with a dynamic perspective; ii) identify which activity and/or infrastructure needs to be improved or changed in order to reduce the environmental impact, enabling cost savings in both the short- and long-term; iii) define strategies for sustainability and foster the sustainable development of a company; and iv) increase a sustainable image. As demonstrated by the pilot case study that has been used to illustrate and analyse the applicability and consistency of the model, the solution proposed and implemented has enabled significant economic and environmental savings through a lower resource utilization.

To conclude, this paper can be considered as a basis for further research. In particular, in order to overcome the limitations of this work, some possible directions are hereafter pointed out. First of all, the proposed Sustainable Textile Scorecard can be extended considering other relevant aspects and KPIs. Moreover, as shown in the empirical application, there could be solutions that entail a higher consumption of chemicals, whose environmental impact could go beyond the Global Warming category. Therefore, future investigations can be carried out to analyse the introduction of other additional impact categories which can be useful to represent environmental sustainability with a wider perspective. Finally, social costs are not included in the model, but could be considered as potential further extensions.

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Sustainability Assessment Tools – State of Research and Gap Analysis

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Abstract. This paper investigates the current tools and frameworks for sustainability development assessments in industrial sectors and aims to find out the gaps between theory and practice toward sustainability assessments. An analysis of existing literature in the area of sustainability assessment tools has been complemented by interviews with experts in the area of sustainability and energy efficiency. Based on the body of knowledge and the practitioner feedback, time required and specificity are key challenges in sustainability development analysis. The paper opens the room for ideas concerning future research initiatives to overcome those drawbacks and challenges.

Keywords: Sustainable manufacturing; energy efficiency; sustainability assessment tools; manufacturing.

1 Introduction

In recent years, sustainable development became more important for policy makers in industrial sectors. Associations such as The World Business Council [1] or the Global Reporting Initiatives [2] have paved the way towards the implementation of sustainability in business and industry. The development of standards and measures [3] are initiations for reporting on the triple bottom line.

As of today there have been remarkable efforts to investigate and establish methods, frameworks and techniques concerning sustainability assessment. This paper discusses the evolution of manufacturing paradigms and systems towards sustainability. Figure 1 shows evolutionary and remarkable steps in the development of the manufacturing function over time.

The necessity of information analysis in order to make efficient decisions high-lights the importance of assessment tools for decision makers. A large amount of sustainability assessment tools exist and each one according to its characteristics provides different information and analysis. Therefore it is able to fulfill a specific purpose, thus choosing the proper assessment tool is a critical decision to be made.

For instance assessment tools for making short-term decisions may be different from those being used for making long-term decisions.

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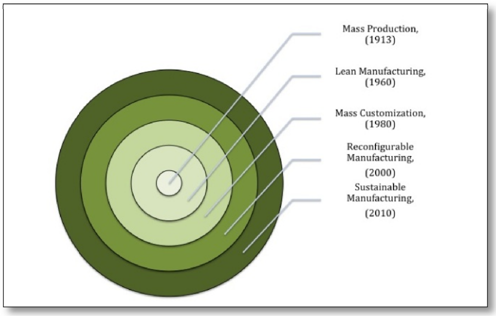

Fig. 1. Evolution of manufacturing systems toward sustainable manufacturing

OECD sustainability studies divided assessment tools in three types: analytical tools and methods, participative tools and methods, and managerial assessment frameworks [4]. Analytical tools try to bring sustainability assessments into communications for instance national income or genuine savings. Participative tools are one of the key tools in integrated assessments and they are based on sharing data, knowledge, views and ideas of different participants such as researchers, policy makers, social organizations, etc. Assessment frameworks are used to investigate different aspects of sustainability and try to find the linkage between them.

Quick assessments and consequently simple policy processes as well as long term and complicated processes follow a four-generic-step procedure according to OECD sustainability development which has published a table that summarizes the theoretical framework used for selection of specific tool. Table 1 shows how each type of tools follow these generic set of steps consisting of four phases, in integrated assessment approaches and consequently helps in decisions regarding selection of proper tool [4].

Table 1. The Role of Tools in Sustainability Assessment Adopted from OECD (2004)

	Phase I Problem Analysis	Phase II Finding Options	Phase III Analysis	Phase IV Follow-up
Participatory tools	Problem framing (mobilizing and integrating knowledge and values)	Supporting scenario building	Providing the context for and improve robustness of MCA, CBA and CEA	Evaluating the assessment process
Scenario tools	Providing he future perspective to future framing	Visioning features, finding options and setting options	Providing references for the application of analytical tools	-
Multi-criteria analysis tools (MCA)	-	Definition of criteria	Comparing different alternatives	-
Cost-benefit analysis (CBA) and Cost-effective analysis (CEA) Accounting tools Model tools	Providing the analytical basis for problem framing	Supporting objective settings	Full analytical characterization of options to enable comparison	Ex-post assessments

This paper analyzes the current state of the art concerning existing assessment methods and investigates how comprehensive these tools are taking the triple bottom line [5] into consideration. The paper is organized as follows: the theoretical background on sustainability frameworks for assessments precedes the methodological chapter and the subsequent review. Finally, the identified gaps are presented and discussed.

2 Theoretical Background

Warhurst states that sustainability development can be measured through a two-step approach [6]. In the first step the progress of sustainability development will be measured by the help of Sustainability Development Indicators (SDIs) in a number of selective individual fields. In the second step overall progress toward sustainable development will be found by assessing these individual fields considering their relation together. Lancker and Nijkamp postulate that an indicator has no correlation and causality with sustainability improvement measurement unless there is a reference threshold for it [7]. This proposition directly talks about benchmarking the indicators and their assessment. So it highlights the need for developing a set of comprehensive indicators, which enables benchmarking in both domestic and international levels.

The Pressure-State-Response framework has been developed by OECD and is widely used as a reference framework [8]. Pressure indicators explain how the pressure of human activities and the way they use natural resources is influencing environment. While the framework is well suited for assessing environmental aspects, it has limitations in performance assessments of the remaining two pillars.

Lundin describes two different approaches that can be used in order to create a framework and indicators. These two typical approaches are distinguished as:

- Top-Down Approach: experts and researchers develop the framework and then they set the appropriate Sustainability Indicators (SIs) for the framework.
- Bottom-up Approach: This approach is based on corporation and synergy. Participants and stakeholders try to share ideas and develop a framework and its required indicators. Examples of this approach can be Sustainable Seattle, Bellagio Principles and Picabue [9].

The LCSP framework was introduced in order to organize the existing indicators and to develop new indicators. The framework suggests starting from easy and simple performance indicators to measure sustainability developments and move toward complex ones. The LCSP framework mainly focuses on environmental, safety and health aspects of sustainable development [10].

One of the popular and famous frameworks toward sustainability development is founded in 1997 by non-profit organizations named Environmentally Responsible Economies (CERES) and the Tellus Institute in Boston. In early 1990s a framework was pioneered for environmental reporting and after implementing more developments on this framework it came up with the framework of Global Reporting

Initiative (GRI). GRI came along with the motive to "do more than environment", hence the scope of the framework was broadened to cover social, economic and governance issues. GRIs guidance became a sustainability-reporting framework, with reporting guidelines at its heart. GRI uses a hierarchy principle covering all the aspects of sustainability including social, economic and environmental aspects. [11]

3 Research Methodology

As this paper is a review on the current literature of sustainability assessment tools, so the methodology applied to carry out this review consists of five consecutive steps. First a web-based search has been carried out to collect all the related documents. After collecting all related materials a short review of each one resulted in a classification scheme according to the level in which they are related to the subject. Following, an analysis of the related material has been carried out to be able to do a gap analysis by integrating and comparing the results coming from the literature review and collected facts from the forth step in which interviews with experts in sustainability have been carried out. The goal of the gap analysis was to find out the differences between what exists in the literature and what is currently in practice, so it can be used as a body of knowledge for future researches.

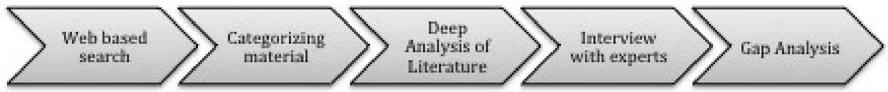

Fig. 2. Methodology

4 State of Research

This section will focus on the main goal of this paper that is evaluating sustainability assessment tools that are currently in use. The context of this section comes from the both literature review and interviews.

4.1 Indicators

Indicators and indices assemble the first part of sustainability assessment tools. Main characteristics of indicators are being efficient and easy to use. Mainly they are quantitative indicators although also qualitative indicators are applicable. Indicators are able to represent economic, social and environmental aspects of sustainability in defined criteria. Harger and Meyer stated that indicators should be as simple as possible while at the same time they should be able to be specific or comprehensive depending to the objective of usage. Indicators and indices should allow to identification of trends through time horizons [12].

4.2 Product-Based Assessment Tools

The difference of these tools with indicators is the fact that in this category, tools intend to evaluate various flows between products and consumptions. These tools are trying to find out the impacts of using resourcing to satisfy the demands on environment. These assessments can be performed through evaluation of production line and their impact on sustainability aspects or through products life cycle assessment from the moment they are intended to produce till their burial. Although life cycle costing assessment includes also economic aspects but these tools mainly are focused on environmental dimensions.

Life Cycle Assessment: The most used tool in the category of product-based assessment tools is Life Cycle Assessment (LCA). This tool is among the oldest and well-developed tools for sustainability assessments. It is considered as a comprehensive tool for assessing environmental impacts because it analyzes actual and potential impacts that a product may has on the environment during raw material acquisition, production process, use, and disposal of the product [13].

Life Cycle Costing: Life Cycle Cost analysis is an economic method that considers all the costs over the entire life cycle. This method calculates all the possible costs related to a product, activity or a process over its lifetime [14]. The main goal of life cycle cost analysis is to highlight the impact of operation costs during the life time compared to the investment costs.

Material Flow Analysis: MFA is defined as systematic accounting of the flows and stocks of materials within a system defined in space and time. It connects the sources, the pathways, and the intermediate and final sinks of a material. Because of the law of conservation of matter, the results of an MFA can be control by a simple material balance comparing all inputs, stocks, and outputs of a process [15].

Life Cycle Energy Analysis: Life cycle energy analysis measures the required energy to produce a product or providing a service [16].

4.3 Integrated Assessment

The third category includes integrated assessment tools. These tools help decision makers in decisions regarding a policy or project. Project related tools are used for local scale assessments, whereas the policy related focus on local to global scale assessments [17]. Integrated assessment is usually based on forecasts than actual results. Many of these tools are based on integration of society and environment dimensions. Integrated assessment tools are useful tools for understanding complex problems [18].

Conceptual modeling: Conceptual Modeling is a useful qualitative tool that can help to simplify complex situations. With the help of flowcharts, diagrams, and charts it is possible to visualize the problem and find out the flows, their relationships, points of weakness and strength. By applying conceptual modeling we can start the initial part of computer modeling and as a result achieve precise solutions.

System Dynamics: Although systems dynamics tools have similarities with conceptual modeling in terms of simplifying complex problems to understand them better there are significant differences between them. In system dynamics computer models of complex situations are built and then they will be examined over time to study the behavior of model over time [19].

Multi-criteria Analysis: Multi-criteria Analysis (MCA) is one the most useful and practical tools in helping decision making processes when we have a complex situation which is necessary to choose between alternatives that are competing together. Above all, this tool is very useful in sustainability assessments where we are in need to analyze complex and inter-connected alternatives in environmental, social and economic dimensions. This method can be used in both qualitative and quantitative analysis.

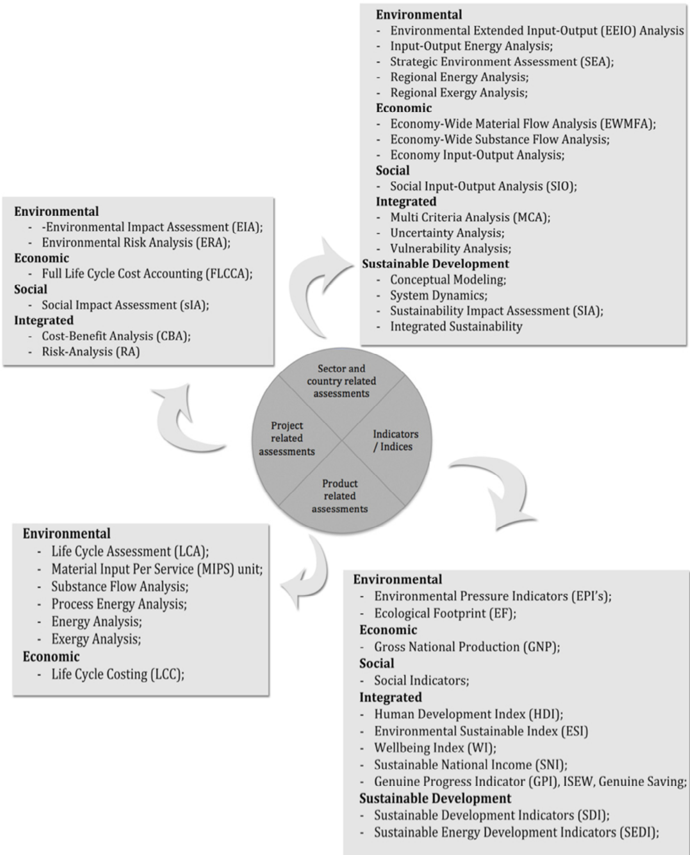

Fig. 3. Sustainability assessment tools and their focus area

Risk Analysis and Uncertainty Analysis: Rotmansdefines risk as a "possibility of damage or loss that may happen because of an event or series of events" [20]. Risk analysis tries to find out theses possible damages by identifying the risks and their probability of happening and help decision makers to take proper actions in order to diminish them or make appropriate mitigation actions.

Vulnerability Analysis: Vulnerability Analysis intends to find out the level of sensitiveness and resistant of the system toward changes and how capable are to cope with these changes. If vulnerability analysis proves that the system is vulnerable, then risk analysis will be executed [21].

Cost Benefit Analysis: Cost Benefit Analysis (CBA), has been used for the first time in order to help decision makers to make trade-off between the costs and benefits of the proposed investments by weighting the costs against the expected benefits [22]. In the area of sustainability this tool can be used in order to make the trade-offs for example, between the environmental benefits of an alternative comparing to its social costs [23]. The remarkable point in CBA is that using monetary units for expressing the expected benefits and similar issues can sometimes be a problem [24][25].

Impact Assessment: Impact assessment has been increasingly used for helping policy makers and legislations toward sustainability. This method has been increased for improving regulations in terms of effectiveness and efficiency [26].

5 Gap Analysis

From what is discussed in the literature and interviews, there are number of existing gaps that have the potential of being future research topics toward sustainability development. Reducing the existing gaps will improve sustainability to a new era. The existing gaps are mainly related to sustainability development assessments and their applications.

One of the existing gaps between scholars and practices is that sustainability assessments are significantly time consuming to be implemented. There are varieties of reasons for this issue. The lack of a set of comprehensive indicators for sustainability development assessment might be supporting this gap. Availability of comprehensive indicators can enable assessment tools to consider all pillars of the triple bottom line concept in the measurements and consequently reducing the need for executing different tools for measuring sustainability considering different aspects and then complementary tools, frameworks or methods to aggregate and compile the results of all measurements so it is possible to announce a unique set of conclusions to support decision makers regarding to sustainability decisions.

The second gap is that existing tools, methods and processes of sustainability development assessments are mostly specific ones which focus on special criteria, sector or sustainability aspect. This can be a challenge in different sectors or criteria because it may require time to find out about the most proper tool that serves the best for the intended purpose of sustainability measurements and evaluations. Although there have been efforts for finding proper solutions to bridge this gap but still this issue has not been eliminated completely. Another reason in this issue is the level of complexity of decisions vary from simple ones to very complex ones depending on how big a project or a company is and also how many variables are involved in assessments so the necessity of using different types of frameworks or tools can be an extra weight for making the assessments more complex.

6 Conclusion

Since sustainability has gained lots of attention as a result sustainability development assessments also became an important issue for companies and industrial sectors. There is large number of methods, regulations, frameworks and tools to reach this purpose.

Here in this paper the effort was to build a body of knowledge of the current methods and tools which are being used with the purpose of sustainability assessments in order to provide managers and policy makers in the industrial sectors clear information about the level of sustainability in which they are operating and hence helping them in the process of decision making. By investigating some gaps making comparisons between what is in the literature and what is in practice carrying interviews with experts in the area some research questions for future works are defined as below:

- Developing indicators for a comprehensive Rapid Sustainability Assessment Tool
- Introducing energy efficiency as a key enabler for sustainability assessments
- Integrating energy efficiency with manufacturing processes and sustainability developments
- Developing methods toward continuous energy efficient assessments

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A Prototype Crowdsourcing Approach for Document Summarization Service

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Abstract. This paper proposes a crowdsourcing approach for informative document summarization service. It first captures the task of summarizing a lengthy document as a bi-objective combinatorial optimization problem. One objective function to be minimized is the time to comprehend the summary, and the other one to be maximized is the amount of information content remaining in it. The solution space of the problem is composed of various combinations of candidate condensed elements covering the whole document as a set. Since it is not easy for a computer algorithm to create condensed elements of different lengths which are natural and easy for a human to comprehend, as well as to evaluate the two objective functions for any possible summary, these sub-tasks are crowdsourced to human contributors. The rest of the approach is handled by a computer algorithm. How the approach functions is tested by a laboratory experiment using a pilot system implemented as a web application.

Keywords: collective intelligence, crowdsourcing, document summarization, human computation, micro tasks.

1 Introduction

There are manual and computerized document summarization services today. Since manual summarization is costly and usually takes a long time, many studies have been conducted on computerized summarization [1][2]. Computerized techniques for document summarization can be classified into extractive and abstractive methods. The extractive method identifies important sentences or phrases in the input document, and outputs a summary by simply connecting the identified sentences or phrases. The abstractive method, on the other hand, newly creates condensed sentences so that their combination can deliver whole relevant information in the original document.

Since the extractive method is easier to automate than the abstractive one, most computerized summarization techniques practically applicable today are classified into the former category. However, a summary obtained by the extractive method has a fragmentary nature, that is, it only covers the fragmentary information contained in the chosen sentences or phrases. Therefore, it is appropriate for indicative purpose but

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for informative purpose. A summary for indicative purpose is used to determine whether the user should read the original document, whereas a summary for informative purpose gives the user sufficient information to proceed without reading the original document.

Thus, for the purpose of informative document summarization service, the abstractive method should be applied. However, computerized techniques in this category are still in early development phase, especially because it is not easy for a computer algorithm alone to create sentences which are natural and easy for a human to comprehend. In order to overcome this difficulty, this paper takes a crowdsourcing approach. Crowdsourcing is a form of outsourcing a task, where the task is divided into many micro pieces and the pieces are outsourced, typically to a lot of anonymous people with a tiny wage over the internet [3]. This approach is also called human computation [4][5][6] and can be used as if a part of a computer algorithm. Its successful applications include parts classification [7], document translation [8][9][10], and document editing [11].

In the remainder of this paper, after introducing a model of document summarization task, a prototype crowdsourcing approach for accomplishing the task is proposed. Then, how the approach functions is tested by a laboratory experiment using a pilot system implemented as a web application. Following its results, discussion and conclusions are provided.

2 Modeling Document Summarization Task

Any document is composed of several units, for example, chapters, sections, paragraphs, or sentences. In this paper, we distinguish two types of units; one is evaluation units and the other is condensation elements. Then, the whole document to be summarized is captured as a set of evaluation units, and each evaluations unit as a sequence of a manageable number of condensation elements. How to define the scope of these units is not unique, but the scope can be assigned to the input document recursively. For example, chapters can be deemed as evaluation units and sections as condensation elements. It is also possible to define paragraphs as evaluation units and sentences as condensation elements. It is assumed that document summarization task starts from a scope having the smallest condensation elements and gradually shifts to a coarser one as the task proceeds. In the following, we will focus on an evaluation element and provide a model for the task of summarizing it. The overall task of summarizing the whole document can be captured as parallel and recursive application of the modeled task.

The task of summarizing an evaluation unit is captured as a bi-objective combinatorial optimization problem. One objective function to be minimized is the time to comprehend the summary, and the other one to be maximized is the amount of information content remaining in it. The solution space of the problem comprises various combinations of condensed elements covering the whole evaluation unit. For example, suppose that the concerned evaluation unit is composed of an ordered set of condensation elements ($= U_0$), and there are several candidate condensed elements

($\in U_1$). Further, each condensed element m corresponds to an ordered set V_m, which is a sub-sequence of U_0. That is, condensed element m is an efficient expression of the information contained in V_m. It is also defined that for all $m \in U_0$, V_m equals $\{m\}$. Then, every feasible solution of the summarization problem can be captured as an ordered set S_k, whose elements are taken from $U_0 \cup U_1$, satisfying the following conditions:

$$\cup_{m \in S_k} V_m = U_0 \tag{1}$$

$$V_m \cap V_n = \emptyset \ \ (\forall m, n \in S_k) \tag{2}$$

Let us denote the two objective functions, the time to comprehend S_k and the amount of information content remaining in it, by $F_1(S_k)$ and $F_2(S_k)$ respectively. Then, the summarization problem can be formulated as:

$$\text{Minimize } F_1(S_k) \text{ and maximize } F_2(S_k)$$

$$\text{Subject to equations (1) and (2)}$$

It is, however, noted that the objective functions $F_1(S_k)$ and $F_2(S_k)$ as well as the set U_1 are not given a priori, and establishing these is also included in the summarization task.

3 Proposed Crowdsourcing Approach

In this section, we propose a prototype crowdsourcing approach for the modeled document summarization task. An outline of the proposed approach is shown in Fig. 1. According to the task model provided above, the summarization task includes three sub-tasks, that is, creation, evaluation, and optimization. These sub-tasks are addressed one by one in the following.

3.1 Creation

As shown in Fig. 1, the proposed approach starts with dividing the concerned evaluation unit into elements. Then, the obtained condensation elements are numbered and stored into a database, so that each element can be taken out easily by specifying its number. At this point, the set U_1 is empty. Hence, condensed elements corresponding to various sub-sequences of U_0 should be created and thrown into the set U_1. In the proposed approach, this sub-task is treated as a set of micro tasks, each of which corresponds to the task of creating a single condensed element. Then, the micro tasks are crowdsourced, and their outputs are also numbered and added to the same database.

How each of the micro tasks is performed by a human contributor is as follows. When a contributor starts the micro task, she/he is shown the whole evaluation unit as a sequence of condensation elements. Then, she/he is supposed to choose a subsequence of them and to create a more efficient expression representing the information contained in the sub-sequence. If someone else has already created a condensed element corresponding to the same sub-sequence, the element is also shown to her/him as a hint.

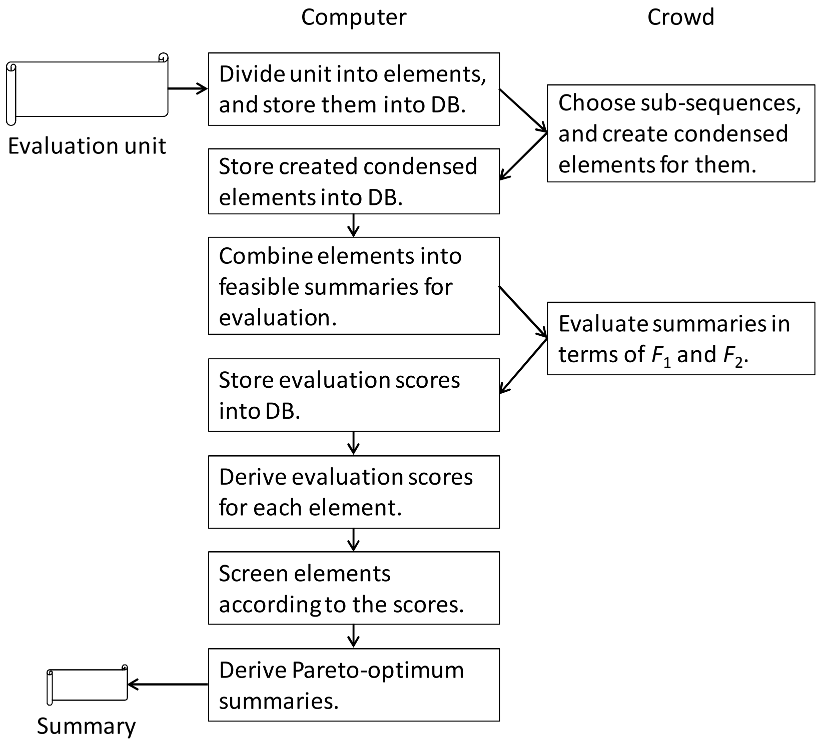

Fig. 1. Outline of proposed approach

3.2 Evaluation

Since the creation sub-task described above enriches the set U_1, the number of feasible combinations of condensed elements, i.e. summaries, will become so large that all of them cannot be evaluated one by one manually. Therefore, numerical expressions for the objective functions $F_1(S_k)$ and $F_2(S_k)$ are necessary. Thus, in the proposed approach, we formulate the evaluation measures as follows:

$$F_1(S_k) = 100 - \sum_{i \in S_k} f_{1i} \quad (3)$$

$$F_2(S_k) = 100 - \sum_{i \in S_k} f_{2i} \quad (4)$$

It is noted that, for simplicity, only main effects are considered in the equations. If the value of $F_1(S_k)$ is 100, the time length required for comprehending the summary is as long as that for comprehending the original evaluation unit. Its value decreases as the time length required for comprehending the summary decreases. On the other hand, when no relevant information is lost in the summary, the value of $F_2(S_k)$ is 100. Its value decreases as the information remaining in the summary decreases.

In order to estimate the parameter values in equations (3) and (4), simple multiple regression using dummy variables can be utilized. The regression analysis needs some learning data, and hence the data should be gathered somehow. In the proposed approach, this sub-task is treated as a set of micro tasks, each of which corresponds to the task of evaluating a single summary in terms of $F_1(S_k)$ and $F_2(S_k)$. Then, the micro tasks are crowdsourced, and their outputs are stored in a database. Which summaries are to be evaluated is determined by the computer according to a rationale called D-optimality of experimental design.

How each of the micro tasks is performed by a human contributor is as follows. She/he is shown the original evaluation unit and a feasible summary chosen by the computer, and is supposed to read and comprehend the both. She/he is supposed to push a button on a web browser by a computer mouse, when she/he starts and ends reading each of the texts. This makes it possible to quantify the time length required for comprehending each text, and objectively evaluate the value of $F_1(S_k)$ according to the ratio between the quantified time lengths for the summary and the original evaluation unit. She/he is also asked to subjectively evaluate the amount of information contents remaining in the summary with a score from 0 to 100. This score can be used as a sample value of $F_2(S_k)$.

3.3 Optimization

When a sufficient number of condensed elements are supplied by the creation subtask, a sufficient number of learning data are obtained by the evaluation sub-task, and numerical expressions are derived for the objective functions $F_1(S_k)$ and $F_2(S_k)$ through multiple regression analysis using dummy variables, then we can proceed to the optimization sub-task. At this point, this sub-task can be captured as a simple bi-objective combinatorial optimization problem. When the solution space is large, various meta-heuristics can be utilized.

However, in the following laboratory experiment, a simple two step approach is taken, since the problem size is not so large. At the first step, non-Pareto-optimum condensed elements are screened out for each sub-sequence of the evaluation unit. Then, at the second step, Pareto-optimum summaries are chosen from the whole possible combinations of the remaining condensed elements.

4 Laboratory Experiment

4.1 Implementation

In this section, how the proposed approach functions is tested with a small-scale laboratory experiment. To conduct the experiment, the prototype crowdsourcing approach for informative document summarization is implemented as an elementary web application. The application uses MySQL as the database storing the condensation and condensed elements as well as the sample evaluation scores. It also uses PHP for handling various interactions with human contributors, and R for deriving the experimental design for the evaluation sub-task and conducting multiple regression analysis using dummy variables.

4.2 Outline of Experiment

The laboratory experiment comprises three phases. The first and second phases test whether the creation sub-task and the evaluation sub-task function properly. The third phase investigates the quality of the output summaries. In the experiment, we use a Japanese document on global warming having three paragraphs and 833 characters as the input evaluation unit, and treat its paragraphs as the condensation elements.

In the first phase, six male senior students of Aoyama Gakuin University participated in the experiment as contributors. The creation sub-task was performed by them using the developed web application, until at least three condensed elements have been obtained for every possible sub-sequence of the evaluation unit, that is, $\{1\}$, $\{2\}$, $\{3\}$, $\{1, 2\}$, $\{2, 3\}$, and $\{1, 2, 3\}$. As a result, it is confirmed that the proposed approach can actually collect various candidate condensed elements from multiple human contributors.

In the second phase, four male senior students of the same university participated. They as a whole have evaluated fifty summaries specified by the computer using the web application. Further, the parameter values of equations (3) and (4) were successfully estimated using the obtained evaluation scores as the learning data for multiple regression analysis. As a result, it is shown that the proposed approach can collect sufficient learning data in practice for establishing objective functions $F_1(S_k)$ and $F_2(S_k)$ from multiple human contributors. Further, after removing too long and too short solutions, three candidate Pareto-optimum summaries A, B and C were obtained by the proposed approach.

4.3 Quality of Output Summaries

In this subsection, we study the quality of the obtained summaries A, B and C by comparing them with the summaries for the same document of similar lengths D, E and F created by Mac OSX Summarize, which is an auxiliary function available on a Mackintosh PC. The comparisons are made in terms of the two evaluation measures, that is, the time to comprehend and the remaining information amount. Thus, two male senior students of Aoyama Gakuin University read all the summaries compared for two times and measured the time. Further, they identified which information contents of the original document remain in the summaries.

Table 1 shows the number of characters, the mean time to read, the standard deviation of the time to read, and the number of characters read per second for all summaries compared. It is noticed from the table that the summaries made by the proposed approach can be read faster than those created by Mac OSX Summarize. This means that the proposed approach is capable of providing summaries easier to read and comprehend.

Table 1. Comparisons interms of time

	Proposed system			Mac OSX Summarize		
Summary ID	A	B	C	D	E	F
Number of characters	311	277	263	392	330	230
Mean time to read (s)	33.3	27.9	26.9	43.9	38.0	25.5
Standard deviation of time to read (s)	4.91	5.75	4.01	2.61	4.34	1.26
Number ofcharacters read per second	9.34	9.92	9.78	8.92	8.68	9.02

Fig. 2 represents which information contents remain in each summary. The contents corresponding to the shaded parts in the original document have been judged to remain. It is observed that the summaries created by the proposed approach have covered whole area of the original document. Whereas, those made by Mac OSX Summarize only capture fragmentary information especially when the length is short, since the summarization function takes the extractive method.

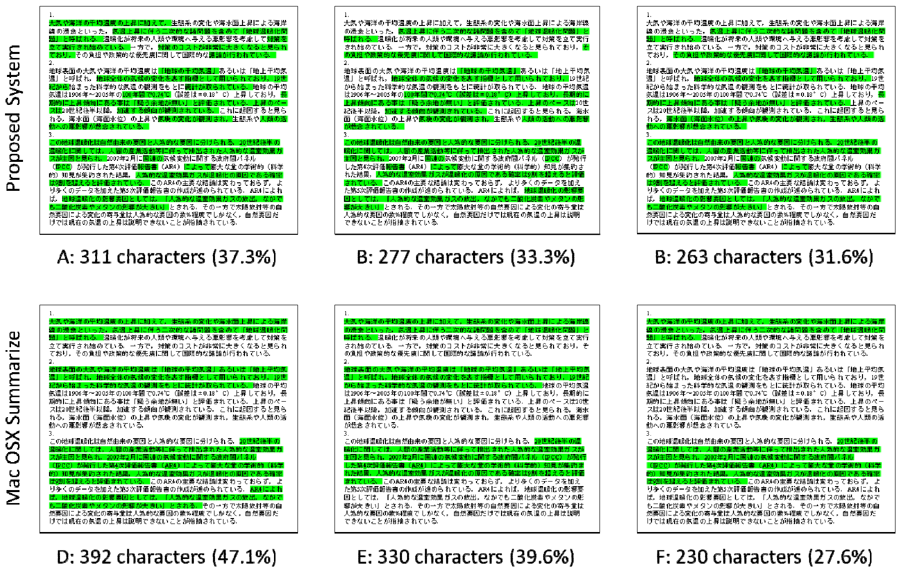

Fig. 2. Comparisons in terms of information

Accordingly, it is also confirmed that the quality of the summaries created by the proposed approach measured in terms of the time to read and the remaining information amount is fairly good. However, the judges pointed out that the summaries made by the proposed approach seem like bulleted sentences and do not flow well.

5 Conclusions

This paper proposed a crowdsourcing approach for informative document summarization service. Further, it confirmed that the approach can function properly by a small-scale laboratory experiment using a pilot system implemented as a web application. However, the approach presented in the paper is still a prototype, and has a large room for improvement. For example, promising improvement options include parallelizing the sub-tasks of creation and evaluation, including interaction effects in the objective functions, combining a computerized summarization technique with the crowdsourcing approach, etc. In order to make the sentences in an output summary flow well, in addition to considering interaction effects in the objective functions, introducing another sub-task of adding conjunctions can be effective.

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On the Development of a Reference Framework for ICT for Manufacturing Skills

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Abstract. In this paper, we plead for the development of a reference framework for ICT for manufacturing skills. The existing e-skills frameworks are either too general or too restrictive. That is why there is a need for a reference framework for ICT skills in manufacturing to be used as a common reference by all Industrial Learning stakeholders when dealing with issues related to ICT skills in manufacturing. The framework should be capable to capture most of state-of-the-art e-skills relevant to manufacturing in addition to the skills related to emerging ICT for manufacturing. Such a framework would encourage manufacturing workers to take training on specific ICT skills. The motivation for pleading for a reference framework for ICT for manufacturing skills and the requirements related to its development are presented in this paper.

Keywords: Industrial Learning, e-skills, ICT for Manufacturing, reference framework.

1 Introduction

The work presented in this paper was developed in ActionPlanT project. It relates to the review of existing e-skills frameworks, the identification of the gaps in these frameworks and the definition of the requirements to address these gaps mainly through a reference framework for Information and Communication Technologies (ICT) for manufacturing.

ActionPlanT is co-funded by the European Commission under the Private-Public Partnership (PPP) "Factories of the Future" initiative of the Seventh Framework Programme (FP7) for research and technological development (Grant Agreement Number 258617). The project started in June 2010 and ended in May 2012. The two main activities of ActionPlanT are:

- Establishing an ICT-enabled manufacturing vision for use cases and services of the future using this analysis as a basis. This vision paves the way for a detailed roadmap which prioritizes and schedules most promising topics for the upcoming Horizon 2020 Programme;
- Developing and validating a concept for Industrial Learning (IL), extensively piloted via Industrial Learning Pilot Events (ILPEs) and workshops amongst stakeholders in industry, academia, and the European technology platforms.

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The work described in this paper relates to the second activity "Awareness & industrial Learning".

In ActionPlanT, IL is defined as *the process of identifying and implementing professional competences triggered by new scientific and technological knowledge and implemented in an industrial context to address new professional needs (i.e., what workers have to cover and to know in order to contribute to new objectives such as business conversion, enlargement, modernization, etc.).*

In ActionPlanT context, we have to do with the development and implementation of new competencies required by new professional needs created by recent achievements of research and innovation actions in the domain of ICT for manufacturing.

The reference framework discussed in this paper is intended to establish the skills related to ICT for manufacturing and IL as defined in ActionPlanT is the means through which the manufacturing workforce can acquire these skills in order cover new professional needs.

The paper is organized as follows. Section 2 is devoted to motivating our plea for the development of a reference framework for ICT for manufacturing. The definition of e-skills is provided in Section 3. Section 4 is presenting the requirements of ICT for manufacturing skills framework. Discussions related to this framework are given in Section 5. Finally, Section 6 presents concluding remarks about the framework.

2 Motivation for a Reference Framework for ICT for Manufacturing Skills

The investment and efficient usage of ICT plays a major role in boosting productivity. Between 1995 and 2004, the US enjoyed a higher average productivity growth than most of the EU member states and the average of all EU15 member states [1]. This is linked to the superior capacity of US businesses to adapt and make the best possible use of emerging technologies, the most prominent being ICT.

IL will face major challenges as new skills will be required by the future workforce [2-4] to deal with new professional needs. On the basis of these needs, approaches to IL and training that introduce emerging concepts appear in the literature [5]. Manufacturing industry is one of the domains where the need for new skills mainly those related to ICT is crucial for competitiveness and innovation.

Policy has also taken notice and action to address this; the EC issued a communication [6] on e-skills for the 21st century establishing a long term agenda for e-skills, and defining 5 action lines at the EU level: promoting long-term cooperation and monitoring progress, developing supporting actions and tools, raising awareness, fostering employability and social inclusion, and promoting better and greater use of e-learning.

The main e-skills frameworks, developed by different professional and institutional sources, have been reviewed in terms of their relevance with current and future ICT in manufacturing. The outcomes from the review of the e-skills frameworks and related issues are summarized in Table 1.

Table 1. Review of existing e-skills frameworks

Observation	**Comment**
The use of different terms such as e-skills, digital skills, ICT skills, etc. is confusing and negatively impacting the review and search for e-skills	*The use of a common terminology and a clarification of the difference between these terms are required*
The reviewed e-skills frameworks are either too general or too restrictive	*A framework devoted to e-skills in manufacturing is needed*
The e-skills from different frameworks are given in various formats and different levels of detail which raises coherence problems when putting them together	*A standard way of representing and writing e-skills can be useful*
Many of the skills in the reviewed frameworks considered as e-skills are not explicitly exhibiting ICT (neither software nor hardware) features to qualify them as e-skills	*It may be useful to rewrite them in a way to emphasize the ICT features they involve if there are any*
There are manufacturing working areas which are not covered by the skills from reviewed frameworks (e.g., e-skills to use supply chain management system, how to set-up manufacturing systems, factory planning, layout planning)	*It may be useful to investigate whether these working areas are not requiring e-skills or they require e-skills which are not yet defined and used*
The e-skills in the reviewed frameworks concern classical manufacturing systems. Issues such as agile manufacturing and collaborative networks are not covered or only to a very limited extent	*There is a need for defining new e-skills corresponding to advanced ICT for manufacturing*
The reviewed frameworks are not capable to capture the new e-skills relating to the ICT for manufacturing issues such as IoT, web-services, digital factory, cloud manufacturing, etc.	*A new framework is needed for the definition of these new e-skills*

The major outcome from the observations in Table 1 is the lack of a set of e-skills capable to cover professional needs related to advanced ICT for manufacturing which are needed by manufacturing companies to improve their competitiveness.

Automotive industry is the industrial sector the most investigated with respect to the development of ICT for manufacturing skills. The ICT skills are defined in relation to the different working areas of automotive production [7]. Being specific to automotive industry, this framework is too restrictive to be used a general framework for ICT for manufacturing.

The e-CF (e-Competence Framework) [8] suggests definitions to the key learning concepts of competence, knowledge, skill, and attitude, which have been developed within a European ICT business environment. It comprises 36 ICT competences that can be used and understood by ICT users and supply companies, the public sector, educational and social partners across Europe. The proposed list of competencies is assumed to be common to all industrial sectors and is not specific for manufacturing.

The digital skills presented in [9] are developed for users of digital technology in the Canadian workplace. The corresponding framework is too general to be used as a reference framework for ICT for manufacturing skills.

The existing e-skills frameworks are either too general or too restrictive to be used as a reference framework for ICT for manufacturing skills. That is why there is a need for developing a framework focusing on manufacturing which is capable to capture most of state-of-the-art e-skills relevant to manufacturing in addition to new skills related to emerging ICT for manufacturing.

A manufacturing-focused e-skills framework could well differ from the existing e-skills frameworks either promoted by ICT vendors or developed for specific sectors or general purposes. That is why we propose to base the manufacturing-focused e-skills framework on the decomposition of the manufacturing system into subsystems and sub-subsystems. The e-skills are defined at the level of sub-subsystems.

3 Defining e-Skills

This paper focuses on e-skills for manufacturing. The European e-Skills Forum adopted in 2004 a definition of the term "e-skills" covering 3 main categories [10]:

- *ICT practitioner skills*: the capabilities required for researching, developing, designing, strategic planning, managing, producing, consulting, marketing, selling, integrating, installing, administering, maintaining, supporting and servicing ICT systems.
- *e-business skills*: the capabilities needed to exploit opportunities provided by ICT; to ensure more efficient and effective performance of different types of organizations; to explore possibilities for new ways of conducting business/ administrative and organizational processes; and/ or to establish new businesses.
- *ICT user skills*: the capabilities required for the effective application of ICT systems and devices by the individual. ICT users apply systems as tools in support of their work. User skills cover the use of common software tools and of specialized and more advanced tools. At the general level, they cover "digital literacy".

There is a large consensus among stakeholders that e-skills are crucial to boost competitiveness, productivity and innovation as well as the professionalism and employability of the workforce in industry [11].

The majority of European workforce has a good level of basic ICT skills (e.g., email communication and use of basic office applications) as a result of the investments made in this domain [12]. However regarding advanced ICT skills, there is a gap between the actual capabilities of the European workers and the expectations of and requirements for ICT skills of their employers [12].

4 Requirements for the ICT for Manufacturing Skills Framework

4.1 Decomposing the Manufacturing System

For the development of a manufacturing e-skills framework, we consider the decomposition of the manufacturing system into 5 subsystems [13]: inputs, manufacturing process, outputs, management and control, and support.

The 5 subsystems and their related links are represented in Figure 1.

We selected this decomposition for the following reasons:

- The subsystems are common to all manufacturing systems.
- All important criteria governing the manufacturing system behaviour are reflected in these subsystems.
- This model is suitable for modelling any manufacturing system structure.

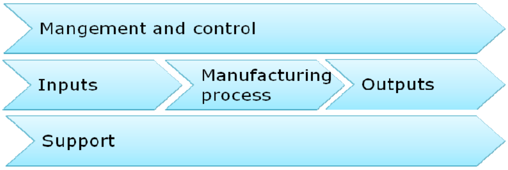

Fig. 1. Subsystems of the manufacturing system

The 5 subsystems of the manufacturing system are too broad to allow the identification of specific corresponding e-skills. That is why these subsystems are decomposed further into sub-subsystems which are more detailed and the manufacturing e-skills are associated to the sub-subsystems of the manufacturing process.

The use of this decomposition allows capturing most of the state-of-the-art e-skills relevant to manufacturing (see examples in Table 2).

Table 2. Examples of state-of-the-art e-skills for management and control subsystem

Manufacturing sub-subsystem	ICT skill	Reference
Strategy formulation	*Contributing to the development of ICT strategy and policy*	European e-CF
	Analyzing future developments in business process and technology application	European e-CF
Performance appraisal and monitoring	*Analyzing costs and benefits of implementing new ICT solutions*	European e-CF
	Selecting appropriate ICT solutions based upon benefit, risks and overall impact	European e-CF
Production planning and control	*Optimizing of production control by the use of PPS-systems/software*	Automotive ICT skills
...	...	...

4.2 Role of ActionPlanT

The ActionPlanT IL model [14] is suitable for creating new knowledge assets related to “cutting edge” ICT for manufacturing, identifying corresponding new professional competencies, and defining relevant learning programs and actions to train workers and engineers to develop these competencies.

The other important result of ActionPlanT project is the roadmap. It is built around 5 clusters aligned with the 5 innovative aspects established in the ActionPlanT vision. These clusters are: (i) Towards Agile Manufacturing Systems & Processes, (ii) the new Seamless Factory Lifecycle Management, (iii) People at the Forefront, (iv) Fostering Collaboration Supply Network, and (v) Aiming at Customer Centric Design and Manufacturing.

Each research priority within the clusters is evaluated with respect to the 5 ambitions: On-demand, Optimal, Innovative, Green, and Human-Centric.

The ActionPlanT roadmap and vision provide a relevant framework for defining new e-skills related to emerging and advanced ICT for manufacturing. They also provide a basis for defining the broad topic areas for which content should be developed in the framework of the training programs required for the transfer of the new e-skills to the manufacturing workforce to cover new professional needs.

4.3 Other Requirements

ICT skill (e-skill) for manufacturing is the basic concept in the framework. That is why there is a need for a clear definition of such concept. It is important to know when a skill can be qualified as ICT skill/e-skill.

The decomposition of the manufacturing process should also be flexible to allow for the addition of new sub-subsystems that may result from new developments in manufacturing technologies.

As ICT is changing very fast, the ICT skills needed for manufacturing are also evolving very fast. That is why the framework should be updateable to allow for the addition of new e-skills that result from new developments in ICT for manufacturing.

There is a need for continuous follow up of the evolution of ICT for manufacturing to make the involved actors aware of the emerging ICT for manufacturing skills they may need for their businesses.

To be appropriate for small and medium enterprises (SME), the framework should not be too specific. Since SME are the companies that most need IL to develop ICT for manufacturing skills that can help them extend, improve their businesses or develop new ones, then it is important to take this issue into account.

5 Discussion

The ICT for manufacturing framework we are pleading for its development is intended to be used as a common reference framework by all IL stakeholders when dealing with issues related to ICT for manufacturing skills. That is why; the development of such a framework should be dealt with in a collaborative way between all IL stake-holders to arrive at a consensus solution acceptable by all involved actors.

The effective development of the framework can be done by a specialized European working group composed of representatives of the different IL stakeholders as it was the case for the development of the European e-CF.

Since ICT are characterized by a very fast evolution, then an important issue to be faced by the framework for ICT for manufacturing is the update of the list of related skills to keep up with the pace of technological change.

Most companies are not aware of the emerging e-skills for manufacturing triggered by the new trends and innovations in ICT for manufacturing that can help them extend their businesses or develop new ones. They need to be regularly informed about the emerging e-skills for manufacturing.

An observatory for a continuous follow-up of the main trends and innovations in ICT for manufacturing, identifying the related ICT for manufacturing skills, and communicating the information to the different IL stakeholders can be a useful solution to the problem. Such an observatory can benefit from the experience and the way of working of other observatories in other domains which have similar objectives.

The competencies/skills from literature are provided in different formats and levels of detail. A common reference framework for ICT for manufacturing skills can provide a basis for developing a coherent and uniform list of ICT for manufacturing.

6 Conclusion

The extensive review of e-skills literature revealed the absence of a reference framework for e-skills in manufacturing which can be used as a common reference by all IL stakeholders and which is capable of capturing the main ICT skills which are needed by manufacturing companies to promote innovation and excellence.

Most of the e-skills from existing frameworks are basic e-skills and are not suitable for the implementation and application of advanced ICT for manufacturing. This motivated our plea for the development of a reference framework for ICT for manufacturing skills capable not only to capture most of state-of-the-art e-skills related to manufacturing but also the skills induced by emerging ICT for manufacturing.

Since ICT are changing very fast, the reference framework should be updateable to allow for the integration of new e-skills that may result from new developments in ICT for manufacturing.

As the framework is intended to be used as common reference by all IL stakeholders, then its development should be realized in a collaborative way taking into account the requirements and views of all concerned parties.

We believe that such a framework will support:

- Companies to determine which training is needed to acquire specific ICT for manufacturing skills.
- Training providers to adopt curricula from “cutting-edge” ICT and tailored delivery mechanisms.
- Fast transfer of ICT for manufacturing from research to industry.
- Etc.

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Intelligent Products: A Spinal Column to Handle Information Exchanges in Supply Chains

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Abstract. This paper outlines some practical problems linked to information exchange occurring in nowadays supply chains, with a special emphasis on the aeronautical sector. The Intelligent Product paradigm is presented as an adequate solution to address some of these problems and to provide rapid gains along the whole product life-cycle. The paper intends to illustrate how the IP paradigm could bring natural solutions to historical problems in supply chains, in rupture with the way they are usually addressed. A short case study describes how the suggested concepts could help to address real problems in nowadays supply chains.

Keywords: Intelligent product, collaborative network, supply chain, information system.

1 Introduction

In today's global market, companies no longer compete as independent entities but as integral part of supply chains (SC) [Min and Zhou, 2002]. Joint-planning so that cooperation and strategic partnerships over the entire SC are now universally considered as conditions for building more efficient and reactive manufacturing networks [Arkan et al., 2012 ; Ding et al., 2011], but sharing information and knowledge is recognized as a pre-requisite for such achievements [Krause et al., 2007]. Nevertheless, answering to the basic questions: "what information to share?" and "how to share it?" remains a difficult task. In this communication, we underline some practical requirements for information sharing, and suggest addressing the second question using the Intelligent Product (IP) paradigm, considered as a natural physical and informational link between partners of the SC.

In section 2 are provided examples of information sharing in collaborative networks. The concept of intelligent products is introduced in section 3, and is applied to the problem of information sharing in SC in section 4. A short case study describes in section 5 how the suggested concepts could help to address real problems in nowadays supply chains.

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2 Information Exchange in Collaborative Networks

Focusing on their core business, nowadays companies work in larger and larger networks but the necessity to be more reactive and flexible induces the paradoxical requirement to efficiently share information and knowledge all along the SC: information and knowledge sharing are nowadays considered as keys for improving the performance of manufacturing systems, internally as well as with external partners [Wadwha et al., 2010]. Moreover, information sharing is an essential condition for developing trust between partners, trust being considered as necessary to maintain long term collaborative SC relationship [Nyaga et al., 2010; Ren et al., 2010].

Which information to share is the object of a large literature, but how to share it is also a difficult question, which has motivated many studies in various domains. Industrial Information systems provide a first element of answer, nowadays ERP (Enterprise Resource Planning) or APS (Advanced Planning Systems) allow for instance a company to share production plans with its suppliers. Web portals are another technology allowing to easily provide information, and are more and more used in Supply Chains (see for instance Sup@irWorld, the web portal allowing Airbus to communicate with its suppliers1). At the same time, Excel™ sheets are still the most common mean to exchange information in Supply Chains...

In most of the cases, information is "pushed" by the large companies, their suppliers (especially the smallest ones) having often difficulties for adequately introducing the provided information in their own information systems. A project called APOSAR has recently been performed in the South-West of France aiming at analysing the relationships between large and small companies involved in aeronautical supply chains [Ming et al., 2013]. Twenty companies were visited in that purpose: seven large ones and thirteen of middle (around 200 employees) or low (less than 100 employees) size, working in various technical domains of the aeronautical field. The following seven requirements for improving information exchange in supply chains are one of the results of this study. Information exchange:

- should be possible internally and externally with the same tools (Req. #1),
- should be secure, i.e. should not require to open an access to the main information system of the company (Req. #2),
- should be consistent with Concurrent Engineering approaches, i.e. should support communication between the actors of the product lifecycle (Req. #3),
- should favour trust, and should be automated, so that the partners can focus on the strategic issues of collaboration (Req. #4),
- should use tools allowing a good consistency with traceability systems, which are often dedicated tools (Req. #5),
- should be based on tools which use could be extended to the late steps of the product lifecycle (delivery, usage, recovery, reuse/recycling) (Req. #6),
- should allow an easy access of actors, for instance using mobile devices (Req. #7).

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[1] http://www.airbus.com/tools/airbusfor/suppliers/

As shown in next sections, the intelligent product may be a natural vector for coping with these requirements.

3 Intelligent Products

Many definitions of Intelligent Products (IP) can be found in the literature, see for example [McFarlane et al., 2002]. In [Meyer et al., 2009] was proposed a typology defining three main types of IP: **identified** IP are at least able to manage their own information, given by sensors, RFID readers and other techniques; **active** IP are able to memorize information, communicate and trigger events or notify users when there is a problem (e.g. IP has fallen, its temperature is too high); **decisional** IP are able to execute decisional algorithms, including possible learning mechanisms. In [Sallez et al., 2010a] was proposed a generic model of active intelligent products based on the concept of augmentation enabling classical passive products to become intelligent and active. A proof-of-concept of active intelligent products in the context of manufacturing has been then implemented (see Figure 1) [Sallez et al., 2010b].

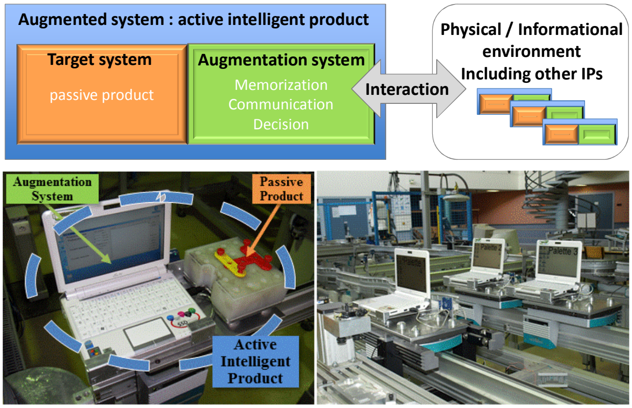

Fig. 1. Active intelligent product in manufacturing: concept and proof-of-concept

In this implementation, the augmentation system was embedded along the passive product, but this is not compulsory: a RFID tag can be used to identify an IP and a remote centralized computer system can support all the augmentation systems. An advantage of remote implementations is related to costs, while drawbacks concern the rise of complexity with the increasing number of managed IPs, the risk to centralize all the information in case of failure, and lastly, to handle information far away from the real physical systems where events occurs. In fact, one of the will to use IP is to bring decisional, informational and communicational capabilities close to the physical world, reducing decision lags and increasing local dynamic solving of disturbances. In a PLM (Product Lifecycle Management) context, the IP can be seen as the vector that crosses all the different phases of the product lifecycle. In that sense, IP is a possible way to implement Closed-loop PLM [Kiritsis, 2011]. In this context, information exchanges between IP and the different crossed information systems allow better knowledge capitalization and a better interoperability among systems. The IP is also a natural vector of interoperability since it carries the data along the whole life-cycle, formatted according to a pre-determined and commonly agreed ontology.

4 IP: A Communication Vector between Customer and Supplier

In manufacturing, IP have been widely proposed for real time production control inside companies. Few works exploiting the potential benefits of IP have been done at the SC level and most of them use level 1 (identified) IP [Sarac et al., 2010] with typical instantiation of the IP concept using RFID technology. The objective to use level 1 IP in SC is to reduce inventory losses and increase information accuracy. The two other levels of IP (level 2: active and level 3: decisional) are still not really exploited in the context of SC, even if some works exist (see for example [Yang et al., 2009]). The interest to use levels 2 and 3 IP in the context of SC, the "intelligent capabilities" being embedded or not into the products, is pointed out in next sections.

4.1 IP as the Spinal Column in Supply Chains

Let us first assume that the IP information system is composed of two distinct parts: a *public part*, which follows the product when it is sent to the different partners, and a *private part*, aiming at internal information sharing, cleared when the product leaves a company. Let us also assume that the SC can be modelled as a direct graph where nodes are companies, and vertices are flows of products between two companies. Under these assumptions, the suggested basic principles may be summarized as follows:

- the manufacturing process of the product is firstly analysed and each node of the SC requiring to gather or modify information stored in the IP is identified.
- A technology is chosen and implemented for giving intelligent functionalities to the product (embedded or distant). The granularity (i.e. an augmentation system for *m* passive products) is also chosen. In the proof-of-concept of Fig. 1, m was set to 1 but this value typically depends on parameters such as production lot size, total value of the product, required cost/constraint for embedding technology, etc.
- The part of the information system concerned with the shared information is attached to the information system of the IP (embedded or distant part of the augmentation system), including triggering or decisional capabilities.
- This local information system is initiated with i) data collected during the successive planning phases performed all along the SC (due date for the focal company, deduced due date for tier 1 suppliers, etc.) ii) constraints of down stream partners to be taken into account by up stream partners.
- The IP information system is periodically synchronized with the main information system using communication terminals (fixed or mobiles).

This behaviour is summarized in Figure 2. Information is first prepared to be attached to the augmentation systems in the planning-based phases (1) and (2). Then the instantiation of the IP (on each branch of the supply chain, only one being represented in Fig. 2) is made (3). During manufacturing (4), at each convergent node of the SC (e.g., assembly, light blue and dark blue nodes), a synthesis of the information brought by each component is performed.

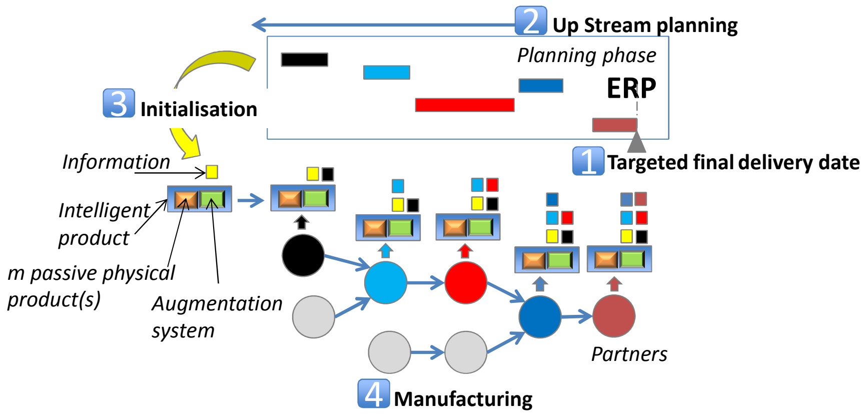

Fig. 2. The intelligent product as a communication vector: basic principle

4.2 Addressing the Listed Requirements on Information Exchange Using IP

Using the proposed principles, the IP becomes the interface among the different actors and information systems all along the SC. This section exhibits how the IP paradigm may help to address the requirements listed in section 2, focusing on information exchange issues.

Answer to req. #1: From planning to delivery, information gathering and processing is logically organised around the IP. Since the product is the only element crossing the whole SC, using it as a physical support is logical. Moreover, it is easier to interface each system with a common one (the IP) than having to design several 1-1 interface systems for all the stakeholders of the SC.

Answer to req. #2: The IP limits this problem, since it is possible to only associate to it what is required for the next part of its lifecycle, then to make the information accessible to the downstream partners. There is no need to open an access to an internal database.

Answer to req. #3: As introduced above, the utilisation done with the carried information may be memorized by the IP itself and reused in the lifecycles of its successors. For instance, a recurrent problem in maintenance can be due to a production quality problem or to a design problem (e.g. undersized part). This allows tightening the links between actors of the SC and facilitates the improvement of successive versions of passive products using this capitalized knowledge gathered by previously used, maintained or dismantled IP.

Answer to req. #4: The IP is an "objective" (tangible) element, exchanged between customer and supplier. It is therefore a trust carrier in their relationship, via unequivocal traceability indicators (e.g. time spent in transportation, average endured, lost time in inventory, condition violation in transportation, etc.).

Answer to req. #5: In the IP, the information system is associated to the passive product during all the phases of its lifecycle: traceability becomes a natural function.

Answer to req. #6: If needed and authorized, the collection of information may continue during the usage of the customer, thanks to the multiple networks now available in the private life. According to the closed-loop PLM concept, different forward and backward information flows are supported by the IP.

Answer to req. #7: It is nowadays easy to interface augmentation systems of IP with human actors (e.g. producers, suppliers or customers). The integration of this "voice of..." (voice of customers, etc.) is then facilitated through the interface with IP.

5 Possible Use in Real Situations

To illustrate the way IP can be used, various situations from the APOSAR project are here presented and analyzed, with a 'what-if the IP paradigm was used instead?' view:

i) Aeronautical supply chains involve many partners of very different sizes, exchanging materials with low quantities and high diversity. Within the network, each partner manages his own local priorities for optimizing his service ratio to his immediate customers, even if the decisions made are not the right ones for the interest of the entire supply chain (no global information is locally known).

ii) In large companies, each logistic manager is responsible for a set of suppliers, i.e. is responsible for getting the orders of "his" suppliers on time. In most of the cases, they only know the due date of the orders, but not the slack time introduced by their own production planners. As a consequence, they put a uniform pressure on the suppliers, even if these ones would require the prioritization of the orders.

iii) As a first solution for previous problem, one of the large companies provides information on its inventory level with each order. In this way, the supplier may decide the real urgency of the order if a problem occurs. Nevertheless, the problem remains when several suppliers provide the same part (the decisions made in real time by each supplier are not consolidated).

iv) In order to decrease their prices through time (which is required by their contracts), the suppliers often group orders, but do not always take into account basic information like due dates, with the result of both early and tardy orders.

v) Large companies are often complaining on the lack of visibility of some of their suppliers, due to limited skills on flow management: they would need to know whether their parts have passed some milestones at their supplier's, in order to monitor their fulfillment. This is for instance done by a surface treatment company, who has launched a web site showing the progress of the orders in his workshops. Nevertheless, the effort to maintain this service appears to be too important for being generalized to other suppliers.

vi) Several cases were mentioned where sub-contractors were waiting for raw materials from their customers, and were warned at the same time by another department that their late in completing the order.

Using the IP paradigm, the global planning of the SC embedded in the IP, periodically updated when synchronization points are met, would address points i) and ii). Constraints can be implemented in the embedded IP information system, which consistence with any new incoming information could be checked: for instance, if the local planning is inconsistent with the global one, an alarm could be triggered (point iv). Checking the consistence of various aspects of the planning (availability of raw materials and due dates for instance, point vi)) could also been made within a given company, before the local information system is embedded in the IP. An IP has intrinsic follow-up capacities. The IP could directly inform the community when it reaches pre-determined milestones, instead of requiring external services in that purpose (point iii)). Point v) is also addressed via the traceability capabilities of the IP.

6 Conclusion

In this communication, we have discussed some practical problems linked to information exchange occurring in nowadays supply chains, with a special emphasis on the aeronautical sector. The authors think that the IP paradigm, implying a strong rupture in the way systems are usually considered and designed, could help to address some of these problems and would provide rapid gains by bringing more "natural" solutions to historical problems in SC. IP paradigm is indeed associated to a more “bottom-up” approach, providing emerging behaviour not really anticipated nor designed. Of course, only general considerations, drawn from our knowledge on SC and our past experience in the application of IP in manufacturing, have been presented. Obviously, more detailed research must be led and real implementations miss to prove these intuitions since specific issues may arise. For example, it is clear that designing the structure of the augmentation systems, and specifying their communication with the partners, would require an important effort, including building complex agreements between partners. On physical aspects as well as on logical ones, it is likely that the implementation cost may be important. This is a reason why the case of aeronautical SC is of specific interest, considering the cost of the parts and the cost of any delay in the delivery of an aircraft. Nevertheless, main obstacles are in our opinion elsewhere. The first one is in the possible nervousness of an emerging or self-organized system based on IP [Barbosa et al., 2012]. Indeed, a SC needs a planned, stable organisation. Getting real time data has always induced the temptation to re-plan in real time, and possibly disorganize the SC (see the influence of the ERP on the planning methods in the 2000's). The second obstacle is more difficult: focal companies of the SC (final assemblers in the case of aeronautical supply chains) have clearly the main interest in the implementation of such system, which can allow them to introduce an eye at their supplier's. This temptation would undoubtedly be a major obstacle for the adoption of the system. On the opposite, such system should be an opportunity to increase mutual trust, which is only possible if a mutual interest is found in the use of the system.

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Linked Data Exploration in Product Life-Cycle Management

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Abstract. Product Life Cycle Management (PLM) strategies have been proven as recommended approach for handling, planning and decision making regarding all aspects of products different life cycle stages. As this domain includes number of actors, system platforms and technologies, gathering information and handling knowledge often emerges as challenging problem. In this paper we propose a methodology to support a PLM approach taking advantage from the emerging semantic web technologies and the underlying paradigm of Linked Data. The main purpose of this methodology is twofold. First, it aims at providing a semantic model for handling different data sources and data types, structuring thus information from all stages of a product life cycle. Second, it extends reasoning mechanisms offered by semantic technologies, to conduct comparative and in-depth data analysis based on data mining and pattern discovery.

Keywords: PLM, Linked data, semantic technologies, ontologies, data analysis.

1 Introduction

In today's modern manufacturing world, products are often highly complex and actors in products life cycle are numerous, diverse and sometimes geographically distant. Yet, to be able to remain concurrent in highly competitive market, quality, ecological impact and pricing have to be optimized over entire life cycle. Different types and formats of data have to be gathered and analyzed on the one hand, and on the other hand, communication between sometimes very diverse software platforms have to be enabled. First step toward this goal is creating unique, all-spanning knowledge base which will map all concepts and relations present in the entire domain. Semantic models are shown to be a good technique for tackling such challenging projects.

In this paper, we first present the challenge in question, by elaborating in details PLM components and complexity. Life cycle stages are defined and key aspects are explained, giving the insight in diversity of processes that need to be taken into consideration. Further on, semantic web technologies are presented and range of available tools is explored. This gives a solid image of possibilities of semantic models, their structure and potential functionalities. Next, concept of "Linked data" is presented, together with the guidelines for defining the domain of relevant product related data. In this context, we propose a methodology based on the application of Linked Data paradigm to the context of PLM. We present the developed generic and specific

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ontologies, as an example of reusable semantic models, developed within the European FP7 project LinkedDesign. Finally example of exploitation of linked data to capture additional knowledge is presented, extending thus reasoning mechanisms offered by semantic technologies.

2 Product Lifecycle Management

Product lifecycle management (PLM) is defined as a concept for the integrated management of product related information through the entire product lifecycle [1]. This vision is enabled by recent advances on information and communication technologies and is needed to support current industry needs for faster innovation cycles combined with lower costs. The aim of this integration is to overcome the existing organizational barriers and to streamline the value creation chain, based on the integration of multiple software components [1-3], generally enterprise resource planning (ERP), product data management (PDM) and other related systems, such as computer aided design (CAD) and customer relationship management (CRM) [4]. The term "lifecycle" generally indicates the whole set of phases, which could be recognised as independent stages to be performed by a product, from "its cradle to its grave". Product lifecycle can be defined by three phases [5-6]:

- Beginning of Life (BOL) including design and manufacturing. In this phase, the product concept is generated and subsequently physically realised. Using many tools, techniques and methodologies, designers, planners and engineers develop the product design and the production process, plan the production facilities and manage manufacture of products with diverse suppliers.
- Middle of Life (MOL) including distribution (external logistic), use and support (in terms of repair and maintenance). In this phase, the product is in the hands of the final customer, i.e. product consumer and/or some service providers, e.g. maintenance actors and logistic providers. The product history related to distribution routes, usage conditions, failures and maintenance can be collected to create an up-to-date report about the status of products.
- End of Life (EOL) where products are retired – actually recollected in the company's hands (reverse logistic) – in order to be recycled (disassembled, remanufactured, reused, etc.) or disposed. Information from EOL about 'valuable parts and materials' and other knowledge that facilitates material reuse should be routed to recyclers and re-users, who can obtain accurate information about product status and product content.

During BOL, the information flow is quite complete as it is supported by several information systems like CAD/CAM/CAE and PDM. However, in contexts where several information systems are used and where other structured and unstructured data sources are spread across different stakeholders, information flow becomes vague or unrecognized [7]. As a consequence, actors involved in each lifecycle phase make decisions based on incomplete and inaccurate information, which leads to operational inefficiencies [6]. The main challenge in this context is to provide a solution ensuring a seamless continuation of knowledge throughout the entire lifecycle and capable of capturing the dependencies between lifecycle stages.

3 Semantic Web Technologies and Open Web Linked Data

3.1 Semantic Web

The Semantic Web[1] provides a common framework that allows data to be shared and reused across application, enterprise, and community boundaries. It is considered as a vision of information that can be readily interpreted by machines, so machines can perform more of the tedious work involved in finding, combining, and acting upon information on the web. The Semantic Web involves three core technologies: Resource Description Framework (RDF), Web Ontology Language (OWL), and Extensible Markup Language (XML). These technologies are combined in order to provide descriptions that supplement or replace the content of Web documents. The machine-readable descriptions enable content managers to add meaning to the content, leading to describe the structure of the knowledge we have about that content. In this way, a machine can process knowledge itself, using processes similar to human deductive reasoning and inference, thereby obtaining more meaningful results and helping computers to perform automated information gathering and research.

3.2 Linked Data Paradigm

The term *Linked Data*[2] refers to a set of best practices for publishing and connecting structured data on the Web. These best practices have been adopted by an increasing number of data providers over the last three years, leading to the creation of a global data space containing billions of assertions— the Web of Data. Linked data is is based on four principles as follows:

All items should be identified using URIs.
- All URIs should be *dereferenceable*— that is, using HTTP, URIs enable anyone (machine or human) to look up an item identified through the URI.
- Looking up a URI leads to more data.
- Links to URIs in other data sets should be included to enable further data discovery.

In contrast to semantic web vision, Linked data is mainly about publishing structured data in RDF using URIs rather than focusing on the ontological level or inference (4).

4 Linked Data in PLM

Having the concept of Linked Data in mind, we propose in this section to define a process of conceptualizing the PLM approach through four main activities: specification, modeling, generation and publication, and exploitation, described in the following sub-sections.

[1] http://www.w3.org/2001/sw/
[2] http://linkeddata.org/

4.1 Specification

At this first stage, the need is to define the requirements to design a semantic model covering several aspects of the product lifecycle. In our previous work [8], we have defined a bottom-up approach based on the User Story Mapping method (USM). This method is user-centric and leads to the definition of current and/or expected scenarios and processes. This bottom-up approach, which combined with appropriate tools and methods (such as questionnaires, standards specifications, knowledge based approaches, etc.), resulted in the specification of the knowledge network and domain for sharing and reusing knowledge in collaborative product development.

4.2 Modeling

This second stage aims at modeling the domain and providing a semantic model to cover the requirements of PLM applications. In our previous work, published in [9], we have designed a fundamental ontology which aims to be easily adjusted and adopted for different product engineering systems, thus eliminating the need for repetition of entire design process for every individual company. Being generalized, this ontology needs to be specialized for each specific application. Schema of concepts of this ontology is given in the following figures. This ontology has been specialized to two use-cases: LCC application in product design, published in [10-11], and metrology in manufacturing.

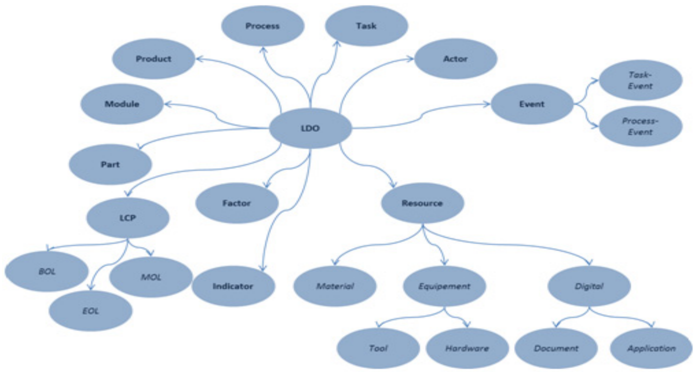

Fig. 1. Generic concepts of LDO

4.3 Generation and Publication of Data Sets

A variety of approaches to mapping data-sources with the ontology and methods for generating RDF statements and publishing them as Linked Data exists in the literature. Virtuoso RDF views [12-14] for instance are production-ready tools for generating RDF representations from relational database content. Some of them even aim at automating partially the generation of suitable mappings from relations to RDF vocabularies.

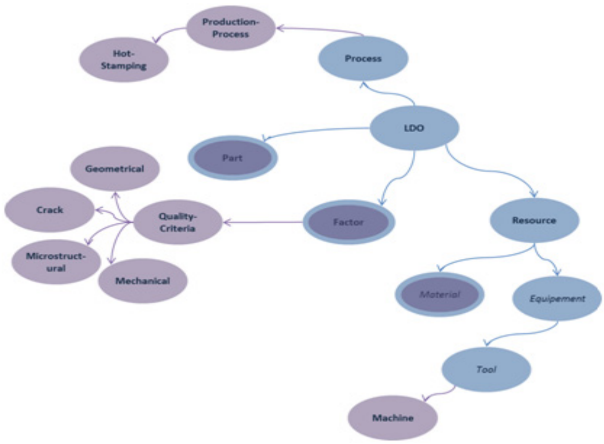

Fig. 2. Specification of ontology for metrology in manufacturing

4.4 Exploitation

This final stage consists of analyzing data taking advantage from structuring as well as reasoning features offered by semantic technologies in order to analyze dependencies between lifecycle stages data from the generated datasets. The next section is dedicated to this phase and provides an industrial use-case for data analysis.

5 Data Exploitation and Knowledge Discovery

5.1 Preparation of Data

Striving towards sharing of data and knowledge exchange between different life-cycle phases has lead to immense improvements in manufacturing world. Data collected during exploitation and maintenance of a product are used by designers to make better decisions during design of future products. Same data are used by engineers to improve manufacturing line designs. Data from manufacturer and maintenance are used for improving recycle and reuse decisions. Yet, selection of data to be exchanged is always very case specific, and it's based on some already assumed cause-effect relations. Design of unified data bases, opens a possibility of having overview of all available information, but in these cases it becomes challenging to manage these high volume data, especially in a case of more complex products, whose manufacturing and maintenance require number of individual processes performed by different actors.

By modeling entire product life-cycle domain in one semantic model, we are able to maintain the same advantage of having overview of all available information and also exploit on structure of RDF metadata. In our work done so far on the domain of product life-cycle, we have used ontology to model this RDF statements graph. This choice was made due to number of additional advantages of ontology such as, reasoning over data, consistency check-up and variety of visualization options.

Having concepts from all phases of life cycle in one model, allows us to define assumed cause-effect relations, thereby completing the model. The real added value is created once we employ reasoning over data, and in this case, we benefit from rule inference specifically. Starting from base set of rules and relations, ontology will automatically expand this network, thus creating all possible rules and relations that can be inferred. This new relations give a very good insight in where unknown cause-effect processes might be found.

5.2 Application of Data Mining

Important part of exploitation of data merged from entire product life-cycle is data mining and pattern discovery, since it results in potentially yet unknown dependencies present in data. Using entire collection of data is unsuitable for processing due to high diversity of data and too large number of topics merged. Appropriate data sets have to envelope potentially correlated concepts and still not span over too wide part of the domain. Rules and relations within ontology, defined by human experts as well as those inferred, are natural indicator on where dependencies exist and thus, they can be used for extracting useful data sets. By merging attributes of concepts between which there is a relation, we get data sets for which data-mining exploration could give new knowledge and understanding of product life-cycle. Since all the attribute values will be of correct type and within predefined ranges, detecting missing data or outliers becomes obsolete. Having data structured within ontology, thus simplify the time consuming data preprocessing step.

Our use-case is driven from metrology applications in automotive industry, and is limited to design and manufacturing processes. Following the proposed methodology described in the previous sections, and using the ontology network implemented in our previous works, we have applied, at this stage of developments, a manual approach to generate related datasets. One example of benefits coming from gathering data from different life stages of a product is given in a Figure 2 and Figure 3.

Fig. 3. CAD model of a part

Figure 2 displays CAD model of a part, as it was designed. On the other hand Figure 3 displays 3-D scans of physical parts manufactured according to design. On a left-hand side image, the manufacturing process was performed successfully, while on the right-hand side shows crack. Having these data sets from design stage and manufacturing stage in same data model, enables development of a tool for automatic crack discovery. This is only one example of prospective exploitation of semantic data model spanning entire product life cycle.

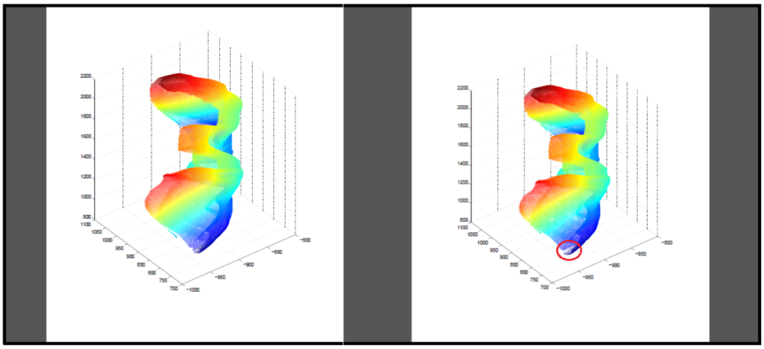

Fig. 4. Scan of a manufactured part, without crack (left) and with crack (right)

6 Conclusion

The application of Linked Data paradigm in the context of PLM seems to be a promising approach to deal with numerous and scattered system data sources involved in the lifecycle. Ontology as a key enabler of Linked Data are interoperable systems that can be merged and aligned, thus eliminating the need for any future translators or communication bridges between different systems. The larger the domain covered with ontology model is, the more powerful exploitation mechanisms become. Design and implementation of such unified data and knowledge model, opens endless possibilities for application of tools for automated data analysis, knowledge extraction, reasoning over data, patterns discovery and domain visualization. The proposed approach can be considered a step toward more efficient knowledge reuse and new querying techniques. Finally, numerous technics in the field of learning mechanisms and artificial intelligence can be applied in this context in order to extend reasoning capabilities beyond inference-based technics offered by semantic technologies. By applying these technics and taking advantage from the Linked Data paradigm and related enabling technologies, we will be able to provide anticipation capabilities supporting decision making in product lifecycle management.

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Ontology-Based Dynamic Forms for Manufacturing Capability Information Collection

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Abstract. Building flexible manufacturing supply chains requires availability of interoperable and accurate manufacturing service capability (MSC) information. These requirements can be met by encoding the MSC information using shared domain ontologies. However, difficulty in understanding the syntax and semantics of the shared ontologies hinders the adoption of such ontology-based approach. In this paper, we propose an Ontology-based eXtensible Dynamic Form (OXDF) user interface architecture to assist non-expert users to collect MSC information and represent that information as instances of the shared domain ontology. To achieve this result, we introduce three key innovations: 1) intelligent ontology navigation that dynamically generates forms and form components from the relevant parts of the ontology; 2) intelligent search engine that helps finding relevant ontology entities; and 3) an update mechanism that allows users to define new terminologies to the shared domain ontology.

Keywords: supply-chain, ontology, interoperation, semantic similarity.

1 Introduction

The competitiveness of manufacturers is increasingly defined by the combined capabilities of the suppliers that make up the OEMs' supply chains [1]. Effective communication between suppliers' manufacturing capabilities and customers' requirements is essential for building a flexible network of suppliers in a supply chain. The quality of manufacturing service capability (MSC) information is one of the determining factors for the quality of manufacturing information exchange and it can be measured by its *accuracy* and *semantic interoperability*.

Today, MSC information is typically published either on the suppliers' web sites or registered at e-marketplace portals. MSC information published on web pages is typically not understandable by computer programs and thus lacks interoperability. Advanced techniques from information extraction and natural language processing may help obtain structured MSC information from web pages. However, due to inherent ambiguity of natural languages, this approach typically leads to a significant loss of accuracy. Some commercial e-marketplace portals require users to enter their MSC information in a uniform format according to the portal's proprietary MSC

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information models. This gives potential for interoperability to users within a portal, but not between portals. Besides, these proprietary models are typically insufficient to precisely capture the intended meaning of users' capability information.

All these problems can be addressed by adopting well-defined domain ontology that allows MSC information of individual suppliers to be described accurately without ambiguity and understood correctly among all stakeholders sharing that ontology. However, manufacturing domain experts have difficulties adopting the ontology-based approach. This is because 1) the syntax and semantics of formal ontology languages are not familiar to users and have a steep learning curve; 2) the scope of a comprehensive domain ontology is typically very large in its size and complex in its structure; and 3) as a newly emerging technique, tools friendly for inexperienced users are not yet sufficiently mature and widely available. In this paper, we report our research in providing such tools. Specifically, we propose a new Ontology-based eXtensible Dynamic Form (OXDF) user interface architecture to assist non-expert users to collect MSC information and encode it using the vocabulary of the ontology. To achieve this result, we introduce three key innovations, including: 1) intelligent ontology navigation that dynamically generates forms and form components from the relevant parts of the ontology; 2) intelligent search engine that helps finding relevant ontology entities; and 3) an update mechanism that allows the user, if needed, to define new terminologies outside the ontology.

2 Manufacturing Capability Ontology

Although a great number of ontologies have been developed and published, only few of them are specific for the manufacturing or related domains. These few include for example GoodRelations[1], an upper ontology for e-commerce, and MSDL (Manufacturing Service Description Language) [2], a detailed ontology for machining services. Ontology segments used in many of our examples are taken from MSDL.

Since manufacturing is a huge and complex domain, it is inconceivable to define a single comprehensive and detailed ontology for the entire domain. Our vision is that the semantic model for the manufacturing domain is composed of a set of ontologies, including one or more upper domain ontologies, a number of detailed manufacturing subdomain ontologies and some widely accepted ontologies for general concepts such as temporal, spatial and geographical. With properly defined links and mappings, these ontologies are connected and form a single logic system that we will refer to as *Manufacturing Capability Ontology* (MCO) in the rest of this paper.

We also assume that MCO is written in OWL. OWL is a combination of RDF data model[2] and a dialect of description logic [3]. The primary advantage of RDF is that it can easily integrate data with different levels of structure, while the description logic and its well-defined formal semantics allow one to perform logical reasoning over the ontology and its instances. With these and other benefits, OWL has emerged as the de facto standard for defining ontologies and sharing them on the web.

[1] http://www.heppnetz.de/projects/goodrelations/

[2] http://www.w3.org/TR/rdf-primer/

3 Overview of OXDF Architecture

The Ontology-based eXtensible Dynamic Form (OXDF) user interface architecture is driven by the Manufacturing Capability Ontology (MCO). The architecture presents an ontology in a *form format* because forms are widely used in commercial e-marketplaces and familiar to and easy to fill by manufacturing domain users. Each ontology class is rendered as an *atomic form*, consisting of the class name and a set of its defined properties called *form components*. As shown in the diagram in Figure 1 below, OXDF starts with a base form (step 1), which is one of the top-level classes selected by users, depending on what kind of information they want to enter. For entering basic information about a company, the base form will present either a *supplier* class or *customer* class; for capability information a *service* class will be presented.

An OXDF form assists users to collect MSC information by navigating through the capability hierarchy of MCO to reach a class that is closest to that particular capability (step 2). In this way, a sequence of atomic forms for the classes traversed during the navigation is presented. Users can enter capability information using the form components (properties) in these atomic forms. When information about that capability is entered, an instance of that capability class is created (step 3) and stored in the instance repository (step 4). Users may fail to find proper atomic form or form component for a particular content. OXDF helps with this situation with its ontology search engine which returns a list of classes or properties that are semantically close to the user's intended content (step 2.1). If nothing is returned or none of the returned entities is satisfactory, users can create a new atomic form or form component (step 2.2), and in effect define their own classes and properties outside of the given MCO. Newly created entities will be stored in another repository (step 5).

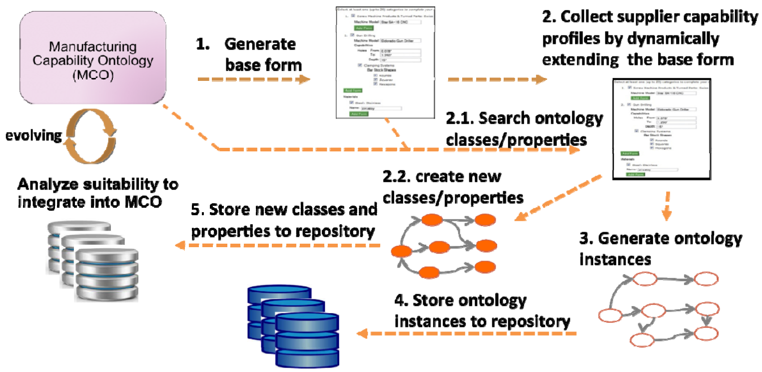

Fig. 1. OXDF overview

4 Ontology Navigation

Related classes in MCO are either organized in a class hierarchy or defined as domain/range of an object property. Thus, OXDF helps users navigate MCO in two ways: *vertically* navigating the class hierarchy by following the subclass links and *horizontally* navigating by following object property links.

4.1 Navigating Class Hierarchy

OXDF renders the class hierarchy as a column tree, as shown in Figure 2 below. Each column of the column tree contains classes at the same level. The leftmost column contains the base form for the chosen top-level class. When the user selects any class in a column, a new column appears on its right containing all subclasses of that class. The column tree is thus expanded until the user finds a class in the right-most column that is closest to her needs. After it is done for one capability, the process starts again for another capability.

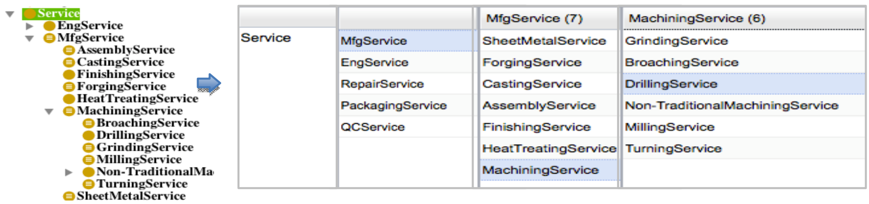

Fig. 2. Column Tree (right) for a segment of MCO class hierarchy (left)

4.2 Navigating Object Properties of Classes

When a class is selected during the traversal of the class hierarchy, the atomic form of that class is created. The components in this atomic form are class properties. Users fill capability information into these components. There are two types of properties in OWL: *datatype property* and *object property*. For datatype property, user only needs to input value of the given primitive type. The object property is more involving. It links the current class (as its domain) to another class (as its range). Completing an object property means to create an instance of the range class. Therefore, when users select an object property in the atomic form, an atomic form for the range class is presented.

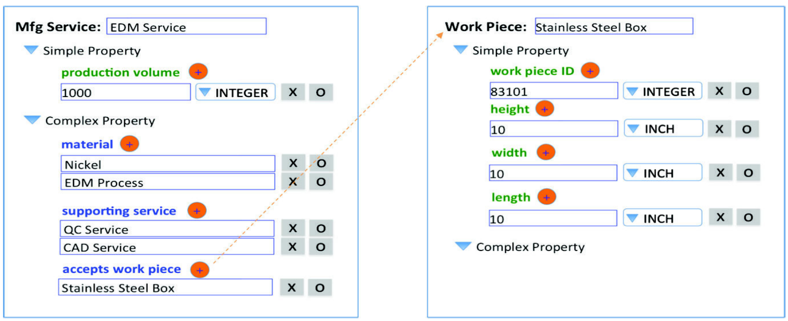

Fig. 3. Atomic form for "MfgService" class

Figure 3 shows an example of collecting information for a capability called "EDM Service". This service is determined as belonging to the class "MfgService" during navigation and the atomic form for this class is presented (left) with two lists of components: *Simple Property* list for datatype properties and *Complex Property* list for object properties. In this example, EDM Service has one datatype property "hasProductionVolume" and several object properties such as "hasMaterial", "hasSupportingService", and "acceptsWorkpiece". These names are converted to natural language-like labels in the form as shown on the left in Figure 3. For each datatype property, a space is given for the user to fill the value. For each object property, the name of its range class is presented together with the property name. When an object property is selected, the atomic form for the range class is presented (right), users can then fill in the properties in that form with more detailed information.

5 Form Extension

When users fail to find an appropriate form (class) or components (properties) to fill in a particular content when navigating MCO, they can extend the forms by searching and reusing entities existing in the ontology or creating and adding new ones if she fails to find anything suitable from the search. Specifically, suppose the user stops at class *C* in the navigation process. If she cannot find a proper subclass of *C* in the column tree for her capability information, then a new class can be created and added as a subclass of *C*. If she finds *C* is a suitable class but does not have components she needs to describe the attributes of the intended capability information, then one or more components can be added into the form for class *C*, thus creating new properties for *C*. These two kinds of form extension are discussed next. The search engine itself will be presented in the next section.

5.1 Form Extension by Creating New Classes

Users can add a class at any level in the class hierarchy. The added class may be either a new class or an existing class that has already been defined in the MCO. Reuse of existing terms is highly desirable since it reduces the need for ontology revision and expansion. When a suitable class, say *D*, is found by search, the user can choose to add the class *D* to the current location (to become a subclass of *C* and displayed in the column tree) or she can navigate to the location in the hierarchy where class *D* is found. For example, when the user needs a "Boring" class as a subclass of "HoleMaking", she can first search the ontology to see if such a class already exists. The search engine returns a list of terms defined in MCO that are close (by semantic similarity) to "Boring", as shown on the left of Figure 4. This list indicates that there is a "Boring" class in the ontology and it has superclass "Turning". After making it a subclass of "HoleMaking", "Boring" class inherits all the properties of "HoleMaking" in addition to all properties it already has as a subclass of "Turning".

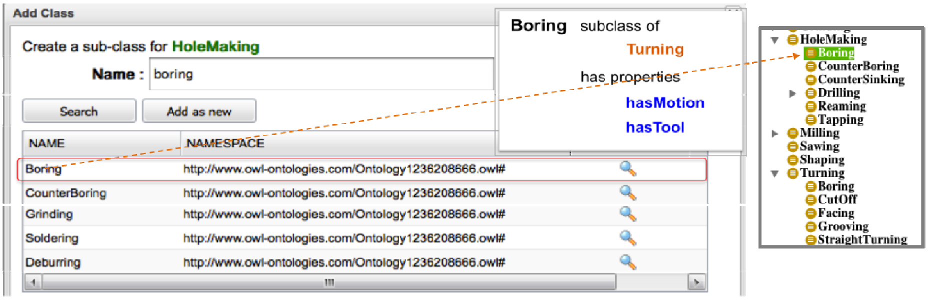

Fig. 4. Search for "Boring" class

Sometimes, due to the lack of familiarity with the ontology, the user may navigate along a wrong path in the class hierarchy. For example, the user may intend to enter information about her lathe machine but ends up at the form for "Machining" which as a class for processes does not have any subclass for lathe machine. Search of the ontology finds that "MachineTool" has "Lathe" as its subclass. At this point, user might notice that she has navigated the MCO along a wrong path, and it makes more sense to keep "Lathe" as a subclass of "MachineTool", since by definition Lathe is a class of physical resources but "Machining" is a class of processes. OXDF can re-direct users to the right location in MCO where "Lathe" is defined. Then, users can enter the machine information there.

When the users fail to find the desirable class in the search results, they can choose to simply create a new class *E* and add it as a subclass of *C*. *E* will appear in the column tree and inherit all the properties of *C*. Additional properties can be added to *E* as described next.

5.2 Form Extension by Creating New Properties

Similarly, when users choose to extend the form for a class with additional properties, they can search the ontology for possible reuse or create new properties. Users can create both object properties and datatype properties. For creating a datatype property, they only need to provide name and value type of this property. For object property, they can optionally create the range of this property. Since the range of an object property is itself a class, it can be provided, again, by either searching the ontology for existing class or creating a new one.

User-created classes and properties, together with their instances can be used as a material basis for potential ontology revision and expansion. For example, if the number of instances of one or a group of similar user-created classes (or properties) reaches a threshold, then a closer analysis is called for to determine if it is appropriate to create a new class and add it into the current MCO.

6 The Search Engine

The input to OXDF search engine is a word or phrase users use to describe the entity (class or property) they want to find in the ontology. The search engine will try to identify all existing ontology entities that have high *semantic similarities* with the user input. Simple keyword search often fails for this task due to the inherent ambiguity of natural languages. OXDF search engine effectively deals with these difficulties by analyzing the synonyms of the entities and utilizing the ontology's subsumption hierarchies of classes and properties.

Let e_1 denote the user search input, e_2 an ontology entity whose similarity to e_1 is to be determined, and $H(e_2)$ the subsumption hierarchy of e_2 whose details are given in Subsection 6.2. The overall similarity between e_1 and e_2 is given as

$$w_1 \cdot Sim_L(e_1, e_2) + w_2 \cdot Sim_H(e_1, H(e_2)) \tag{1}$$

where $Sim_L(e_1, e_2)$ computes the similarity between labels of e_1 and e_2 and $Sim_H(e_1, H(e_2))$ computes the similarity between e_1 and the subsumption hierarchy of e_2. w_1 and w_2 are weights for the two similarities, and are set to 0.5 by default.

6.1 Label Similarity Computation

Part of the semantics of an entity lies in the words used to label that entity. Label similarity computation attempts to measure semantic similarity between words in two entities e_1 and e_2. We use a synonym-based algorithm proposed by Kang [4] to calculate $Sim_L(e_1, e_2)$. This algorithm first draws two sets of synonyms of words that compose e_1 and e_2 respectively from WordNet [5]. $Sim_L(e_1, e_2)$ is computed based on pair-wise n-gram similarity measures between the words from the two sets of synonyms.

6.2 Structural Similarity Computation

As stated earlier, OXDF search engine takes subsumption hierarchy of ontology entity (i.e., e_2) into consideration when computing similarity between e_1 and e_2. Without considering such contextual information, search engine might miss important entities that are semantically related to the user's input but with lower label similarity.

$H(e_2)$, the structural information used by the search engine, is the set of entities from the subsumption hierarchy of e_2, including all ancestors and descendants of e_2 but not e_2 itself. Let t denote an entity in $H(e_2)$. Then the relatedness between t and e_2, is denoted as $Rel(t, e_2)$. OXDF search engine uses Wu-Palmer similarity [6], a normalized distance measure to calculate $Rel(t, e_2)$:

$$Rel(t, e_2) = \frac{2 \cdot depth(LCA(t, e_2))}{SL(t, e_2) + 2 \cdot depth(LCA(t, e_2))} \tag{3}$$

where $SL(t, e_2)$ is the length of the shortest path between t and e_2 , and $LCA(t, e_2)$ is the lowest common ancestor of t and e_2 . Then, $Sim_H(e_1, H(e_2))$, which measures the similarity between e_1 and the subsumption hierarchy of e_2, is computed as follow:

$$Sim_H(e_1, H(e_2)) = \arg\max_{t \in H(e_2)} (Sim_L(e_1, t) \cdot Rel(t,\ e_2)) \tag{4}$$

Take the similarity computation between a user-provided property "shapability" and a property "hasColdFormability" defined in MSDL as an example. The subsumption hierarchy of "hasColdFormability" contains two properties: "manufacturingProperty" and "hasShapability". Table 1 shows label similarity and relatedness among "shapability" property and properties in hierarchy of "hasColdFormability"

Table 1. Rel *and* Sim_L between properties

properties in *H*("*hasColdFormability*")	Sim_L: label similarity with "*shapability*"	*Rel*: relatedness with "*hasColdFormability*"	$Sim_L \cdot Rel$
manfacturingProperty	0.12	0.50	0.06
hasShapability	1.00	0.80	**0.80**

The highest score among all the $Sim_L \cdot Rel$ values is 0.80. Thus, Sim_H("shapability", *H*("hasColdFormability")) is 0.80. Applied Kang's approach [4], Sim_L("shapability", "hasColdFormability") is 0.34. By applying (1), the overall similarity between "shapability" and "hasColdFormability" is 0.57, which is much higher than 0.34 when only label similarity used.

7 Related Work

OXDF is developed based on our earlier work called XDF [4] which helps users navigating XML schema and generating XML instances for MSC information. The major shift from XDF to OXDF is that we adopt OWL ontology as the underlying formal model instead of XML schemas. The main motivation for this change is that XML schemas have relatively limited formal semantics and thus information encoded in XML instances suffers semantic ambiguity, making information less accurate and interoperability harder to be achieved.

Existing ontology engineering tools also support various ontology manipulations. However, these tools are primarily designed for professional ontology engineers. OXDF, on the other hand, aims at helping domain personnel who typically are knowledgeable of the manufacturing domain but lack experience in the syntax and semantics of the logic system of OWL ontologies. A number of tools or plugins tailored for non-expert users have also been reported in the literature [7]. Their main purpose, however, is to help users to access the ontology and obtain relevant entities by various navigational and query methods, not to collect the information from the users and organize the collected information as ontology instances as OXDF does. Also, they do not support dynamic creation of new classes and properties.

8 Further Work

We will investigate alternative technical approaches for search and ontology navigation. Search may become more efficient by focusing on the relevant parts of the ontology rather than searching the entire ontology as we have in the current architecture. This is extremely important because a comprehensive MCO would be very big and most of the classes/properties are not relevant when collecting information about a particular manufacturing capability. We are also interested in extend our OXDF to help semi-automatically extract capability information from manufacturers' web sites. With the guidance of the MCO, information extraction may become more accurate and the results can be used to tentatively populate the dynamic form before involving the human users.

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Cyber-Physical Production Management

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Abstract. Today a high adherence to delivery dates is the main logistic target for manufacturing companies. To control the increasing complexity of production planning and control manufacturing companies use IT systems. However, the applied IT systems often do not provide a reliable forecast of delivery dates and thus affect the required adherence to delivery dates. The paper describes a cyber-physical approach to optimize the production planning and control towards a reliable detailed planning. Therefore, it is necessary to determine the deviations between the production schedule of the IT system and the production processes in reality. With the knowledge of the revealed deviations and their causes the process of production planning can be adjusted towards a more dependable high resolution production planning and control.

Keywords: production planning, production control, simulation model.

1 Introduction

The central challenge for manufacturing companies is to handle the increasing dynamics of markets and individual customer demands [1-2]. It becomes apparent that the production planning and control (PPC) is the key element in meeting these requirements [3-5]. Due to these trends the complexity in planning manufacturing processes is increasing constantly. However, the behavior of complex systems cannot be predicted in detail [6]. Therefore, the use of IT systems (e.g. Advanced Planning and Scheduling systems, APS systems) has become necessary for manufacturing companies to support the PPC [7]. The use of such IT systems often does not predict the future situation of the production reliably. Instead, the use of these IT systems quickly leads to complex structures in PPC. Hence, the transparency and flexibility of order processing is no longer available for the company [8]. The results of several analyses of the Laboratory for Machine Tools and Production Engineering (WZL), especially in companies with individual and small series production, demonstrated that the implemented APS system has deficiencies regarding the forecasting reliability of the planning processes. The start dates of each production step of any product are corrected continuously over the entire planning period until the completion of the product. The dates are usually adjusted upwards, whereby the delivery date is delayed. Thus the adherence to delivery dates is decreasing. Due to a lacking transparency of IT systems, causes for deviations are not traceable for the practical planner.

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One reason for such deviations is that changes in the real production system are not adapted adequately in the IT system. Adjustments require expertise and a lot of time. To ensure an effective planning in the future, deviations between the planning of the IT system and the real production must be uncovered. This is necessary in order to ensure a reliable planning as well as the confidence of the practical planner in the planning of the IT systems.

2 State of the Art

The manufacturing processes are not only complex but also chaotic. The behavior of complex systems cannot be predicted or only for a short period [9]. The value of scientific knowledge is the ability to make predictions for the future. These predictions become problematic in case of complex systems with chaotic processes. Similar causes can have completely different effects. Even in case of nearly identical facts, the effects are different [10].

2.1 IT Systems to Support Production Planning and Control

APS systems were established at the end of the 90s to increase the benefit of IT systems in manufacturing processes by improving the planning systematically. APS systems use exact mathematical optimization techniques and heuristics to predict the future production schedule. The specific type of planning model and the solution algorithm used to calculate the production schedule in general are not transparent for the practical planner [11]. With the models implemented in the IT systems today the current situation of the production is not depicted in the systems, because the model is defined, when the system was implemented the first time. The initial version needs to be adapted frequently because of new products or variants, new machines or process optimizations. In many companies these adaptions are not executed, because they demand manual expense [12]. The planning carried out by the system cannot be correct under these conditions and deviates from the reality in the production. In addition to the initial predetermined master data the control strategies, for example for sequencing, are also permanently defined. An optimal configuration of the control strategy is not provided by current APS systems. Simultaneously, a solution of the possible combinations of control strategies regarding the dependencies of individual jobs and machines is too complex for humans.

2.2 Cyber-Physical Principles in Production Planning and Control

To handle the challenges described in the beginning a promising approach is described by cyber-physical systems (CPS). The term CPS refers to a new generation of systems with integrated computational and physical capabilities that can interact with humans through frictionless user interfaces [13]. Thus, humans making decisions are supported optimally. Moreover, CPS meet the necessary requirements for the realization of a reliable planning. They are characterized mainly by an increased computing power that is needed to perform as many different simulations simultaneously [14]. Using appropriate sensor technology, CPS are able to directly receive physical data as well as using all the available data by connecting through digital networks [15]. To determine the initial conditions of the model largely accurate, it is important that relevant factors (e.g. production data, machine data, etc.) are recorded as precise as possible in production. By the use of CPS and the corresponding intelligent sensor technologies access to more data is enabled and therefore a more accurate determination of the initial conditions is possible.

3 Requirements

Nowadays companies rely on detailed planning systems to manage the complexity of the production and to support the PPC. Requirements for such IT systems include a reliable statement on the completion date of all orders and thus the reliable attainment of the customer agreed date. Since date adherence is the leading logistic target in manufacturing companies [16], it is essential to meet the customer agreed date. If a reliable planning of the detailed planning system is ensured, the production controller will be able to shift his focus from the prioritization of delayed orders in order to realize the dates agreed by the customer. Instead, he can focus on optimizing the PPC.

Therefore three key issues have to be regarded:

- How can deviations between the production schedule, determined by the IT system, and the production processes in reality be identified?
- How can a simulation model be optimized depending on the identified deviations to reflect reality?
- How can a reliable prediction of the future situation in the production be made using the optimized simulation model?

These requirements for future detailed planning systems must be met in the near future so that manufacturing companies can succeed on a global market. In the following these requirements will be regarded by describing the approach of cyber-physical production management.

4 Cyber-Physical Production Management

4.1 Step 1: Identification of Deviations

The approach of cyber-physical production management is based on statistical modeling using simulation. The idea is to implement a judgment system (second-order cybernetics), which monitors the deployed IT systems (ERP system, APS system etc.), as it is displayed in figure 1. Therefore, it is necessary for the judgment system to get information from the ERP system about current orders and work schedules. In addition, information of the detailed scheduling system (APS system or MES) about its current planning is essential, too. The first challenge is the storage of the planning, because today the current planning is overwritten after every planning run. This is solved by implementing a so called data-collector, which stores the data history of every day plans in a database.

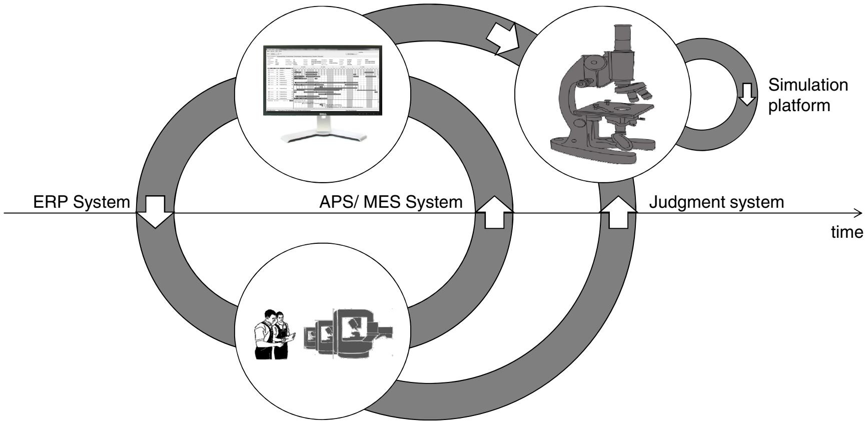

Fig. 1. Approach of cyber-physical production control [17]

The third important information is the feedback data of the production (production data logging, machine data logging etc.). Due to intelligent sensor technologies of CPS the feedback data can be specified. With the stored plans on the one hand and the knowledge about the resulted situation in the production on the other hand the judgment system has every information it needs to compare the systems planning and the reality on the shop floor. By comparing the plan of the detailed scheduling system and the real situation deviations from the plan can be determined. Therefore, every order position is regarded in the plan and the feedback data for an interval, which is predetermined by the frequency of the data-collector. The practical planner gets the information on how good the detailed scheduling system matches with the reality on the shop floor and how good the model is that he is using for production control, which is implemented in the system.

4.2 Step 2: Best Fitting Simulation Model

As it is shown in figure 1, the judgment system is supported by a simulation platform. After the quality of the planning of the detailed scheduling system is judged in the first step, the question to be answered is how to get a model displaying the production system more adequately. Therefore, a simulation model is build with defined parameters for:

- Order release,
- sequencing and
- capacity control.

The implemented model is parameterized with the feedback data of the production (High-resolution Data Collection) for a significant period. After each simulation run, the result is compared to the feedback data as it has been done before with the planning of the detailed scheduling system. Thus, the quality of the simulation model is determined. Depending on the result the parameters of the model are adapted (Optimization) and the simulation is run again (Simulation). This control loop is displayed by the inner control loop in figure 2. The outer control loop describes the aim of every company to constantly optimize their production system to achieve their targets superiorly. The more simulation runs are made with improved parameters and compared to the real situation on the shop floor the better the simulation model gets. The increasing computational power enabled by cyber-physical systems facilitates more concurrent simulations in less time.

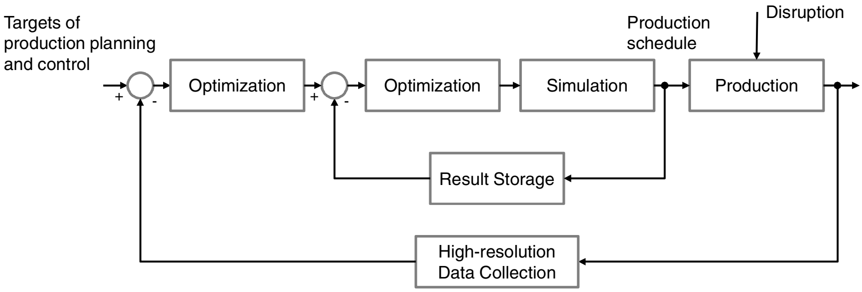

Fig. 2. Architecture of cyber-physical production control

4.3 Step 3: Planning by Simulation

With the resulting best fitting model and data of future orders provided by the ERP system a new planning can be enabled, which has a more exact prediction accuracy. This was analyzed by data of a company with individual and small series production. As described in 4.1 the deviations between the detailed scheduling system and the reality on the shop floor are determined. The planning reliability of the detailed scheduling system was by only 25 % after 3 days in comparison to the real situation on the shop floor, which is displayed in the left part of figure 3. Afterwards, we implemented a simulation model with following parameters:

- Order release: Date planned by the applied IT system
- Sequencing: FiFo (First-in-First-out)
- Capacity control: According to shift schedule

The simulation model was run with these parameters and compared to the real situation on the shop floor during the same interval. The result, shown in figure 3 on the right side, demonstrates that the planning done by the implemented simulation model shows better results in comparison to the real production even with these simple parameters.

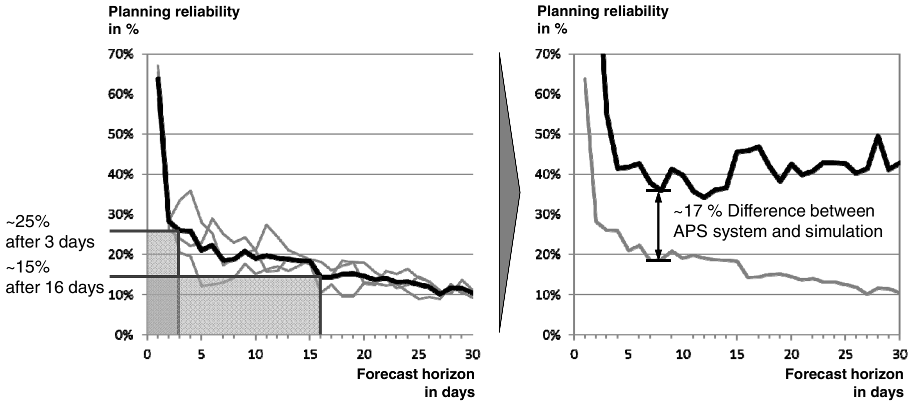

Fig. 3. Planning reliability of APS system and simulation

5 Outlook

5.1 Measuring of the Reliability

Figure 3 illustrates that a more reliable planning of production processes is possible, if the current situation on the shop floor is implemented in the model, which is applied to run the planning. The quality of the planning done by simulation runs depends on the quality of the particular simulation model. The simulation model is described by the feedback data. Thus, the information describing the situation on the shop floor affects the quality of the simulation model and therefore the planning.

The practical planner has to make his decision based on the planning he gets from the system. For him it is important to know, how reliable this planning is. The next steps will be the evaluation of feedback data depending on the source, which provides the information. Information of RFID (Radio Frequency Identification) devices is for example more reliable than manual feedback. With the evaluation of the received data the reliability of the implemented simulation model and thus the reliability of the planning can be evaluated.

5.2 Different Scenarios of Planning

Production processes are chaotic [18], which leads to a divergence that cannot be regarded completely in the planning. A small change of the initial value (e.g. the sequencing strategy of a single machine) can result over a longer period in large deviations. Therefore the prediction accuracy will decrease for longer forecast periods. For an accurate prediction, there are two conditions:

- A realistic description of the initial conditions, which is improved by the use of new sensor technologies and
- an exact model for the planning runs, which is more realistic due to cyber-physical systems (see 4.2).

Since both conditions even in cyber-physical systems are never completely fulfilled in practice, prediction uncertainty arises inevitably. The next step is the determination of the most probable situation on the shop floor in the future. To determine the most probable situation on the shop floor a simulation model can be used whose initial conditions differ slightly from each other. Thus, faulty feedback data are relativized and the chaotic behavior of the production processes is taken into account. The further the forecast period goes into the future, the higher the differences of the individual predictions. The resulting forecast corridor indicates the most probable state of the production in the near future.

6 Summary

The described approach of cyber-physical production management is based on the abilities of cyber-physical systems. They enable the possibility to get better information due to the use of new sensor technologies and to run a huge number of simulations at the same time due to an increasing computational power. Therefore, deviations between today's detailed scheduling systems and the real situation on the shop floor, being described more detailed than before, can be determined. With this information better simulation models for planning runs can be depicted. By comparing differently parameterized simulation models with the real situation on the shop floor the best fitting model can be determined. With this model an optimized planning can be executed, which supports the practical planer efficiently. The next steps will be the evaluation of the performed planning by determining the quality of the input data and the probability of its reliability. Thus, the practical planner is provided and the increasing complexity becomes controllable. Finally, the efficiency of the production will be increased.

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Integrating Lean and MRP: A Taxonomy of the Literature

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Abstract. The natural evolution of MRP and JIT has led to what we know today as ERP and lean production respectively. More than thirty years have passed since the introduction of JIT production into the Western world and since then, discussions regarding the dual existence of MRP and JIT persists in the operations management domain, though now more often in the form of ERP and lean. Needless to say, the dual existence of the two systems has led to an interest amongst both academics and practitioners about the comparability and compatibility of the two approaches. The aim of this paper is to review the literature that focusses on the compatibility of the two. As such, we present a taxonomy of the lean and MRP integration literature.

Keywords: Lean Production, Just-in-Time, Material Requirements Planning, Manufacturing Planning and Control.

1 Introduction

Material requirements planning (MRP) and JIT production are two most prominent approaches for production management and inventory control in manufacturing firms. MRP has been widely applied since the 1970s, whilst JIT production, relatively younger in its use in the West, was initially seen as "the magic bullet" by both practitioners and academics. JIT implementation is a demanding process and lacks the support of a standardized software package due to its initial detachment from information technologies. (Dixon, 2004). MRP, on the other hand, has more recently become the core of enterprise resource planning (ERP) software. A natural consequence of the persistent co-existence of MRP and JIT in industry is the emergence of the desire to compare the two systems, whether in the original form of MRP and JIT or more recently, lean and ERP. As such, the fundamentally different natures of the two approaches are a further contributor for the interest in such a comparison.

Perhaps the most important contributor to the notion of mutual exclusivity of MRP and JIT systems is the prevalence of "push" and "pull" terminology used to denote the control strategy of material and information flow (Hopp and Spearman, 2004). For many, MRP control, which centrally creates production orders, is viewed as synonymous for push; whereas JIT is viewed as synonymous for pull. In this paper, we use literature review to assess the history of MRP and JIT integration, and identify possible areas for further research.

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2 Theoretical Background: MRP, JIT, and Lean Manufacturing

On one hand, the term material requirements planning (MRP) refers to the MRP logic embedded in today's complex business software. In its most basic definition, MRP is a manufacturing planning and control (MPC) approach that relies on the principle of determining a schedule for the dependent demand items from the independent demand, through the processes of bill of material explosion, netting, and offsetting (Orlicky, 1975). Around 50 years after it first appeared, MRP planning is still accepted as the standard for determining the buying and making decisions of manufacturing companies, answering the ”What?”, ”How much?” and ”When?” questions (Ptak, 2004).

On the other hand, lean manufacturing has its roots in JIT production, which is the most important component of the Toyota Production System (TPS). The term “lean” was popularized the book “The machine that changed the world” (Womack *et al.*, 1990). According to Schonberger (2007), lean manufacturing was in the first years of its creation of a term more or less equal to JIT production, which had entered the Western world already a decade earlier. Schonberger further argues that lean manufacturing widened in scope in later years by further associations with other Japanese manufacturing approaches, which were mainly quality centered, and also with further western enhancements on its JIT production core. In any case, lean is today a comprehensive concept encompassing areas other than manufacturing. JIT production, however, remains at the heart of lean manufacturing, unchanged since its maturity in Japan in the 1970s (Schonberger, 2007).

3 Taxonomy of MRP and JIT Integration Studies

In our taxonomy for classifying existing literature on MRP and JIT integration studies, we use four main categories: conceptual, analytical, empirical, and information systems. As the names suggest, conceptual studies offer a conceptual model of an integrated control system, whereas analytical research makes use of mathematical models and simulation to test the effectiveness of such hybrid systems, usually limited to the shop floor test of combined push-pull principles. Empirical integration research denotes research carried out in a case company. In this category hybrid control models are developed by taking the particular manufacturing environment in the company into account and developing specialized solutions. The final category, which we call information systems research, deviates from the previous three in that the focus is not on suggesting exhaustive solutions, but rather highlighting the software aspects of integration.

Conceptual Approach

Conceptual integration studies have usually had a more general approach to MRP and JIT integration as compared to empirical integration studies and analytical integration studies. As such, a number of conceptual integration studies do not present a detailed hybrid control system, but offer only a high level description of the features of possible hybrid solutions, if not merely presenting the motivation behind the search for a hybrid system (Belt, 1987; Lim, 1985; Vaughn, 1988).

Conceptual integration studies almost exclusively agree that JIT is a perfect shop floor control tool, whereas MRP has excellent planning capacity. This realization, which had already been revealed by MRP JIT comparative studies, prepared the stage for integration studies. However, among conceptual integration studies, those which propose a clear hybrid model definition follow two divergent paths. The first of these paths tries to combine MRP and JIT in a manner that they keep their original character and slight modifications are needed to enable their co-existence in a hybrid manufacturing system. Hence, the name "combination studies" would be more appropriate for these studies. The hybrid models in the other group of studies represent true integration in the sense that one or both of the MPC systems undergo a fundamental change to create the hybrid system. Therefore we will coin here this category of conceptual integration studies as "modified MRP" studies.

Among the "combination studies", Flapper *et al.* (1991) and Lee (1993) represent the main contributions. These models (and a subset of studies inspired from them) set MRP as the main framework, which carries out planning and control tasks as a regular MRP system would. The difference is that the MRP controlled area of production is restricted and a subset of production with repetitive characteristics, which is otherwise suitable for JIT production, is organized into production cells controlled by JIT principles. Thus, MRP computation and production complexity is greatly reduced, while shop floor control is facilitated and optimized by JIT production cells. Both Lee and Flapper et al. suggest that MRP can control the final output of production cells by providing only a final assembly schedule.

The most significant "modified MRP" study is that of Nagendra (1999), who proposes a hybrid model where the number of Kanban cards in the system is MRP controlled. However, the number of Kanban cards is not controlled for an entire production cell, but for each pair of workstations in the production system, which is closer to a job shop than repetitive mass production. Since workstations can produce a variety of component parts for multiple downstream workstations, creative solutions are needed to determine job priority and lead time, which is a necessary input for the calculation of the number of Kanban cards. In the proposed solution, job priority is determined through a one-time calculation of the optimal solution, stored in a database for each possible combination of work-in-process levels and work amounts at the downstream stations and their upstream pair. Nevertheless, the model proposed by Nagendra (1999) is not in total agreement with lean principles as it tries to achieve optimization through computation rather than empowerment of the shop floor workforce. The realization of lead time and work priority determination also relies solely on a heavily computerized shop floor, which increases the volume for both data entry and handling.

Analytical Approach

For the majority of studies in this category, comparison is not just between pull and push control principles, but rather one or more hybrid control principles are compared to pure pull or pure push strategies in the search of the advantages of the optimized hybrid system. A smaller group of analytical integration studies begin with the premise that an integrated control is inherently better than simpler control techniques. This group exclusively tests changes in hybrid systems and in the manufacturing parameters focusing on the fit of the hybrid system to the manufacturing environment rather than the advantages it would provide.

Complex mathematical analysis and simulations provide the means for performance comparison of different control techniques in manufacturing environments ranging from simpler systems with few processes to more complex manufacturing environments such as multistage production environments with multiple lines, also with parallel configurations. In all of these manufacturing environments, optimized hybrid systems consistently out-perform simpler control principles in the different dimensions of inventory performance and service level (e.g. Deleersnyder *et al.*, 1992; Hirakawa *et al.*, 1992; Hodgson and Wang, 1991; Takahashi and Soshiroda, 1996). Deleersnyder *et al.* (1992) show that hybrid systems keep much of the control simplicity that Kanban systems offer, while dealing better with the uncertain demand through maintaining the push component. Takahashi and Soshiroda (1996) and Hirakawa *et al.* (1992) use the variability of production quantities and inventory level at each stage as the performance criteria in their mathematical model of a multi-stage production inventory system. Both report that hybrid systems are associated with smaller variability, and changes in demand variation don't change this fact, although it has an effect on the best configuration of the hybrid system, in other words on the place of push-pull boundary. Furthermore, pull in downstream combined with push at upstream produce superior results compared to the reverse case. Hodgson and Wang (1991) use simulation rather than a mathematical model to test their hybrid system in a much more complex manufacturing environment. However, the result remains the same and hybrid systems continue to be associated with better performance. Both Ding and Yuen (1991) and Geraghty and Heavey (2005) arrive at similar results from their respective simulation studies. Finally, Huq and Huq (1994) show that even in a job shop manufacturing environment that is traditionally associated with MRP control, JIT control principles (when embedded in the existing MRP system) have quite consistent and comparable performance levels, even if important manufacturing parameters like variations in setup times and process times undergo significant changes.

Despite their simplifying nature which cannot take all the components of JIT production into account, analytical integration studies consistently find in a variety of manufacturing environments that an optimized push-pull hybrid system performs better than a pure pull or pure push environment.

Empirical Approach

Research in this category is especially valuable in that it provides us with concrete examples of the viability of the previously described conceptual models and gives further insights about integration problems and opportunities. For example, Marques and Guerrini (2012) present a case study about a Brazilian metallurgical company that produces agricultural machines, which provides an especially interesting perspective on MRP JIT integration. The authors suggest that the case company does just the opposite of what the majority of American companies transitioning from a traditional MRP to a JIT MRP system do. The company began to implement an MRP system as part of the manufacturing planning and control in the company, which surprisingly until that time had completely relied upon lean production principles. Foo and Kinney (1990) also provide a case study where we meet the characteristics of the conceptual models that were presented in the combination studies (applied in a complex manufacturing environment). The case company is a telecom equipment manufacturer with a product variety which is almost limitless. In addition, demand variability is also quite high. The product and demand characteristics of the company seem to again have little room for the JIT practices imposed by a possible hybrid MPC tool. However, as in the previous case, the conviction is that JIT techniques in general and pull shop floor control in particular could improve shop floor performance significantly.

Finally, Lee and Shin (1996) present a case study of a Korean washing machine producer making the transition to an integrated MRP JIT system in response to the company's increasing product variety coupled with increasing demand volatility. Old product and planning structures, however, pose a challenge for such a change. Thus, BOMs will need to undergo radical change, in that modularity is increased and decreased levels will correspond to different planning horizons. This change facilitates a multi-level planning approach with rolling plans and time fences as in a typical JIT production environment, and shop floor control can be transferred to JIT production. Although not specifically stated, MRP seems to be in control of most of the purchasing and a mediator for planning in this case study, as in the hybrid models previously described in the combination studies.

Information Systems Approach

Initially, JIT proponents were against highly computerized production control, since this was thought to complicate and slow down the simple information flow achieved through the use of manual Kanban (Plenert and Best, 1986; Sugimori *et al.*, 1977). Thus JIT was considered incompatible with "high-tech production" and complex information systems in particular, as MRP-based software gradually became more and more complex and comprehensive. In their review of MRP JIT integration, Benton and Shin (1998) report that the issue of interfacing existing MRP systems with the newly implemented JIT systems is rarely referenced, although there is abundant research on JIT implementation and problems in its implementation stages. Considering the lengthy coexistence of JIT and MRP during the implementation of JIT, often resulting in a permanent coexistence, the somewhat disinterest in their integration is certainly related to the limited nature of JIT software packages. Earlier JIT software packages were typically supportive in few aspects of JIT production rather than providing company-wide solutions as a result of the underestimation of information systems' role in the performance enhancement of JIT production. On the vendor side, the trend to integrate MRP and JIT software had actually already commenced in the late-1980s following the trend of MRP JIT integration (Discenza and MacFadden, 1988). Similar to Benton & Shin, Discenza and MacFadden also note the academic disinterest in software integration at that time, in light of the interest of providing conceptual and analytical models of integration.

In more recent years, however, a swift change has occurred in the conviction that ERP is far from providing the software support needed for lean production. The onset of the notion that ERP could in fact be supportive for lean production is partly related to the lean offerings of ERP vendors, but by no means excludes the possible contribution of the standard ERP functionality to lean production. According to Riezebos *et al.* (2009), ERP systems are in many aspects supportive for the principles of lean production. They claim that the standardization of jobs and facilitation of communication with the suppliers are among the most important lean supporting functionalities of ERP systems.

While there might be some possibilities for standard ERP systems to support lean production practices (although possibly with the need for some bolt-ons), a growing trend amongst ERP vendors is the marketing of "lean ERP" packages. For example, Bradford *et al.* (2001) provide an overview of the leading ERP vendors' lean ERP solutions in an exploratory study, whilst Powell *et al.* (2011) provide a more comprehensive list of the key areas of support, which incidentally could be provided both by traditional ERP systems and more contemporary ERP solutions with lean modules and functionality. What is more, the lean functionalities listed provide support for both lean practices for planning and production and also a limited number of more general lean tools. Powell *et al.* (2013) also present a pioneering study among lean and ERP integration case studies in that it sets out to develop a methodological framework for the dual implementation of lean and ERP.

4 Conclusion and Further Work

Our literature review on MRP JIT integration reveals that it became a much more widely accepted and researched area especially after ERP systems became commonplace software and a lean ERP trend started to emerge. Although it is by no means an easy task to reconcile JIT production with ERP systems and a variety of ways exist for this purpose, today the necessity of IT support for JIT production is undisputed (Dixon, 2004). However, the remaining questions are "how" and "where" the integration should take place. The question "how" is an extensive question with both theoretical and practical implications. With regard to theory, it relates to questions such as should the integration take place through combination or modification? Which of the control principles should be used as the main framework? And how should the control responsibility be shared among the two control principles? In terms of practicality, on the other hand, it concerns the practical means to interface the two systems in general and the use of information systems for this purpose in particular. The second question of "where" can also be broken down into two questions: which manufacturing environments are feasible for hybrid system use? And what should be the criteria for matching the right hybrid system with the right manufacturing environment among the various combinations?

Our literature review revealed that some of the above questions have only partial answers in the existing literature. The questions regarding "where" are especially neglected, as the majority of integration studies are not very clear about the application area of the proposed hybrid models. Practicality comes next, as the information systems approaches towards integration have only currently started to attract academic attention with the rise of "lean ERP". Thus, further work should present answers that address these questions, perhaps through the development of further conceptual models of integrated systems. We also suggest that there is a distinct need for more empirical studies in the field of MRP JIT integration.

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Supply Chain Integration for Sustainability Faces Sustaining ICT Problems

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Abstract. This paper is concerned with the role of supply chain management in sustainable operations. It argues that sustainability requires increased supply chain co-ordination using ICT for product life cycle management. Accordingly, the paper researches integration problems in supply chains due to ICT. It addresses the question, why operational decisions are often not based on integrated information in supply chains. It argues that several current information/ communication technologies are essentially heterogeneous. Therefore, it is not easy to integrate these. The paper distinguishes (1) transactional systems (2) real-time monitoring/control systems (3) decision support systems (4) human communication (text, audio, video). Integration problems should be studied by analysing the underlying characteristics of the technology.

Keywords: ICT, sustainability, supply chain integration.

1 Introduction

Information systems and information technology plays a key role in sustainable supply and return of goods. When companies want to prove that materials are acquired in a socially responsible way, they need information systems. When returning products have to be refurbished, these products have to be identified by suitable information systems. When companies want to perform a Life cycle Analysis, they are dependent on correct and appropriate information systems.

Moreover, the focus on supply chains and return networks requires interoperability of supply chain partners' information systems. Because of the fact that these partners change dynamically, the real requirement is that interoperability can be realized "on the fly" with hardly any human effort.

Current practice in supply and distribution networks is far away from this ideal. Despite of considerable investments in all kinds of ICT, the real decision makers are still deciding by rules of thumb based on flawed information, rather than by up-to-date, correct and complete information.

Apparently, there are still many ICT applications which are difficult to integrate, even in a single company. This phenomenon is the basis for the research question to be addressed in this paper: *What makes ICT applications essentially different, creating sustaining integration problems?*

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In answering this research question, the researchers first of all corroborated their assumption, that supply chain decision makers are indeed facing heterogeneous systems. For this corroboration, in-depth interviews were held nine cross-docking firms. Section 2 reports about the findings. Section 3 presents an applications typology, based on the findings of Section 2. This leads to a characterization of heterogeneity (and therefore, difficulty in integration) which is elaborated in Section 4. Section 5 concludes the paper.

2 Information Used by Operational Decision Makers in Manufacturing and Freight Logistics

After case studies in manufacturing (De Snoo et al., 2011) and distribution (Meyer et al. 2010), we had to conclude that it is apparently difficult for operational planners of goods flows to use scheduling systems. In order to understand better, what constitutes the problems of these planners, it was decided to proceed with more detailed studies.

Transportation is an essential part of supply chains, distribution and contribution networks of physical goods. Therefore, we decided to organize detailed interviews with 9 distribution companies in The Netherlands who were engaged in cross docking operations.

The results of these interviews can be summarized as follows. While managers of these operations considered the investments in operational ICT systems to be considerable, the planners would typically not rely on the information provided by systems, for the following reasons.

- First of all, planners could follow individual trucks via GPS systems on screens with maps, but these systems would not provide insight into causes of delays or expected problems. Accordingly the planners preferred to be called or mailed by drivers and be informed on the context, expected problems and potential solutions.
- Second, the planners would not trust transactional systems (ERP systems, warehouse management systems, distribution management systems), because these systems were not always up to date. This is also due to the fact that these systems are not integrated with the GPS systems.
- Third, the planners would not trust their scheduling or decision support systems, because these systems are fed by the transactional systems. Moreover, these systems take a snapshot of the transactional systems, which may be bypassed by reality. Finally, constraints as perceived by the planners always differ from the constraints modeled in these systems.

From these interviews, it may be concluded that heterogeneity (GPS, Voice, transactional, decision support) and varying time properties of data is indeed an issue in practice. NB: these findings concentrate on operational decision problems.

3 Conceptualization

Our conceptualization of enterprise information systems and information technology is outlined below (see Fig. 1). Note, that the increase of technologies over the last decades leads technologies such as streaming video being considered as ICT, while in the past, video streams were not considered as ICT applications.

3.1 Real-Time Monitoring and Control Systems

Real-time *monitoring* systems observe the value of certain variables, using sensors, cameras, microphones, GPS systems etc. Such systems basically generate streaming data. Although streaming data may be technically discrete, they can be thought of as continuous. Streaming data can be used to measure the behavior certain variables (temperatures, pressures, noise, etc.). The streams are kept in log files.

Streaming data may be in a form which is suitable for human processing (video, audio, text) or in may be in a form which is suitable for machine processing (usually numerical data). The latter may be transformed into the former.

As is well known, real-time *control* systems are automated systems able to influence certain variables via actuators with the purpose to keep other variables close to a specified set point or trajectory.

Real-time data can be used to generate discrete transactions for transactional systems (see arrow 1 in figure 1). However, generating transactions is not trivial, as will be discussed in Section 4.1. Alternatively, such transactions are posted by humans (see arrow 2 in figure 1).

3.2 Transactional Systems

Transactional systems keep track of the relevant objects of enterprises. Such objects are e.g. freight, trucks, drivers, containers, locations, customers, orders and so on. The essence of transactional systems is that objects have a state. The state of an object changes in discrete steps (transactions). For example, a truck has either arrived or not arrived at a location. The freight either has been loaded or has not been loaded. The customer has accepted the shipment or has not accepted the shipment. And so on for all relevant objects.

Transactional systems are not built to capture full history. At each point in time, these systems contain the actual state of each object. In other words, the systems cannot recast the past (other than a few days, needed for database recovery in case of disaster). Of course, such systems keep track of the past via log files and archives, but conceptually it is not possible to delete, query or update the history.

Transactional systems are based on classical databases, whether relational or object oriented. The essence of such databases is a clear separation between the schema and the instances, corresponding to the distinction between types and instances in programming languages. The knowledge at type level defines the attributes and methods applicable for an object instance. Accordingly, transactional systems have explicit semantics as expressed in the database schema and in the business logic which is called when transactions are posted (these semantics and logic constitute an *ontology* in knowledge engineering parlance).

Finally, transactional systems are designed to be used primarily by humans. Although sometimes automatically generated transactions are applicable (see previous section), the primary goal is to inform humans on the state of affairs of objects relevant for the organization concerned.

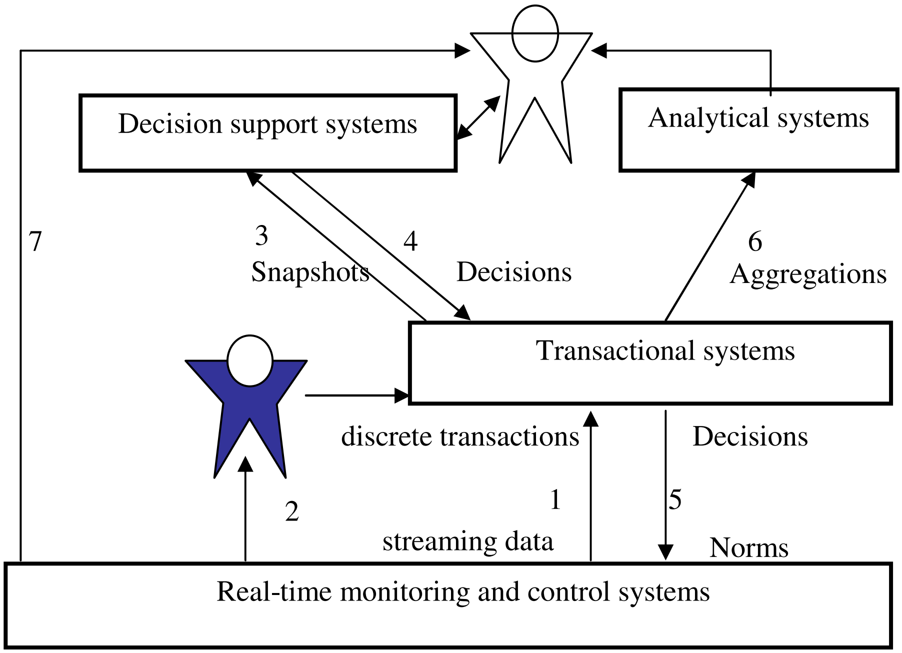

Fig. 1. conceptualization of enterprise information systems

3.3 Decision Support Systems

(Operational) decision support systems are systems which support operational decisions by software models. These models relate decisions to performance measures. In cross docking, such decisions allocate trucks to doors, they schedule trips, or they allocate shipments to trips. The models compute the best choices and provide advice to the decision makers, based on the state of relevant objects (shipments, orders, location of trucks , etc.).

Decision support systems (DSS) have to take a snapshot of objects' states before they can start their calculations (see arrow 3 in figure 1). After such a snapshot, the decision maker may interact with the DSS to study trade-offs between different decisions. The models may vary in their mathematical sophistication or in the level of detail. The "snapshot" data are usually kept in fast computer memory (RAM) during computation.

As indicated by arrow 3, the DSS models of objects are based on transactional information. In many cases, the transformation of transactional information into DSS information is not easy. These problems are discussed in more detail in section 4.3. Reversely, decisions taken may have to be stored as objects in the transactional systems (see arrow 4). This involves peculiar problems, also discussed in section 4.3.

3.4 Analytical Systems

Analytical systems are data warehouses where information of objects of the same type are stored. These systems typically collect information from transaction processing systems over periods of time. Accordingly, they provide insight into the dynamics of (aggregations) of objects.

Analytical systems use databases which are based on Online Analytical Processing (OLAP) technology. OLAP databases are often represented as cubes, which can be seen as tables with an additional time dimension. The tables are in themselves organized at different levels of aggregation. These systems can be queried for all kinds of analysis, but unlike transactional databases it is not possible to navigate between related object types.

Analytical systems are nowadays in use as the basis for many management reports, especially for strategic and tactical decisions. For operational decisions, they are only incidentally used. Our investigation in practice did not reveal high usage at operational level. It has been included here for the sake of completeness.

Analytical systems retrieve their information from transactional systems either within the company (see arrow 6 in figure 1) or from external sources. Section 4.2 describes some difficulties in this transformation. There is usually no information flowing back from analytical systems to transactional systems, with the exception of e.g., forecasts. The problems encountered here are similar to those related to DSS.

The above systems and their distinguishing features are summarized in Table 1.

Type of system	**Structured or un-structured**	**Snapshot or time-varying?**	**Continous or discrete data?**	**Main way of data storage**
Analytical systems	Structured	Past until now (aggregated)	Discrete (often in periods)	OlAP databases
Decision support systems	Structured	Snapshot and future	discrete	In-RAM storage
Transactional systems	Structured	snapshot	discrete	Relational or object-oriented
Real-time systems	Can be both	Past until now (detailed)	Continuous	Files

4 Integration Problems between Different Types of Systems

4.1 Integrating Real-Time Systems and Transactional Systems

When data streams follow a structured format (e.g. by measuring known physical temperature, pressure, etc.), it is in principle possible to generate transactions for transactional systems, as depicted in figure 1 by arrow 1. Although this is possible, it is not trivial, for several reasons.

First of all, transactional systems are not designed to capture these streaming data, because these data are usually not meaningful as changing states of objects. Nobody is interested in the coordinates of where a truck resides at every other second. Rather, it is interesting to know if the truck arrives in time at its destiny, and whether it is able to load or unload; it is interesting to learn that the unloaded cargo is accepted by the next party; etc. This information is mostly still subject to human interpretation and therefore it still requires human data entry (arrow 2). The same holds for sensor data on equipment condition related to refurbishment: it requires an explicit human decision to assess when to act.

Second, the usual differences in technical and syntactical standards between different IT applications will emerge. Although more and more technology becomes available to generate interfaces, there is still a long way to go before "plug-and-play" is reached.

Last but not least, there are always differences in semantics. A major sustainability challenge is to decrease waste of food. Food may have a status "fresh" and a status "perished", but also some intermediate states. The nature of the states and conditions under which a product proceeds through these states may differ between applications (e.g. fish differs from fruit). Therefore, sensor data are unlikely to match the semantic categories applicable in specific cases without dedicated programming effort.

Therefore, the conditions of streaming data leading to a transaction may be programmed (e.g. by software on a truck), but such software posting transactions is customer-specific and expensive to build and maintain. With current state of the art, it cannot be configured or installed "on the fly" in e.g. third-party trucks which happen to transport the cargo concerned. Similarly, in the context of refurbishment and sustainability, a product being maintained or disassembled will not be automatically reported to the OEM or upstream in the supply chain. Rather this requires a separate (manual) transaction, for which many things have to be arranged organizationally.

Accordingly, the first sustaining problem encountered in ICT integration resides between streaming data and transactional systems (see arrow 1 in figure 1).

NB. The above arguments apply à forteriori to non-structured data. It is clear that e.g. video streaming data cannot easily be integrated with other ICT applications such as transactional systems. Basically, humans have to look at video data or listen to audio data and capture meaning. Attempts to create automatic alerts from audio data (e.g. with voice recognition) are encouraging, but this does not mean that *in general* transactions can be posted in transactional systems without human intervention.

4.2 From Transactional Information to Analytical Information

Many decision makers will currently employ data warehouses for analysis of historical data or other time series. These data warehouses contain data of similar objects (e.g. sales data, quality control data or purchasing data) aggregated over certain dimensions such as time periods, geographies of market segments. The power of a data warehouse is that quickly drilling down into data or slicing and dicing becomes possible.

Analytical data are structured data, often based on transactional data from transactional systems; quite often, analytical data are generated for the archives of transactional systems. Because analytical data are derived from transactional data, they should both based on the same semantics (or ontology).

However, these semantics may yield problems. An obvious problem emerges when the semantics of a transactional system changes over time. In the context of supply chain management, the semantics of systems of different parties involved may also be different. For example, the notion of “sales figures” may be interpreted as “booked sales”, “invoiced sales” or “earned sales” by different systems.

In the context of sustainability, different interpretations of many sustainability measures is a major problem. This is elaborated in Ingwersen and Stevenson (2012) where the term *product category rules* is used to denote standard values for environmental load calculated in LCA. The disadvantage of such standard is, that actual effort to reduce environmental load by companies is not acknowledged. Accordingly, there will be an ongoing debate on “numbers” related to sustainability issues in data warehouses.

We conclude that this *semantic heterogeneity* will be a sustaining problem in supply chains engaged in sustainability (see arrow labeled “6” in figure 1).

NB: some early work has been done to overcome semantic heterogeneity by automated semantic negotiations “on the fly”, see Van Blommestein (2007).

4.3 From Transactional to Decision Support Systems

In contrast to data warehouses, which contain aggregated data related to one type of objects in past or future periods of time, decision support models often try to simulate the future across multiple objects. These systems support planning or scheduling of logistical operations and take into account different resources such as trucks, cross docking doors, human operators, etc.

In contrast to analytical data, the data for these decision support models is based on a *snapshot* of transactional data at a particular point in time (“now”). Obviously, the semantic heterogeneity problem also plays in the context of creating data for decision support models from transactional data. However, there is an additional issue for *operational* decision making problems. This is due to the fact that the time proceeds while decisions are being taken. At the same time when the snapshot is taken, new transactional information becomes available which may change the picture to some extent. Accordingly, the decision maker is forced to keep an eye on actual developments while using the DSS model and while to taking the first decisions in real time. No wonder that it is difficult to use such models (see arrow “3”).

A DSS calculating LCAs suffers from similar problems in timing and semantics. An LCA is based on a snapshot of product data. This DSS is full of assumptions on coefficients for sustainability performance (from handbooks or LCI databases). Genuine improvements in sustainability will affect these coefficients, but in the DSS software, it is very cumbersome to adjust such coefficients. Moreover, maintaining correct engineering data is a challenge in itself. Ideally, such DSS for LCA should be interactive and integrated with PLM and ERP systems.

5 Conclusion

In this paper, several sustaining problems in supply chain integration have been identified. These problems are inspired by future requirements to information systems from expected sustainability developments. These problems are:

- Creating automated transactions from streaming data (preferably “on the fly”)
- Automated solution of heterogeneous semantics or ontologies between transactional systems and/or data warehouses and decision support systems
- Automated solution of the problem of changing snapshots for operational decision support systems
- Automated analysis of text and feedback of the results in enterprise systems.

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Parameter Management in Configuration for the Design of Products Families

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Abstract. This paper presents a design approach shows the usefulness of the software in the management of parameters in the design of products. Indeed, until now, the definition of this type of interface depends only on knowledge of the designers. It was therefore difficult to group settings to facilitate modular design. To highlight this, the methodology presented in this paper is to describe a journey through various design software to reduce the designers' work. Rules that the designer has put in place during the design of the product, called "design rules" also define the interface. This has the advantage to guide the designer in his work and to allow a rapid evolution of the interface in the case of product development. The objective is to reduce the time of the routine engineering to devote more time to innovation. At the same time, this method allows you to define assembly sequences based on parameters needed to design the product. Some calculations to be carried out before others because the calculated parameters are necessary in one to another. The definition of an ordered graph allows to directly obtain valid assembly sequences necessary for design while offering designers a thread.

Keywords: Product design, specific parameters, functional parameters, optimized design sequence, modularity, product range.

1 Introduction

To design a product, specifications should be established. To obtain them, the needs, the environment and the functioning are analyzed. This system analysis results in a list of components, parameters, functions and rules, which are sometimes a myriad. This number of criteria, which can be huge, to be taken in consideration requires a lot of work. To spare this time, the specifications can be simplified with the use of some software.

After having analyzed the needs and the environment, the internal functional analysis begins. Depending on the fact that the design of the product is only a redesign or an innovative design, the internal functional analysis can be preceded by the definition of pre-concepts and of the new product structure. During this analysis, the list of components, taking part in the product structure, and of functions are introduced and then organized in a tree structure. To

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each component and to each function, characteristics are associated with values and tolerances : these are respectively the specific parameters and the functional parameters [ROBERT 2011] [1].

This paper introduces the utility of software in the management of parameters during a product design. Because product design is a competitive domain, but also because it spares time for the product designer team, application of software to simplify the work can be an asset. By this way, the definition of the product and its related assembly sequence will be more quickly obtained.

2 Software

2.1 ACSP

ACSP is a Collaborative Project Monitoring workshop [TOUSSAINT 2010] [2]. It helps designing the project by : the integration of the concept of concurrent engineering, a rapid visualization of the project state and progress, and the project related data management and accumulation.

Its six main features are : user access management (login and password), file management (management of versions), data management (project type, product, process, use), life cycle management and document state, communication management (messages, forums), and accumulation and reuse (project templates, data standards).

2.2 Kadviser

Kadviser is a Knowledge Based Engineering (KBE) software [PETIT] [3]. A KBE application aims to help mechanical designers by providing them a set of functionalities necessary to use and update the know-how of a company.

This software provides a connection with PLM systems (Product Lifecycle Management), CAD software (CATIA, Nx6, etc.) and Microsoft Office tools (Excel, Word, etc.).

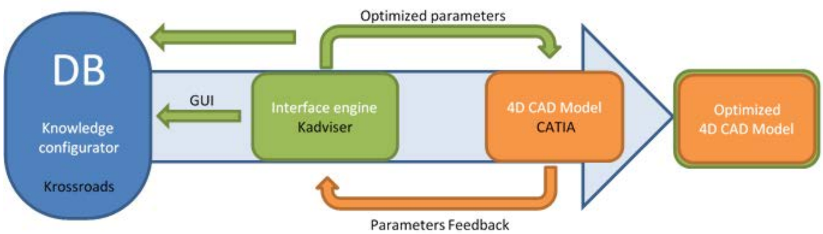

Fig. 1. Kadviser general architecture

Kadviser is also known for its constraints propagation inference engine. In fact, it does ignore the writing direction of rules. The order has no influence on reasoning. The inference engine applies the principle of reversibility, which means : For the expression “a”+”b”=”c”, where values “a” and “b” are known, the inference engine may determine the value of “c”. If values “a” and “c” are known, it will find “b”.

In a design project, it can be coupled with a Collaborative Project Monitoring workshop, such as ACSP.

2.3 ORASSE Knowledge

In the product design domain, it exists the FARD (Functional And Robust Design) methodology [ROBERT] [4]. Its aim is to design and generate quickly the entire product variety of a sale modular family without forgetting to respect the customer requirements (functional design) and the assembly constraints by helping in the choice of the assembly sequence.

A new software has been developed by A. Robert named ORASSE, which applies this methodology. In the ORASSE Knowledge version, the user will be guided, step by step, to obtain an optimized design sequence. Its most convenient aspect is the time spared (almost 60%) in the product structure.

Over recent years, Design Structure Matrix (DSM) was used in different domains, including product design, and led to the emergence of different types of DSMs. [BROWNING 2001] [5] proposes a classification of DSMs into two categories : time-based DSMs and static DSMs. From these categories, four main applications represent the research focus of the use of DSM techniques :

o Component-Based or Architecture DSM : Used for modelling interactions among product components or subsystems. It can be useful for appropriate modularisation of complex systems. Matrix-components DSM which was originally proposed by [KUSIAK] [6].

o Team-Based or Organization DSM : Used for modelling and depicting interactions among organization structures such as design teams.

o Activity-Based or Schedule DSM : Used for modelling processes and activity networks based on information dependencies among design activities.

o Parameter-Based (or Low-Level Schedule) DSM : Used for modelling relationships between design decisions and parameters.

One weakness of these three most common methods for identifying modules is the problem in designing multiple products [HOLTTA-OTTO 2005] [7]. These methods optimize each product of a family but not the family as a whole. To solve this problem, the family can be reduced to a generic product that is used in order to create product variants in a same family thanks to a set of geometric parameters. These geometric parameters can change the dimensions of each variant without any modification of the product architecture. Then, there is a family of products based on the same architecture that can differ from their dimensions. Orasse positioning is then to define a functional architecture from a functional analysis combined with the use of a DSM method in order to assign components in each module. Then, independent functional modules can be obtained.

3 Management of the Parameters Step by Step

After the internal and external functional analysis is done in ACSP, the user enters the functional parameters in ORASSE Knowledge, because it will be this software, which will simplify the parameters matrix.

N°	Nom	Active
1	Maximal lenght of the model	☑
2	Maximal width of the model	☑
3	Maximal height of the model	☑
4	Resolution on y	☑
5	Number of building extrusion head	☑
6	Lenght of the machine	☑
7	Width of the machine	☑
8	Height of the machine	☑
9	Resolution on x	☑
10	Resolution on z	☑
11	Number of reels	☑
12	Diameter of reels	☑
13	Dimater of wire	☑
14	Width of spool	☑
15	Diameter of spool	☑
16	Tension	☑
17	Amperage	☑
18	Column height	☑
19	Lenght of front and rear beam	☑
20	Lenght of right and left beam	☑
21	Lenght of front and rear case	☑
22	Lenght of right and left case	☑
23	Diameter of axis	☑

Fig. 2. List of parameters in ORASSE Knowledge

Some pictures can be added, in order to clearly identify the specific parameters with their associated numbers on the component picture.

Fig. 3. The plastic coil with its specific parameters

Then the user inserts the list of specific parameters and of functional parameters, associated to each component and to each function, in ORASSE Knowledge, by putting them right under their respective component and their respective function.

In ORASSE Knowledge, the functional parameters and the specific parameters are gathered per colour, depending on which function or component they belong to, and nserted in a matrix, always with their affiliations colour. In this matrix, the links between the different parameters are established.

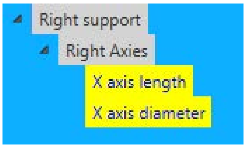

Fig. 4. Components and specific parameters

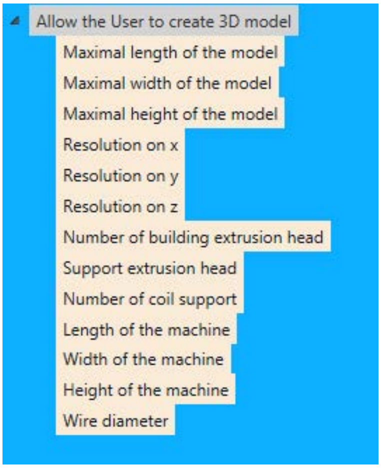

Fig. 5. Functions and functional parameters

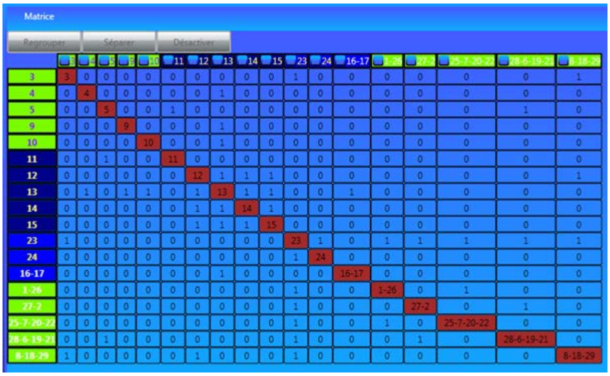

Fig. 6. Matrix parameters-parameters

Fig. 7. Matrix parameters-parameters with modules calculated by ORASSE Software

ORASSE Knowledge automatically generates a graph with the components' numbers. The user has to add the direction of the arrows, which represents the contacts between the various parts, corresponding to the kinematic links between the components. In our example of the 3D Printer, the product design gathers around 300 parameters and some of them are "strongly" linked, as we can see on the graph. ORASSE Knowledge will then simplify the graph by erasing the "strong" contacts and gathering the concerned components.

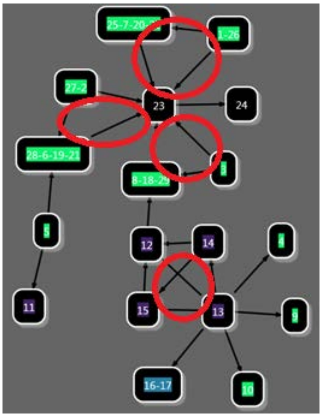

Fig. 8. Graph before simplication

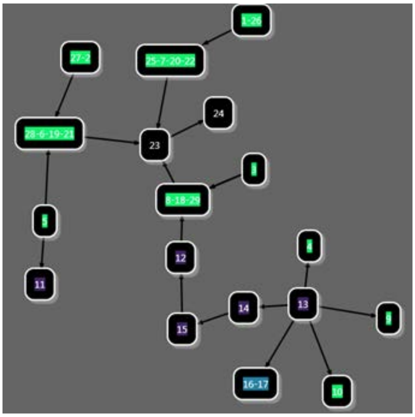

Fig. 9. Simplified Graph

After the graph simplification, the software suggests to start the design sequence with one of the less attached parameters. To continue the design sequence, only the numbers connected to the previous one on the graph are suggested : the user chooses a number that seems plausible for him with his critical design engineering knowledge. At the end, an optimized design sequence is obtained.

Fig. 10. One of the possible design sequence

These sequence is the most suitable for the product under consideration in this case study and according to the knowledge of the assembly planner. The assembly planner is guided during his/her choice by the decision support system. Using the algorithm, this system informs the assembly planner of three main constraints :

o The functional architecture to respect modular structure of the product by a link of colours o The product structure with blocks of components defined with the DSM matrix

o The assembly constraints with relationships between components and assembly planner knowledge

The decision support system guides the assembly planner by proposing choices ranked in accordance with these constraints for selecting the most suitable assembly sequence. But, at any time, he/she can also choose another more suitable solution according to his/her knowledge of the assembly process of the particular company.

These parameters are then inserted in Kadviser by the user. In this software, the parameters are related among themselves by calculus formulation, in such a way that when the parameters are informed in the interfaces, all the functional parameters and the specific parameters will be automatically calculated according to the relation formula in Kadviser. For instance, if the diameter of the ball crew is informed by the user, Kadviser will be able to give its diameter, its length and the screw thread. By this way, the 300 parameters, that the user has to insert, can be reduced to only a dozen, which will control the modularity of the model and then enable the generation of an entire range.

4 Conclusions

In this paper, a new approach for the parameters management during a product design has been introduced. It consisted in the generation of a design sequence after having simplified the matrix parameters-parameters with ORASSE Knowledge. The graph being reduced, consequently the parameters are also become less numerous.

To improve their management, the other aspect exploited is the relation between them : in Kadviser, the user can establish calculus formulas to link a parameter with the other ones. This dependence criterion makes the determination of the parameters quicker by inserting some key values, instead of having to recalculate the entire specific parameters : it is the base of the modularity of the product, which will enable the creation of a whole product range.

The use of technological means facilitates the teamwork during a product design, but especially, it helps sparing time. This last point is the most important asset, especially nowadays with the constant competition in the engineering domain : the product designer team will have more time for innovation and the costs will be reduced.

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Physical Asset Management Practices in Industry: Comparisons between Greece and Other EU Countries

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Abstract. Physical asset Management is “the optimal life cycle management of physical assets to sustainably achieve the stated business objectives”. A "physical asset" is defined as a physical item that has potential or actual value to an organization. During 2011-2012 the European Federation of National Maintenance Societies (EFNMS) European Asset Management Committee (EAMC) carried out a survey of industries seeking to map physical asset management practices. The survey contained questions concerning the business environment of respondents, management practices, key performance indicators usage, organizational policies and driving factors. This paper presents the survey deeper findings regarding the responses, influences of industrial sector and business environment on physical asset management practices, identification of typical existing asset management profiles and improvement suggestions. Focus is given on comparing asset management practices between Greece and other EU countries, offering insight into different technological, business environment and other factors influencing physical asset management practices.

Keywords: Asset Lifecycle Management, Maintenance in Manufacturing.

1 Introduction

Physical asset Management is “the optimal life cycle management of physical assets to sustainably achieve the stated business objectives”. The concept takes into account capacity considerations, design, investments, operations, maintenance of production equipment and disposals. One of the main tasks of Asset Management is to guarantee that the changing business requirements and physical assets match together in an optimal way, taking into account all life cycle aspects of equipment. In the present business environment, Physical Asset Management is becoming a key challenge for business organisations and has acquired more importance as a management function than ever before. However, the state of implementing Physical Asset Management best practices in industry is not sufficiently well recorded or documented.

The current financial climate makes it all the more important to look into such practices and trends within European Industry [1]. Among the tools that can be used

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to assess the maturity level of the Asset Management function is the PAS 55 model, developed by the Institute of Asset Management in the UK [2]. Other initiatives have sought to map specific aspects of Maintenance Management practice in some countries, such as Italy [3] and Spain [4]. A European-wide survey or a more global one over a common baseline was missing.

An initiative to support establishing the current status of Physical Asset Management was taken by the European Federation of National Maintenance Societies (EFNMS) European Asset Management Committee (EAMC), with the launch in 2011of a survey in order to map Physical Asset Management practices in EU industries [5][6]. An initial analysis of the obtained results has shed light into the current state of Asset Management practice in the EU and more work on supplementing the currently obtained results is foreseen [7]. With Greece being among the countries severely hit by the financial crisis and with its industry just starting to switch to more export-oriented operation [8], it is of particular interest to focus on the survey results to draw some insight into differences between physical asset management practices in Greece compared to the rest of Europe. This paper presents an analysis of the main findings of such a comparison. An extension of the survey is planned for 2013-2014.

2 Physical Asset Management

Physical Asset Management integrates functions from different ISA-95 layers, including operational, tactical and strategic functions and therefore requires an integrated approach in decision making. It integrates asset creation and development, asset operation, upkeep of assets, repair and upgrading of assets, as well as recycling and disposals. An important part of asset development is the determination of capacity needs and capacity creation which involves investment planning and investment execution. Asset operation is the handling of assets for their intended function, mostly production, and especially the part of production operations that influences assets and their prevailing production capability. The third dimension, upkeep, stands for the maintenance function. Asset management strongly supports sustainable development by striving at efficient use of scarce resources taking into account market, technological, legal and normative constraints, market dynamics, as well as sustainability. Upgrades go beyond replacements, in the form of repair, renovation or remanufacturing. An important aspect of physical asset management is to strike the right balance between performance, cost and risk in pursuing the enterprise goals. It supports managing investments, capacity and production in a more efficient, better quality-assured, safer and more competitive way. There is a need for more efficient asset management to deal with the different sources of losses during the life cycle of production equipment and physical assets, thus demanding more efficient asset management, such as:

- economic lifetime is not in balance with technical lifetime
- all processes are not functioning at the same operating rate
- during process and product transitions production capacity of large concentration of assets is utilised
- demand does not match with capacity

- during installation and start of investment production losses may be huge
- Overall Equipment Effectiveness (OEE, including low availability, low speed and low quality rate) causes production losses
- due to low flexibility of assets equipment is used in ineffective way (product mix and insufficient adaptation to demand fluctuations)
- design and manufacturing of equipment is not up to date.

To drive improvements in Physical Asset Management practice, the current status needs to be identified and this has been the primary aim of the EAMC survey.

3 Physical Asset Management Survey

To carry out this exploratory survey EAMC launched a survey of European Industry, on the basis of a questionnaire designed to collect background information for the development activities in the area of Physical Asset Management and the maintenance function as a part of Physical Asset Management [6]. Another objective was to offer European organisations insight into the mode of operations in Physical Asset Management within various business and technology environments. The survey questionnaire included the following groups of questions:

A. Organisation and management principles

1. Organisations business environment (7 questions): e.g. rate of change, life cycle phase of the industry and principal business drivers

2. Organisation and decision making in the area of asset management (5 questions): e.g. financial responsibility of asset management, participation in various phases of investment processes

3. Management and control (7questions): e.g. use of aggregate and other key performance indicators for asset management, criteria for investment decisions

4. Asset knowledge management (4 questions): e.g. coverage of criticality analyses, use of asset history systems, working culture

B. Maturity of management activities

1. Policy and strategy (4 questions): e.g. development of asset management policy and strategy, demand analysis, asset management plans

2. Whole Life Costing (WLC) justification and risk analysis (3 questions): e.g. evaluation of capital expenditure requirements for the whole lifecycle

3. Asset lifecycle management (6 questions): e.g. various lifecycle phases practices

4. Asset knowledge management (4 questions): e.g. definition of standards, guidelines or best practices for classifying, collecting and storing asset knowledge

5. Asset management capability (3 questions) e.g. auditing and review the safety, efficiency and effectiveness of asset management activities

6. Asset management review and improvement (3 questions): e.g. measurement, development and monitoring the organisation's asset management performance

C. Future driving forces of asset management activities

Long term return on assets, OEE and legislation are among 10 proposed drivers.

The questionnaire is available at: https://e-lomake.fi/lomakkeet/2033/lomake.html. The survey was implemented during spring 2011 and organisations representing 24 countries and 23 industrial sectors contributed the study.

4 Greek Industry Survey Findings

The analysis aims at indentifying the current status regarding Greek industry, compared to the rest of Europe. This is of interest especially since the current crisis puts on severe pressure for improvements in competitiveness, which currently, according to the latest figures from the World Economic Forum shows Greece to be a stubbornly persistently low performer [9]. This is despite Greece featuring at a relatively high ranking in terms supporting pillars, such as infrastructure, technological readiness and educational support. Due to the specifically negative macroeconomic environment, Greek industry would have to perform even better in terms of Physical Asset Management practices to raise its competiveness level.

The EAMC Asset Management survey has drawn participation from 33 Greek industries. These were distributed among the following sectors:

- Manufacture of food products
- Manufacture of wood and of products of wood and cork, of furniture, etc
- Manufacture of paper and paper products
- Manufacture of coke & refined petroleum, chemicals & chemical products
- Manufacture of basic pharmaceutical products and pharmaceutical preparations
- Manufacture of rubber and plastic products
- Manufacture of fabricated metal products, of machinery and equipment, of motor vehicles, etc.
- Other manufacturing
- Distribution of gaseous fuels through mains
- Water transport / Other utilities
- Service provider / facilities management

Comparative results were obtained against 102 responses from other European countries. In general, some variations were found between Greek and other European industries in terms of organisational and management issues, as well as in terms of future drivers. No major variations were observed in the maturity of asset management activities. This may be an indication that physical asset management is not falling behind other European countries management, but other organisational and even legislative issues are considered as needing more improvement. When considering only manufacturing industries, more deviations are found. A first difference is observed in the lifecycle phase of industry wherein Greek distribution was more skewed towards slow-growth and mature to aging industry (Fig. 1). Another difference is on the planned operating rate of the production equipment. In Greece, the obtained responses indicate that this peaks at the middle-usage rage between 51-75%, whereas overall in responses obtained from all European countries, the responses indicate a

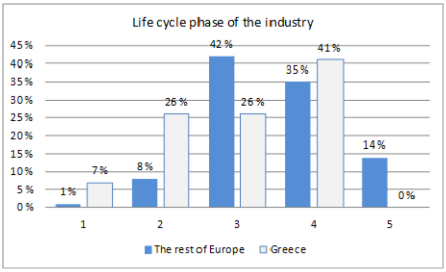

Fig. 1. Lifecycle phase of industry. 1. Emerging 2. Fast growth. 3. Slow growth 4. Mature. 5. Aging / Declining

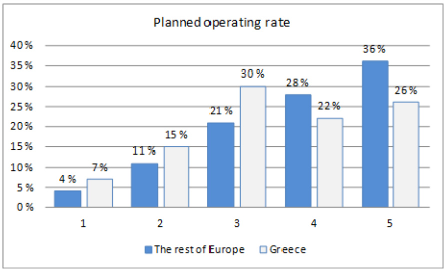

Fig. 2. Planned operation rate: 1: <25%, 2: 25-50%, 3: 51-75%, 4: 76-90%, 5: >90%

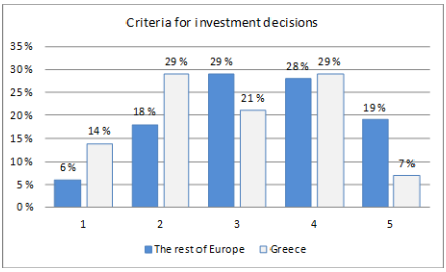

Fig. 3. Criteria for investment decisions: 1: Cost of purchase, 2: Cost of purchase and installation, 3: All the costs of investment before full scale production, 4: Life-cycle costs, 5: Life-cycle profit

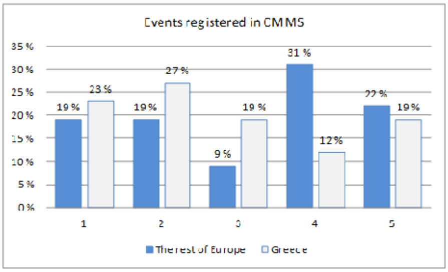

Fig. 4. Asset events recorded in CMMS: 1: <10%, 2: 10-40%, 3: 41-70%, 4: 71-95%, 5: >95%

much more skewed distribution towards higher operating rates (Fig. 2). One of the few deviations in the asset management practices was in the criteria for investment decisions. In Greece a clear majority of the respondents used investment costs-based decision making, whereas the other regions utilized more life cycle cost or profit based decision making (Fig. 3). A reason behind this tendency can probably be the deviating life cycle phase structure of the industry in Greece.

In Greece, financial responsibility for physical asset management seems to be more on the shoulders of the maintenance function, whereas in the group of the other regions it is allocated to the asset manager, asset management teams or the top management. The extent of usage of asset management information systems, such as that of a computerised maintenance management system (CMMS) also appears to differ. Overall, a higher proportion of asset events tend to be registered in a CMMS in other countries, compared to Greece (Fig. 4).

The identification of risk-based maintenance requirements does not show a strong concentration either into low or high-priorities in industries (Fig. 5). Generally, most industries consider it to be in place, but there is a higher proportion of European industries that consider it effective and fully integrated with all other relevant aspects

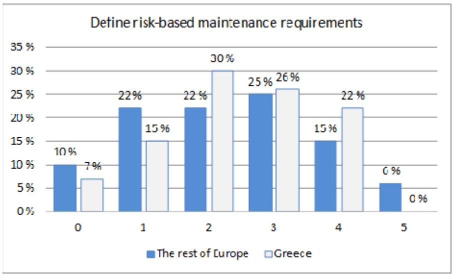

Fig. 5. Risk-based maintenance requirements: 0: least – 5: maximum

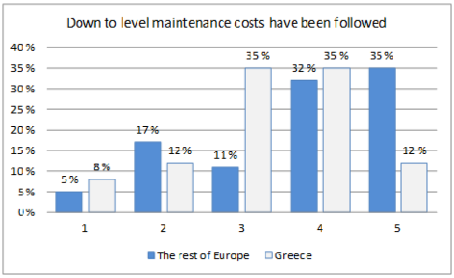

Fig. 6. The level, down to maintenance costs have been followed

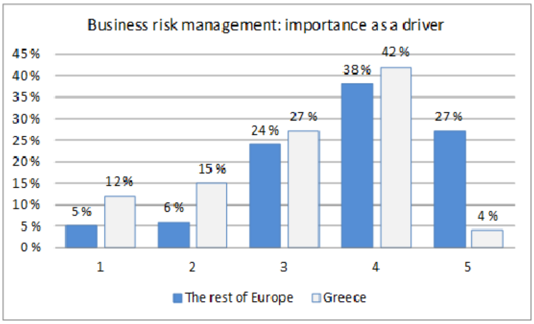

Fig. 7. 'Business risk management' importance: 1: least – 5: maximum

of asset management in all other parts of the organisation, whereas in Greece the same proportion considers it effective but more see it integrated. The best practice is missing in the responses from Greece.

More deviations can be found if we focus on manufacturing industries. Other regions in Europe apply the follow-up of maintenance costs at the more detailed indenture level, compared to Greece (Fig. 6). Deviations are also found in producing annual asset management plans, acquisition of assets and ensuring new assets meet specified requirements. Respondents in Greece were not as satisfied with procedures as in the other regions.

Considering the drivers of asset management decisions and practices, business risk management is in general considered significant or very significant, with a smaller proportion in Greek industry considering it very significant compared to other countries. On the question whether these variations depend on real differences in asset management practices or whether they are due to variations in the business technological environment, multivariate regression analysis shows that. 'Expected economic age of production equipment' and 'business risk management as a driver' have the strongest influence on investment criteria (Fig. 7). Greek asset management practices have some impact on this factor, but statistical significance was only indicative, with explanatory power at 0.27 %.

Table 1. Factors having impact on investment decision criteria

Dependent Variable: 14 Criteria for investment decisions R= ,555 R^2= ,308 Adjusted R^2= ,271 F(6,112)=8,323 p<,000	beta	p-value
		0,000
	0,250	0,011
55 Driver: Business risk management	0,295	0,002
5 Expected economic age of production equipment	-0,279	0,001
Greece	-0,136	0,108
53 Driver: Dependability, safety and environment	-0,150	0,108
48 Driver: Long run capacity optimization	0,135	0,126

Table 2. Factors having impact on financial responsibility for AM of existing equipment

Dependent Variable: 8 Financial responsibility for AM of existing equipment R= ,460 R^2= ,211 Adjusted R^2= ,184 F(4,115)=7,7021 p<,000	b*	p-value
Intercept		0,176
55 Driver: Business risk management	0,323	0,000
Greece	-0,282	0,003
3 Life cycle phase of main products	0,183	0,030
Others	-0,203	0,032

Business risk management as a driver, life cycle phase of main products and Greek specific practices seem to have some influence on financial responsibility for asset management activities (Tables 1-2). The overall explanatory power of the statistical model was 0.18 %. In the case of 'Maintenance costs calculation Greek specific practices seem to have some impact on the results, but the impact was not very strong. The same applies to 'Events registered in CMMS'.

5 Conclusion

Asset management within manufacturing is considered an increasingly important contributor towards enhancing production quality, safety, performance and efficiency, as well as environmental sustainability Nonetheless, the status of implementation of Physical Asset Management best practices in industry is not sufficiently recorded or documented. The EFNMS via its EAMC Committee has taken the initiative to seek to map the status of Physical Asset Management in Europe. This action is taken by the EFNMS Asset Management Committee (EAMC), with the launch in spring 2011of an EU-wide survey in order to map Physical Asset Management practices in the different kind of business environments in Europe. The survey has identified key areas for improvement among European industry, such as 'Risk & Review', 'Asset Knowledge' and 'Asset Management Strategy and Planning'. Focusing specifically on Greek industry, there is a need to place greater emphasis on the importance of specific drivers for asset management. Greater information integration and enabling technologies usage should be sought, while asset management linkage with production and asset utilisation performance aspects, such as production equipment planned rate should be better established. Other aspects such as risk-based prioritisation, lifecycle considerations and return on assets are worth improved attention. A greater push within Greek industry is needed to better establish links between asset management and upper management functions. Decision making should not be solely driven by acquisition and installation costs considerations, but life cycle costs and profits should be taken more into account. Asset management in Greek industry is advised to manage costs not only at a macro-level but at a lower asset level, and indenture could also reflect on this. The nature of the reported survey has been exploratory but is a good basis for developing future studies, providing benchmarking findings against which to seek to place current practices in the infrastructure sector and manufacturing industries.

Acknowledgements. The EFNMS Physical Asset Management Survey was designed by the EAMC Committee of EFNMS and supported by National Maintenance Societies and especially the Hellenic Maintenance Society (HMS) on Greek Industry. The authors wish to acknowledge the contribution of EAMC members on the survey results. The first author wishes to acknowledge partial support through GSRT (grant 09SYN-71-856, project WelCOM) and the support of P. Pistofidis for the survey of Greek Industry.

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An Effective Policy for Recycling Parts for the Production Management of Consumable Supplies

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Abstract. Recycling has been gaining prominence as a way of preserving natural resources, and the number of companies in the recycling business is increasing. However, there is no effective decision policy for recycling parts. Therefore, this study (1) selects products and models them to simulate the production activities in a recycling company with the help of a computer; (2) designs and analyzes some decision policies for disassembling used products that avoid excessive inventory and limit the use of new materials; and (3) proposes the most effective policy that decides the number of collected products to be disassembled and offsets the deficit with new parts. Finally, the authors proposes balances of the amount of disposes and total cost.

Keywords: Recycling, Simulation, Production Management, Inventory.

1 Introduction

Recently, recycling has been seen as one way of preserving natural resources, and the number of companies in the recycling business has been increasing.

Recycling companies collect and disassemble used products and clean or repair their parts, with which they produce new products. However, most of the collected products are damaged, and the extent of the damage varies among parts. Moreover, the number of recyclable parts that can be acquired from collected products varies (hereafter referred to as the yield rate; the rate of the amount of parts that can be retrieved from a fixed number of products). The difference in yield rates among various parts influences the recycling company greatly. For example, if the yield rate of a certain part is low, the company needs to purchase that part or increase the number of products to be disassembled. If the company intends to recycle natural resources, it should increase the number of products to disassemble in order to limit using new materials. However, having excessive inventory is not desirable, either. For these reasons, the difference in yield rates among the different parts makes it difficult to decide the appropriate number of products to disassemble.

Regarding disassembly operation in recycling, studies on the disassembly-oriented design (Onoda 2003), studies on a optimal ordering and recovery policy for reusable items (KOH,G. 2002), and studies on inventory management of remanufacturable

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products (TOKTAY,B. 2000) are presented. These studies, however, did not consider the difference in yield rates among parts. Moreover, these studies focused on only total cost and did not describe reduction of scraps.

This study, thus, aims to devise a policy regarding the ideal number of products to disassemble that avoids excessive inventory and limits the use of new materials.

2 Target Company and Products

2.1 Status of the Target Company and Products

We selected Plant N, which recycles consumable supplies for copy machines as an Original Equipment Manufacturer (OEM), as the target company. This company has nine processes for recycling products, from collection to shipment. In this study, we focus on the disassembling process.

Target product "AA" is the marking unit of copy machines. It has 31 parts excluding connecting parts such screws or washers. Moreover, it comes in different varieties as shown in Figure 1. "Destination" indicates the client companies to which the products are shipped. "Function" indicates the capability of printing; for example, "6K" means that the product can print up to 6,000 sheets of paper. There are two methods of preparing parts: one method uses new parts that are bought (hereafter referred to as NewParts) and the other uses recycled parts that are disassembled from collected products (hereafter referred to as ReParts). "Specification" indicates the configuration of NewParts or ReParts. Each R, S, and T specification has its own rule.

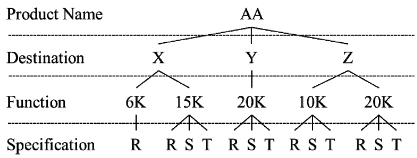

Fig. 1. Product Type

2.2 Current Decision-Making Policy for Disassembling

In the target process, the current policy regarding the appropriate number of products to be disassembled comes from the required number of the lowest yield rate parts. This policy allows the collection of all the parts from the disassembled products. However, the inventory of parts with a high yield rate becomes larger, which results in a large amount of scraps. Certainly, using the parts of used products instead of new parts and having an excessive inventory of parts are desirable from the environment perspective. However, almost all companies have limited human resources, limited places to store parts and products, and limited funds to utilize scraps in thermal recycles. Thus, to continue the recycling business, the decision-making policy should be concerned with both the environment and economy.

Here, we devise a policy that decides the appropriate number of products to be disassembled, by using computer simulation and considering the above points.

3 Modeling

3.1 Modeling of the Company and the Process

To analyze the influence of the decision-making policy on production, we simulate the disassembling process of the target company. The model company disassembles collected products and supplies recycled parts to produce new products.

We set the other conditions which is like working time in the model company as per those in the target company, as shown in Table 1. The model process is usually operated by four workers for 6 hours a day. Further, to increase production, the number of workers and working hours can be increased to 6 and 7.5 respectively.

Table 1. The Conditions in the Model Company

	Workers (people)	Working Time (hours)	Disassembling Capability 1 (/day)	Disassembling Capability 2 (/hour)
regular	4	6	160	27
Increase 1	4	7.5	200	27
Increase 2	5	7.5	240	32

Analyzing the amount of collection and shipment in target company, we see that they almost are stable, hence, the amount of collection does not influence whether or not the ReParts are sufficient for production.

3.2 Modeling of the Product

A recycling company obtains parts from used products. Therefore, the company's control items for the parts are different from those of general production companies. General production companies mainly control commonality, whether each part adapts to other products or not, and prices. On the other hand, in addition to commonality and price, recycling companies have to control the amount of collection, method of preparing parts, and yield rate of ReParts. As mentioned earlier, the amount of collection does not influence this simulation. Here, we set four control items for the model product: (1) commonality; (2) price of parts; (3) method of preparing parts; and (4) yield rate.

To model the parts, we classify these control items. Then, we categorize the target parts as per these classified control items and regard the corresponding items as model parts.

Before classifying the items, we consider certain factors regarding the control items. The target products have 3 part types: common parts, unique parts, and base parts. The common parts are useful for all product types. On the other hand, the unique parts are useful for each specific product type; however, among the unique parts, some parts can be useful for other product types

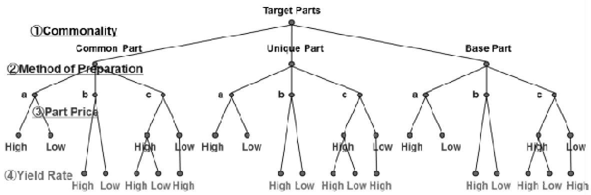

Fig. 2. Classification Items

after processing. Hence, these alterable parts (hereafter called base parts) are classified separately. Moreover, the target company does not recycle parts that have a low price and low yield rate; hence, the items that correspond with these conditions are excluded. Considering these factors, we classify the items as shown in Figure 2.

We then categorize the target parts as per the classified control items. We find that the target parts correspond with nine out of the 21 items. Hence, we set these nine items as the model parts. We set the names of the model parts as follows. (Name of model part: Xx-p/r)

X: commonality: A: common part; B: unique part; C: base part
x: method of acquisition: a: NewParts(always); b: ReParts(always); c:ReParts(if possible)
p: parts price: Hp: high-price parts; Lp: low-price parts
r: yield rate: Hr: high-yield-rate parts; Lr: low-yield-rate parts

4 Design of Simulation Conditions

4.1 Evaluating Conditions for Designing Decision-Making Policies

We evaluate the advantages and disadvantages of decision-making policies. We also consider factors such as yield rates, price, commonality, and the number of parts required for production. The following factors are relevant for deciding the number of products to be disassembled:

- Yield rates of parts

It is important to evaluate the part that we regard as the reference value to decide the number of products to be disassembled. If we regard the lowest-yield-rate part as the standard, we will be able to collect each part in sufficient quantity for production but the inventory of some parts will become excessive. On the other hand, if we regard the highest-yield-rate part as the standard, we will collect only the required parts for production. Thus, we select the part numbers required for production as the index to decide whether the part with the highest yield rate or that with the lowest yield rate should be the standard in the disassembling process.

- Prices of parts

The target parts include both expensive and cheap parts. A recycling company should keep the purchasing costs low by enhancing the percentage of ReParts. Thus, we prioritize the collection of high-priced parts in the disassembling process.

- Commonalities of parts

Unique parts are not compatible with any other type of products. Hence, if the number of unique parts becomes excessive, it will increase the inventory cost. Thus, we prioritize common parts in the disassembling process.

- Part numbers required for production

Some target parts are acquired only from recycling. Therefore, if a company does not acquire the required number of ReParts, production will stop. Thus, we prioritize ReParts, which cannot be substituted with NewParts.

4.2 Design of Decision-Making Policies for Disassembling

By considering the above points, we devise policies for deciding the number of products to be disassembled as follows:

Decision Policy 1: Adjusting to the lowest-yield-rate part

In this policy, the number of products to be disassembled comes from the required number of lowest-yield-rate parts for production. A key characteristic of this policy is that a company can collect all parts for production from recycling but the volume of inventory will increase.

Decision Policy 2: Adjusting to the highest-yield-rate part

In this policy, the number of products to be disassembled comes from the required number of highest-yield-rate parts for production. A company can keep the number of disassembled parts and inventory low, but it cannot collect lower-yield-rate parts only from recycling, which makes the purchasing cost high.

Decision Policy 3: Adjusting for the shortfall of NewParts

In this policy, the number of products to be disassembled comes from the deficit of NewParts. A company acquires a fixed number of NewParts and makes up for the shortfall with ReParts. A characteristic of this policy is that a company can keep the number of disassembled parts lower than that in Decision Policy 1 but the purchasing costs will increase.

We set the upper limit of the fixed number of NewParts at 500 and the lower limit at 100 for simulation considering the capacity of the model company.

Decision Policy 4: Fixing the number of products to be disassembled

In this policy, the number of products to be disassembled is fixed and the company covers the shortfall with NewParts. A key feature of this policy is that a company can limit the excessive inventory of certain parts but the purchasing costs will increase.

We set the upper limit of the fixed number of products to be disassembled at 500 and the lower limit at 100 for simulation considering the capacity of the model company.

Decision Policy 5: Adjusting to the lowest-inventory part

In this policy, the number of products to be disassembled comes from the required number of lowest-inventory parts for production. An important feature of this policy is that a company can collect almost all the parts for production but the inventory will increase, although it will be lower than that in decision policy 1.

We set two cases of lowest-inventory parts in this policy: lowest-yield-rate parts and highest-yield-rate parts.

5 Implementation of Simulation and Analysis of the Results

5.1 Input and Output Data

The input data of the simulation are as follows:

- Company data: disassembling capability, number of workers, and hours of operation in the model company
- Collection and Shipment: actual quantities of collection and shipment of each type of product per day in target company of 454 days
- Parts: commonality, method of acquisition, price, and yield rate
- Initial inventory: the initial inventory of the collected products and parts is 1000 parts.

The output data of the simulation are as follows:

- Operation: unshipped products because of a deficit in parts
- Inventory: the number of collected products before disassembling per day
- Parts: the amount of inventory, purchasing, and scrapping for each part

5.2 Analysis of the Result in Simulation

We analyze the simulation results from the viewpoint of unshipped products, the number of products to be disassembled, product inventory before disassembling, inventory of parts, and purchasing amount by using a radar chart. Policy 3 of disassembling includes the cases in which the fixed number of NewParts of 100–500 changes gradually along with the fixed number in every item. Thus, we consider only the upper limit of 500 and the lower limit of 100 in this analysis. Moreover, policy 4 of disassembling includes the cases in which the fixed number of products to be disassembled of 100–500 does not change; thus, we consider only the upper limit of 500 in this analysis.

Figure 3 indicates the influence of each disassembling policy for the model company. It also shows that the number of products to be disassembled is the largest in policy 1 and the lowest in policy 2, while product inventory is inversely proportional to this number. Then, the purchasing number increases in policies 2 and 3. In policy 2, the number of products to be disassembled comes from the required number of highest-yield-rate parts; hence, the number of lower-yield-rate parts tends to be low. In policy 3, the model company's acquisition of a fixed number of NewParts causes the purchasing number to increase. Lastly, all policies except policy 3 (which has a fixed number of NewParts of 500) can keep the scrapping number lower than the current policy can. In the case of the fixed number of NewParts of 500 in policy 3, the purchasing number exceeds the required number of parts for production; thus, the scrapping number increases.

Next, we illustrate the inventory of parts, purchasing number, and scrapping number in Figures 4 and 5 respectively.

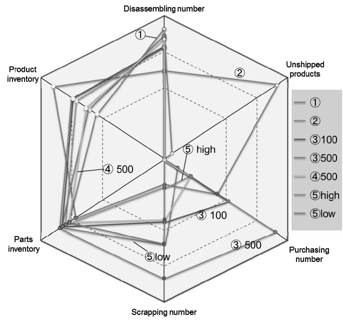

Fig. 3. Influence of disassembling policies

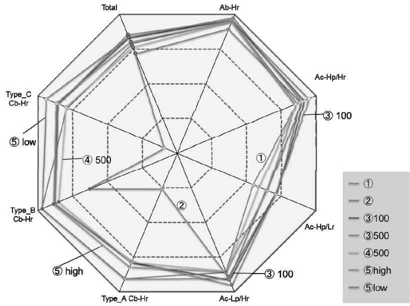

Fig. 4. Parts inventory

1. Changes in the inventory of each part

No major differences in inventory were observed among the policies, except in policy 2, wherein the inventory is kept low but the number of unshipped products becomes high, which we see is the result of inventory shortage. Thus, policy 2 is considered impractical.

In contrast with the current policy (policy 1), policy 4 can keep the inventory low except for Ac-Hp/Lp. The number of products to be disassembled comes from the required number of lowest-yield-rate parts in policy 1; hence, the inventory of Ac-Hp/Lp is less likely to be excessive.

2. Changes in the purchasing number of each part

From Figure 5, we can see that policies 4 and 5 can keep the purchasing number low, while policy 1, in which we decide not to buy NewParts, cannot. In policy 1, 4 and 5, NewParts compensate for the deficit of ReParts; hence, the purchasing number tends to be low. On the other hand, in policies 2 and 3, the purchasing number becomes two or five times that in the other policies and is considered very high.

From the above analyses, we think that policy 4 is the most economical and ecologically sound.

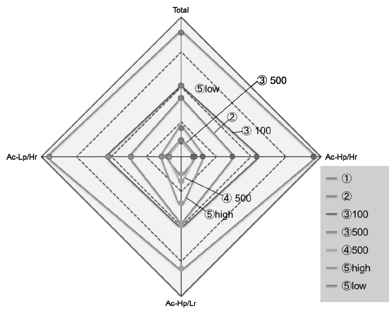

Fig. 5. Purchasing number

6 Conclusion

In this study, we modeled products to simulate the production activities in a recycling company with the help of a computer. Second, we designed and analyzed some decision policies for disassembling used products that avoid excessive inventory and limit the use of new materials. Finally, we devised the most effective policy that decides the number of collected products to be disassembled and offsets the deficit with new parts from the result of simulation.

This study considered only one process in the target company; for future studies, we need to extend the target size to the whole factory and make the production flow efficient using simulation.

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Research on Recognition Algorithm of Track Substructure Defects Based on Vehicle Dynamic Responses

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Abstract. Track stiffness abrupt change caused by track substructure defects can lead to rather large dynamic irregularity when the train goes through it. Thus the dynamic action between wheel and rail is increasing, which will influence the safety and comfort of the train. In this paper, the dynamic responses of vehicle and track are analyzed based on vehicle track coupling model in which two kinds of defects of track substructure are simulated. To reduce the maintenance cost, a recognition algorithm of track substructure defects using vehicle dynamic responses is proposed based on Support Vector Machines. Finally, a case has been studied based on the algorithm proposed in this paper, and the simulation results show that the method is effective to recognize the track substructure defects such as unsupported sleepers, loosened fasteners, and the accuracy of recognition can be reached to 90%.

Keywords: track substructure defects, vehicle track coupling model, vehicle dynamic responses, support vector machine, reduce cost.

1 Introduction

When the defects exist in the track substructure, such as unsupported sleepers, loose fasteners, the track stiffness will vary largely within a short distance which is called track stiffness irregularity and it leads to the increased dynamic action between train and track. The rail vibration is obviously aggravated and the interaction force come a large transition to cause an impulse due to the track substructure defects, which will influence the train safety and ride comfort meanwhile it will intensify track degradation because worse track geometry irregularities will be brought. Hence, it is very important to inspect the track substructure defects in time to ensure the safety operation of train. Now the track defects are often detected visually by maintenance staff or periodically by special inspection vehicle. All these methods are time-consuming and have potential danger if the defects cannot be found in time between the inspection periods. A detection method is proposed in this paper, which the sensors are mounted on the normal trains in service and the vehicle dynamic responses are used to detect the track defects based on the proposed algorithm in this paper.

V. Prabhu, M. Taisch, and D. Kiritsis (Eds.): APMS 2013, Part II, IFIP AICT 415, pp. 525–532, 2013.

In recent years, a few scholars have investigated the vehicle track dynamic responses considering the track stiffness change. Luo etc. [1-2] studied the influence of the track stiffness on the vehicle and rail deformation at high-speed railway bridge transition regions. Sun and Chen etc. [4-5] investigated the distribution rules of the track stiffness at the turnout regions and the reasonable value for the ballastless track. Zhu and Ahmed etc. [6] made a research on the dynamic interaction relationship between wheel and rail under the condition of the unsupported sleepers with vehicle-track spacial model and the gap size influence on the interaction force. Lei [7] studied the influences of four transition patters including abrupt change, step change, linear change and cosine change on the vehicle and track dynamic responses at the speedup railway. The research results show that the cosine change of the track stiffness is the most effective to the train operation safety at the transition regions.

In this paper we are aimed at solving the problem of the track substructure defects recognition based on the vehicle dynamic responses, thus we can mount the accelerators on the in-service vehicle to find the track substructure defects, no need to arrange the special inspection vehicle [8] to run just for the defects recognition which is costly and need a long occupied period. The paper is organized as follows: Section 2 introduces the vehicle-track coupling model proposed by Zhai and Sun, which is used in the Section 3. Section 3 simulated and analyzed the dynamic vehicle and track responses under the condition of track substructure defects based on the model introduced in Section 2. Section 4 proposed a recognition algorithm with vehicle dynamic responses based on Support Vector Machine, in which genetic algorithm and PSO algorithm are separately used to optimize the SVM parameter to get the better recognition results. And a case is studied based on this proposed method, and the results show that the algorithm proposed in this paper is effective to track substructure defects recognition.

2 Vehicle- Track Vertical Coupling Model

Zhai and Sun vehicle – track vertical nonlinear coupling model [9] is adopted in this paper, consisting of vehicle model and track model as shown in Fig. 1. The vehicle is viewed as a multibody system running on the rail at the speed of v, consisted of the car body, the front and rear bogies, the wheelsets. M_c is mass of the car body and J_c is its nod moment of inertia, and M_t is mass of the bogie and J_t is its nod moment of inertia. M_w is mass of each wheelset. K_{pz} is the stiffness coefficient and C_{pz} is the damping coefficient of the primary suspension. K_{sz} is the stiffness coefficient and C_{sz} is damping coefficient of the second suspension system. Track model uses rail-sleeper-ballast-subgrade three layers model. Rail is viewed as an infinite length Euler beam resting on continuous elastic support which is discretized along the longitude. Rail sleeper uses rigid unit and ballast is discretized into block unit.

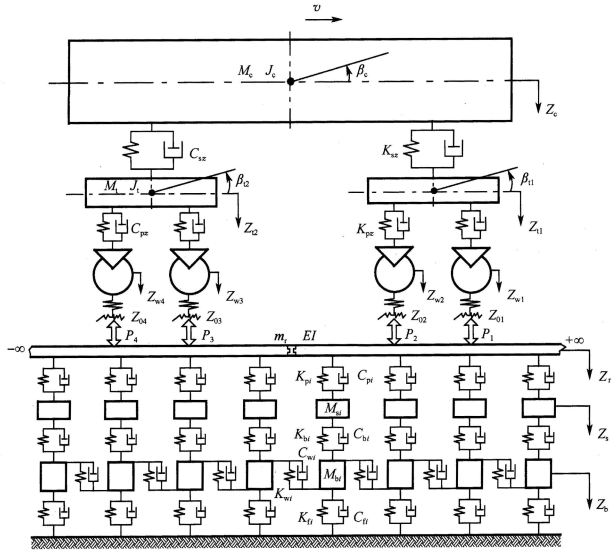


Fig. 1. Vehicle track vertical coupling model

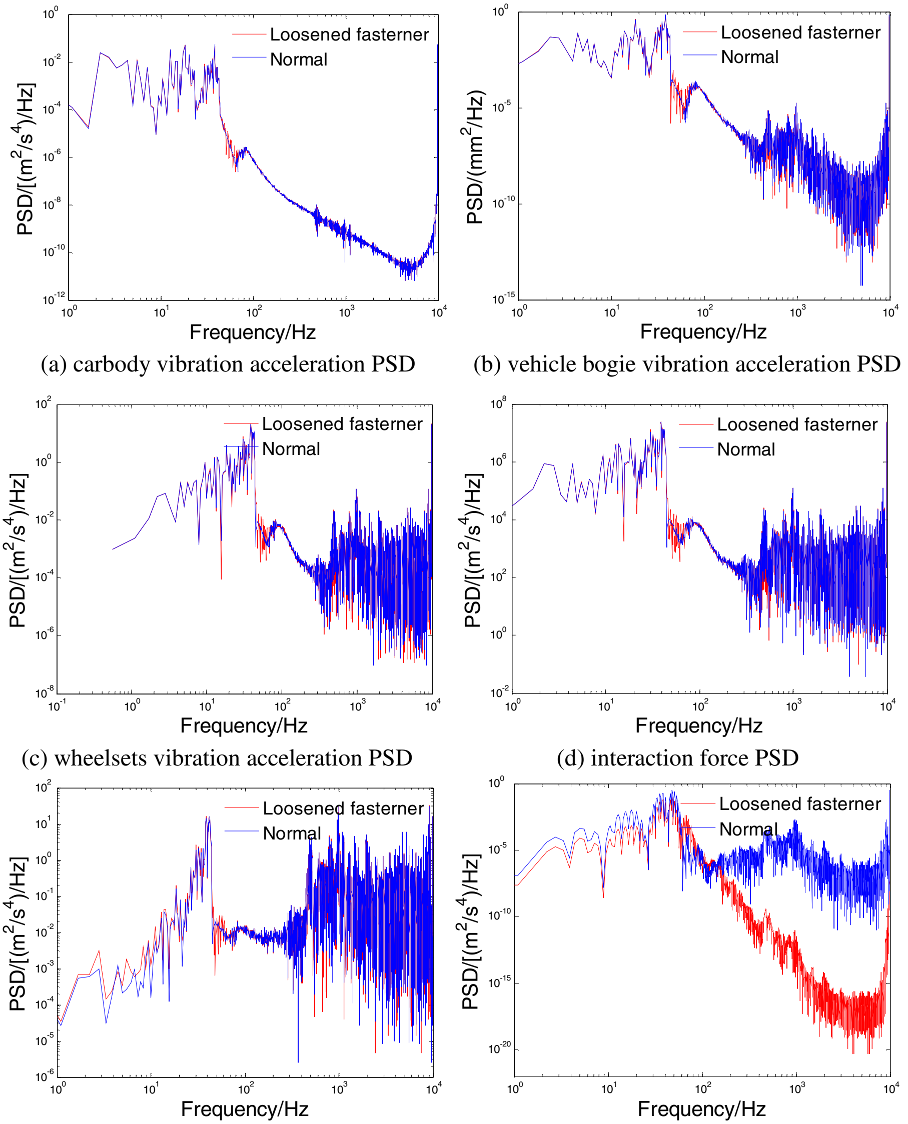
The vertical coupling relationship is realized by vertical wheel and rail contact model, expressed in the equation of vertical interaction force. In this paper Hertz nonlinear elastic contact model is used, which is also the most classic and effective model.

3 Vehicle Track Dynamic Responses under the Condition of the Track Substructure Defects

Generally, the track substructure defects include unsupported sleeper, loosened rail fasteners, loose or hardened ballast. The first two kinds of defects occasionally exist after long-time train operation, which are also mainly discussed in this paper. Here we adopt the different value for the different track layer stiffness and damping to simulate the track substructure defects. For a loosened fastener, we suppose in the Fig. 1 model $K_{pi} = C_{pi} = 0$. For an unsupported sleeper, we suppose in the Fig. 1 model $K_{bi} = C_{bi} = 0$.

3.1 Loosened Fasteners Condition

First we suppose there are 5 loosened fasteners along 100m track, which are No. 40, No.70, No. 110, No. 130 and No. 160 (which is selected randomly), to calculate the vehicle and track dynamic responses under this situation. The other simulation conditions are as following: the train speed is 160km/h, the track condition adopts China speedup line parameter. The calculation software is coded with Matlab, in which the vehicle and track dynamic responses are calculated by numerical integral method. The simulation results is shown in Fig. 2 which is expressed in the frequency domain, and the red curve represents the dynamic responses with the defect of loosened fasteners, the blue one is the normal situation without defects.



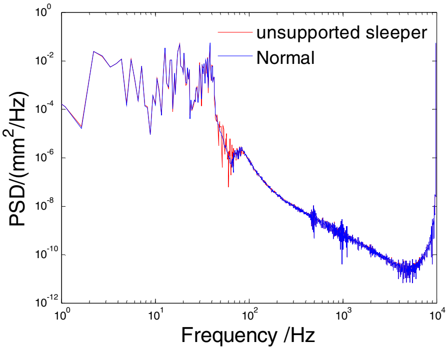
(a) carbody vibration acceleration PSD
(b) vehicle bogie vibration acceleration PSD
(c) wheelsets vibration acceleration PSD
(d) interaction force PSD
(e) rail vibration acceleration PSD
(f) No.70 sleeper vibration acceleration PSD

Fig. 2. Vehicle and track dynamic responses under the condition of loosened fasteners

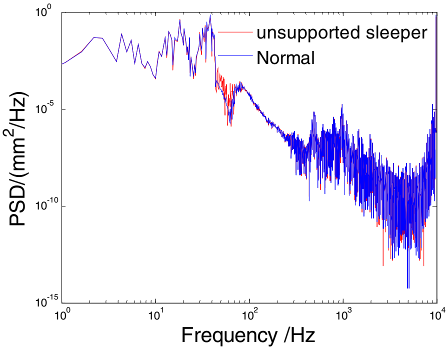
The difference can be seen from Fig.2 between normal situation and defects condition at the 40Hz to 80Hz, but the difference on vehicle dynamic responses is minor while the track is more obvious. The vehicle dynamic responses are at low frequency and track dynamic responses are at higher frequency. At the same time, the vertical displacement of the track components are compared and it is found that rail vertical displacement is increased obviously but those of sleeper and ballast are decreased.

3.2 Unsupported Sleeper Condition

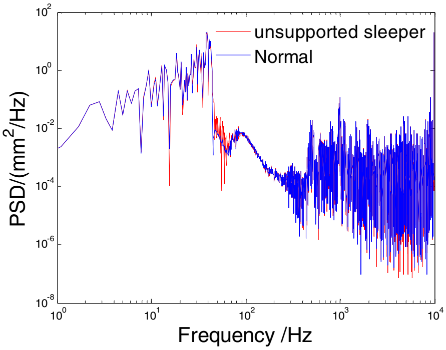
Then we suppose there are 5 unsupported sleepers along 100m track, which are No. 40, No.70, No. 110, No. 130 and No. 160, to calculate the vehicle and track dynamic responses under this situation (in order to compare the different defects influences, we



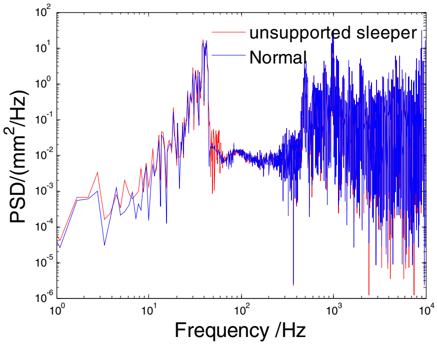
(a) carbody vibration acceleration PSD



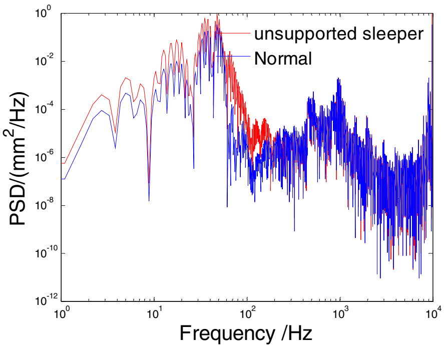
(b) vehicle bogie vibration acceleration PSD



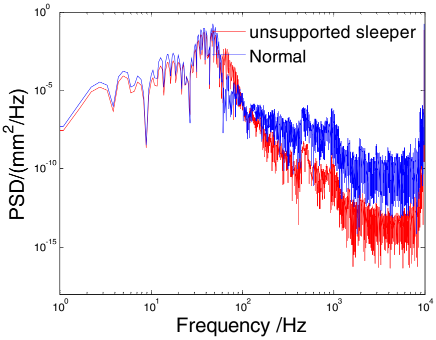
(c) wheelsets vibration acceleration PSD



(d) rail vibration acceleration PSD



(e) No.70 sleeper vibration acceleration PSD



(f) No. 70 ballast piece accelertion PSD

Fig. 3. Vehicle and track dynamic responses under the condition of unsupported sleeper

define the same defect positions) . The other simulation conditions are the same as previous simulation. The simulation results under the condition of unsupported sleepers are shown in Fig. 3 which is also expressed in the frequency domain, and the red curve represents the dynamic responses with the defect of unsupported sleepers, the blue one is the normal situation without defects.

The difference can be seen from Fig.3 between normal situation and defects condition, the same as loosened fastener situation, the difference on vehicle dynamic responses is minor while the track is more obvious. At the same time, the vertical displacement of the track components are also compared and it is found that rail and sleeper vertical displacement are increased obviously but ballast displacement is decreased. It also can be found that vehicle dynamic responses vary unobviously under the different track substructure defects conditions.

4 Recognition Algorithm of Track Substructure Defects Based on Support Vector Machine

Based on the above simulation results, we can easily come to the conclusion that the track dynamic responses are more obvious than the vehicle under the condition of track substructure defects. For example, it can be recognized easily by the rail displacement. So theoretically, we can recognize the defects according to the track dynamic responses with simple algorithm. But there are thousands of miles railway lines in China, it is impossible to mount sensors along all the in-service lines for the cost and maintenance work. Hence, a recognition algorithm is proposed in this paper, which makes use of vehicle dynamic responses and Support Vector Machine (SVM).

The vehicle track coupling model in Section 2 is nonlinear model due to the wheel-rail contact relationship, so it is also impossible to solve the track stiffness parameters by the vehicle dynamic responses. Support Vector Machine is a newly developed pattern recognition method in recent years, which foundation is statistical learning theory and structural risk minimization. SVM uses a nonlinear Kernel function to transform input data to a high-dimensional feature space in which the input data become linearly separated.The training sample vehicle responses data come from the results of Section 3, and there are three kinds of data, one is wheelsets vibration acceleration under the normal condition (i.e., no defects in track substructure), the second is wheelsets vibration acceleration under the condition of loosened fasteners, and the third is wheelsets vibration acceleration under the condition of unsupported fasteners. The total sample data is 123 groups, 90 as training sample and 33 as testing sample. There are 11 normal condition, 11 unsupported sleepers, 11 loosened fasteners in the testing sample data. Each group has 368 data.

The selection of kernel function of SVM is an important step, the popular admissible kernels include Gaussian RBF, polynomial, Sigmoid etc. Gaussian RBF is chosen as kernel function in this paper. There are two learning parameters in constructing SV machines, i.e., the penalty parameter C (that determines the trade-off between the training error and VC dimension of the model), and the shape parameters of the kernel function (variances of a Gaussian kernel). The most common method to choose the parameters is a cross-validation. To improve the SVM classification effective, we also adopt genetic algorithm and PSO algorithm to optimize the C and δ. Table 1 is the comparison results with different parameter selection methods. The SVM classification procedure of track defects is coded with Matlab. The input data of SVM are wheelset acceleration and the output is number 0, 1, 2 which respectively express normal, loosened fastener, and unsupported sleeper.

Table 1. SVM Performance comparison for each parameter selection methods

	Cross-validation	PSO	GA
Classification Accuracy Rate	90.91%	100%	96.97%
Calculation time (s)	331.34	211.72	25.04
Parameter Value	C=1 δ =32768	C=31.1735 δ =420.2098	C=82.2372 δ =68.4522

For the cross-validation method, if we want to get the optimum value, the search range must be large and step must be small, but this will cause a longer calculation time, or the accuracy can't be achieved. PSO algorithm can get a higher accuracy but the calculation time is longer than GA.

Then we use the recognition algorithm to study a supposed case to test the algorithm validity. Suppose that there are six track substructure defects along 100m-long track as follows, No.61, No. 62, No. 63, No. 100 fasteners are loosened, No.130 and No.160 sleepers are unsupported(the samples are also selected randomly to show the adaptability of algorithm). The vehicle axle-box accelerations (wheelset acceleration) are used to identify the track substructure defects. The recognition results are shown in Table 2.

Table 2. Recognition results of track defects

Track status	The true situation	Recognition results
Normal	136 positions	126 positions
Loosened fastener	4(61, 62, 63, 100)	10(60, 61, 62, 63, 64, 65, 100, 103, 127, 130)
Unsupported sleeper	2(130, 160)	6 (97, 99, 131, 132, 160, 161)

The classification accuracy rate is 92.25% calculated from Tab. 2. The wrong recognition positions are all around the true defects, and all the track defects have been recognized, but one position is classified wrongly (No. 130). In fact, this case is a rather worse situation because there are several continuous loosened fasteners which lead to the influence on vehicle dynamic responses at the near defects track position. This situation is not common in the real, and the wrong recognized positions are all around the defects which can be acceptable by maintenance.

5 Conclusion

Track substructure defects are one of the reasons leading to track stiffness irregularity, which is one of the dynamic excitation sources to the vehicle track coupling system,. In this paper a recognition method of track substructure defects is proposed base on vehicle track coupling model and support vector machine. With the SVM advantages, which can realize the linear classification in high-dimension space using kernel function, the track substructure defect recognition and classification has been achieved based on vehicle dynamic responses. This method can provide a new idea for the track condition inspection from the in-service vehicles.

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Critical Analysis of the Management System of Hazardous Solid Waste Generated in the City of Santos in the State of São Paulo

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Abstract. The world is undergoing major transformations with significant social, political and economic changes. Science and technology have evolved much from the twentieth century, and the intensification of industrial activity has its production techniques increasingly sophisticated, multiplying physical territory, what unfortunately had a negative impact on the environment. The objective of this study is to perform a critical analysis of the current Integrated Solid Waste System in the city of Santos in, the Brazilian coast, focusing on hazardous waste, identifying opportunities for improvement. Representative sectors governances were heard through the application of a structured questionnaire based on three pillars: Environmental Education for the population, Communication System and Infrastructure offered by the municipal authority. The results show weakness in the system of management in relation to environmental education and communication system, as well as absence of the main timeline of actions to achieve the proposed results.

Keywords: Hazardous waste, Reverse Logistics, Management System.

1 Introduction

The Industrial Revolution, from about 1850, led to strong growth in world production consumption of goods, with emphasis on efficiency and effectiveness through the concepts advocated by the Classical School: Bureaucracy, Human Relations and Systems Thinking. These business schools saw the natural environment prevailed as a mechanic and deterministic thinking, nature being considered an obstacle to the development of society. Science and technology have evolved much within the twentieth century, and the intensification of industrial activity had its production techniques increasingly sophisticated, multiplying physical territory, which unfortunately had a negative impact on the environment [1]. For decades the process of environmental degradation increased, being believed that the economic growth by itself would provide the best conditions due to society. However, it was observed that uncontrolled economic growth was causing irreparable damage to the ecosystems and that these damages, at medium and long terms, should turn earth uninhabitable to humans [2].

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To study this situation, the United Nations – UN promoted the debate of environmental issues, and designed Prime Minister of Norway, Gro Harlem Brundtland, head of the World Commission on Environment and Development, to study this theme. As result of this labor, it was presented a report entitled "Our Common Future", which established the concept of Sustainable Development, based on three pillars: economic growth, social equity and environmental balance [3]. This report was the basis for discussions of the United Nations Conference on Environment and Development, known as RIO-92 or ECO-92, thus allowing the creation of Agenda 21: Global Sustainable Development [1].

The evolution of environmental issues brought to discusson a new variable: sustainability. This requires a strong reflection in trying to understand the new reality, providing a paradigm shift. Since then, it was tried to integrate socially responsible practices, environmentally sound, traditional techniques associated with the production and management of the industrial sector, given the aim of society to consume products free from wastes and harmful effects to the environment. According to the United Nations, which used demographic estimates, the world population reached the milestone of 7 billion people in 2012. This means, among other necessary steps, that, for humans live harmoniously, it is imperative to establish public policies for solid waste management and deployment of an effective management system.

2 Objective

The objective of this study is to perform a critical analysis of the current Integrated Solid Waste System in the city of Santos presented by the municipal authority in 2011, focusing on hazardous waste, identifying opportunities for improvement.

3 Contextualization and Methodology

The city of Santos, founded in January, 26, 1546, has written in its flag “*Patriam Charitatem et Libertatem Docvi*”. It is a port city, head of the Santos Metropolitan Region, located on the coast of São Paulo state, Brazil. It houses the largest port in Latin America, which is primarily responsible for the economic dynamics of the city, together with tourism, fisheries and trade. In 2010, the Santos municipality had 419,757 inhabitants, according to the census conducted in the country. The United Nations Program for Development of 2000 placed the city of Santos in sixth place in the list of municipalities by the human development index, and it is currently the 17th richest city in the country. With the discovery and explotation of pre-salt project (oil laying very deep under sea devel) by Petrobras (the chief Brazilian oil enterprise), the city of Santos will house the headquarters of the Business Unit Gas Exploration and Production of Oil in Santos Basin.This certainly implies strong growth in business and commercial activities in the city, with its repercussions on the sustainability problem.

A case study conducted by the authors to evaluate the Integrated Management System of Solid Waste in the city of Santos approved in 2011, proposed by the Department of the Environment, on the subject of waste management hazards, especially fluorescent lamps, batteries, junk and X-ray slides, presents a systemic approach to evaluate the ability to manage the entire process as a system, identifying and understanding the network of processes and their interactions. Hazardous wastes have characteristics of flammability, corrosivity, reactivity, toxicity, pathogenicity, carcinogenicity, mutagenicity and teratogenicity, presenting a significant risk to public health [4]. The aim of the project is to classify the responsibilities for achieving results, reducing barriers to better integration between the interested actors, in accordance with the principles of Quality Management.Therefore, in the case study, were heard governances representing the sectors of the residential and commercial buildings, and retail trade in Santos, represented by the presidents of its representative entities, by applying a structured questionnaire based on three pillars: environmental Education for the population, Infrastructure and Communication System offered by the municipal authority.

4 Theoretical Background

This study is based on developing a critical analysis of the Plan of Integrated Solid Waste Management in the Municipality of Santos in 2012, aiming to get compliance with the National Policy on Solid Waste Plan of 2010 and the Basic Guidelines of Sanitation of 2007 [5]. Solid waste or garbage are the remains of human activity, considered by generators as useless. This waste is classified into three categories: hazardous, non-inert and inert [6].

The integrated management of municipal waste is a coordinated set of regulatory actions, operational and financial planning, based on environmental and economic health criteria, to collect, segregate, treat and dispose the garbage in the city. Moreover, the municipal authorities are key pieces in the integrated management of municipal waste. They not only have the responsibility for implementing actions that aim to mitigate their effects, but also that of educating citizens, technicians and planners for this urgent need [4].

It is estimated that the world population produces around 40 million tons of waste per year. Society requires the transformation of natural resources into products to benefit their needs in general. These products, when they reach the purposes for which they were created, ie, the end of its useful life, are discarded. This whole process eventually leads to the deterioration of the natural environment, because the amount of solid waste produced by society is unquestionably one of the sources of environmental degradation [7]. To address this situation, from the 1980s the theme "reverse logistics" was explored with greater intensity at the academic, public and corporate levels, aligned with the philosophy advocated by the planet's sustainable development presented by the World Commission on Environment and Development. In the 1990s, some world-renowned authors conceptualized reverse logistics as a "new area of business logistics, concerned to consider the multitude of logistical aspects of the return to the productive cycle of the different types of industrial goods made of these materials and waste industrial controlled by reuse of the well and its components or recycling of the constituent materials, giving rise to secondary raw materials which reintegrate the production process” [8].

The world changes at every moment. New products are launched in the market to meet the needs of people. This requires advanced technology and the use of natural resources. Consequently, the mindset of the consumer also changes in this process, because it requires changes in production processes and a new stance on ethics and social responsibility. Having a properly socially responsible business is a requirement of the current market. To be effective, this vision must be structured in the long term, ensuring benefits for future generations. In 1987, John Elkington proposed a management model known as "Triple Bottom Line", by which, the entire business management should be based on economic, social and environmental issues [7]. For these actions to be effective, it is imperative to have a change in the mindset of people and, therefore, of the population. For this, two actions are essential: Education and Communication. Corroborating this idea, the authors refer to the 13^{th} Deming point "Institute a strong program of education and self-improvement." According to this outstanding master on quality, training and self-development are important means for continuous improvement of people, both from the professional and personal standpoint [9]. Translating this point to a system for environmental management, environmental education is a very complex issue because, when dealing with a population, there is a great diversity in the level of knowledge and discernment in matters relating to the environment [10].

On the other hand, a communication strategy is an essential part in the analysis of the life cycle of a product, based on the inventory of generates waste, since it directs to population the communication efforts related to the categories of impact and its main social and ambiental effects.

5 Method of Control

For this study, the PDCA cycle was customised fot better evaluate the Integrated Solid Waste System in the city of Santos, as shown in Figure 1 prepared by the authors.

The success of any management plan lies in the managers’ ability of how to identify and solve problems. World Class Organizations have expertise in knowing how to apply the PDCA (Plan – Do – Check – Act) cycle throughout the organization. The PDCA cycle seems simple at first glance, and, in fact, is simple. However, those who use this method intensively over the years realize that, the more it is used throughout the organization, the more it is seen its complexity. This method allows: greater involvement of people, commonality of language and communication, understanding of each responsibility for the success of the system, continuous learning, use of several areas of science and uptake of best practices [11]. Moreover, a communication strategy is a key part of the analysis of the life cycle of a product, based on the inventory of waste generated, for directing the communications efforts

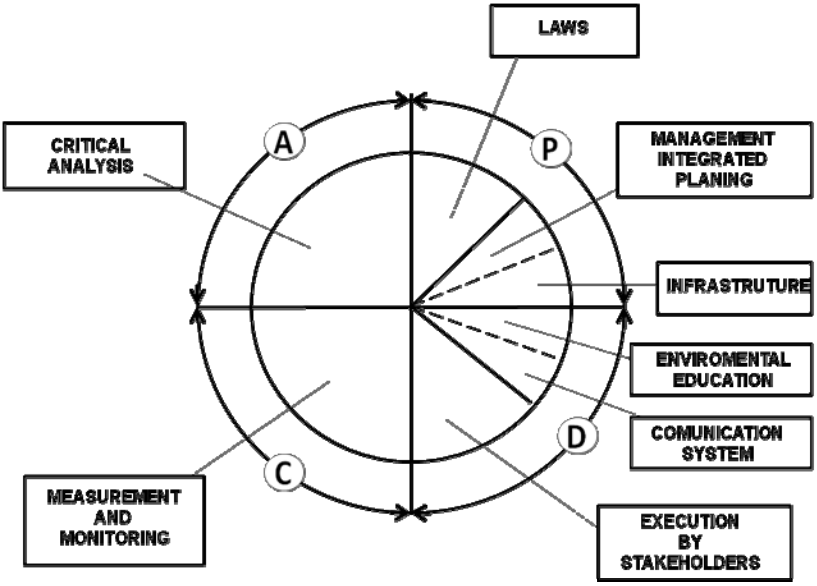

Fig. 1. PDCA cycle adapted to the Integrated Solid Waste System

throughout the organization, the more it is seen its complexity. This method allows: greater involvement of people, commonality of language and communication, understanding of each responsibility for the success of the system, continuous learning, use of several areas of science and uptake of best practices [11]. Moreover, a communication strategy is a key part of the analysis of the life cycle of a product, based on the inventory of waste generated, for directing the communications efforts for the population towards to the selection of impact categories and its main social and environmental impacts.

6 Discussion and Results

To comply with the National Policy on Solid Waste, 2010, the Department of Environment has developed the Integrated Management Plan based on the environmental management system established by ISO 14001:2004, with the control method of PDCA. Four grate goals were established in order to develop the integrated management: promoting the feasibility of reverse logistics flows to the waste generated in the municipality, expansion of discussion within the **Metropolitan** Agency in relation to waste management, development of contingency and emergency plans, and specific amplification of selective waste, deployed for each type.

The document is structured with an introduction by addressing the physical, economic and social aspects, a diagnosis contemplating an inventory of each type of waste and oversight responsibilities, goals for the integrated management, alternative use of reverse logistics for reuse or purification on of waste, investment proposals, operational environmental performance indicators, corrective and preventive actions to be practiced, contingency actions, environmental education programs and technical training, social communication and periodicity of quadrennial review.

The diagnosis for hazardous waste from the health sector is quite detailed, but for the waste under study is very superficial. The author have observed the absence of a guiding schedule of actions, thus existing the risk of becoming a "letter of intention".

In order to straiten the critical analysis, there ware elaborated three questions and applied to the society representatives mentioned in contextualization and methodology:

1. How fo you evaluate the present Environment Education Program offered by the municipal authority to the population?
2. The communication system used by the municipal authority to inform population about the correct storage and disposal of dangerous waste is clear and objective?
3. The present infrastructure of reception and destination of dangerous waste in the city of Santos is adequate from the viewpoint of the reduction of Effects to environment?

The participants agreed in affirming that the topics referred to the issues Ambiental Education to the population, Communication System and Infrastructure offered by the municipal authority are rather week and discorected from society, what is worrying and must be improved.

It is not clear the system to collect hazardous waste among the population under study. However there are several companies with their efforts to capture and destination waste within their social responsibility programs.

Nevertheless, the structure proposed by the municipal authority was considered potentiality good and, if put in action as planned, have a nice probability of success to protect environment. However, the analysis of the indicators proposed in the plan shows lacks, what may make impossible the renement of the waste inventory for adequate mitigation.

The Integrated Solid Waste in the city of Santos, novelty implemented by the municipality, contributes to improve the quality of life of the population. The system is classified as level 2 *(limited information or little understanding of the objectives of the improvements required, some good results available*), according to the description of maturity levels established by ISO 10014:2006 - Quality management -Guidelines for realizing financial and economic benefits, focusing on the Principle of Quality "System approach to management"[12].

7 Conclusions

Public sector has a peculiar quality management focused on the establishment of laws, ordinances and inspections. However, this is not enough from the perspective of modern management in the XXI century. The examined plan is not conclusive for the correct identification of the problems, which shell inevitably contribute to the low productivity of the system.

Therefore, the authors propose to strengthen the systems approach to management, the adoption of the Theory of Constraints by Eliyahu M. Goldratt, which is a systemic management philosophy, based on the application of principles and methods of human organizations to Exact Sciences[13].

It is fundamental the development efforts for an effective management practice through the PDCA model considering the opportunities of improvement identified by the society representative governance. PDCA cycle has become a universal management concept, a true legacy, a tool whose owner is humanity in the service of identifying and solving problems that are present in the globalized society.

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Relevance of Kotter's Model for Change in Successfully Implementing Lean

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Abstract. Though lean consists of numerous tools and techniques that are applicable to entire value stream, there are not many guidelines on how to implement lean from the managerial perspective. Lean implementation has succeeded and failed in many different organizations. This paper attempts to map success factors of lean implementation as suggested by some studies with Kotter's eight steps model for change.

Keywords: Lean, managing change, lean implementation.

1 Introduction

Lean is the production philosophy which focuses on the elimination of waste (Muda) through continuous improvements of producing the product with no defects[1, 2]. The concept of Muda originated in Japan and the philosophy was introduced by Taiichi Ohno from Toyota in early 1950s [3]. This concept was widely accepted later as Toyota Production System [1, 4] and was named as Lean by Womack et. al. [1]. From the operational perspective, lean involves implementation of all the tools and techniques at the shop floor which eliminates waste not only within the manufacturing plant but also in the entire supply chain [5-10]. Kaizen, setup time reduction, 5S, Kanban, JIT, cellular manufacturing, single piece flow, Single Minute Exchange of Dies (SMED), Supplier base reduction, Total Preventative Maintenance (TPM), are some of the examples of the tools and techniques used at the shop floor [9,11].

For an organization to be lean, it not only requires mastering the lean tools and techniques but it also requires a way of thinking that would focus on value adding processes, producing only the quantity demanded by the customers and establishing a culture to improve [7]. Shah and Ward define lean as ''an integrated socio – technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability''[10].

There are no standard guidelines to each and every step of lean implementation [12- 14]. But for an organization to successfully implement lean from either mass production, job shop or any production system, it requires an expertise in change management in addition to the tools and techniques of Lean Manufacturing. Several researchers have emphasized that successful implementation of quality improvements

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requires wide-ranging change management programs that addresses both organizational and technological aspects of quality improvements [15 – 18]. Hence there is a rationale to explore the connection between lean manufacturing technique and change management principles. By nature, people want to stay in their comfort zones and they are resistant to change. Mismanaged change may result in higher cost, delay or even complete failure, while properly managed change can turn resistance into the source of innovation [19].

Change while implementing lean, may be arising from one or more of 1) differences in tools and techniques from Job Shop or Mass Production, 2) differences in Organizational Culture and 3) differences in National/ geographic culture. In spite of these differences and challenges in implementing change, there are numerous examples of successes and failures of lean implementation across cultures and nations. In this paper an attempt has been made to map the reasons for successes and failures of lean implementation as suggested in published journals with Kotter's 8 steps of Managing change [20, 21] and it is suggested that change management techniques are vital in successful implementation of lean. Though there are numerous change management techniques /models available, this study is limited to Kotter's model. A more extensive future study which takes into account of the reasons why lean implementation has succeeded or failed in a larger number of organizations and uses it to develop a customized change model for lean is suggested. This may help reduce the chances of lean implementation failure in the future.

2 Methodology

Chen and Meng, 2010 have extensively discussed why Chinese enterprises fail in deploying Lean [22] and Scherrer-Rathje et. al have discussed why lean implementation failed in the first attempt at Machine Inc and was successful in the second attempt at the same organization [23]. Major reasons discussed in both of these papers will be used to map with Kotter's Model for change [20, 21] and factors for success, of both, will be explained in terms of these models.

3 Reasons for Lean Implementation Success and Failure

3.1 Reasons for Lean Implementation Success and Failure from Chen and Meng (2010)

Chen and Meng studied more than 20 enterprises which implemented Lean Production for two years and were not successful. Their study revealed several reasons for failure and they also suggested how lean implementation could succeed in China (See Table 1).

Table 1. Reasons for success and failure of lean as suggested by Chen and Meng, 2010

Reasons for Failure	Reasons for Success
• Paid attention only to the tools • Expect very quick results • Changing one tool while neglecting others	• Get support from leaders and involve management at different levels • Involve employees and help change work habits • Emphasize standard work • Long term commitment • Establish HR system that supports lean philosophy • Deploy Lean Systematically and gradually

3.2 Reasons for Lean Implementation Success and Failure from (Scherrer-Rathje, Boyle, & Defrorin, 2009)

Scherrer-Rathje et. al studied two lean implementation efforts within the same large, global company, Machine Inc. Lean implementation in Machine Inc. in 1997 was a failure while its implementation in 2006 was a success. Their study was based on 20 interviews that they conducted with managers and employees of Machine Inc which had experience/involvement in lean implementation in 2006 and/or 1997. See table 2 for reasons for successes and failures as indicated in their study.

Table 2. Reasons for success and failure of lean as suggested by Scherrer-Rathje et. al, 2009

Reasons for Failure	**Reasons for Success**
• No commitment from Senior Management • No autonomy • No Organizational Communication	• Visible Management Commitment • Formal mechanism for autonomy • Formal communication and open discussion of short term and long term goals • Formal mechanism for long term sustainability • Communication of wins • Evaluation of Efforts

4 Kotter's Eight Steps Model for Change

Kotter's eight step model for change [21] comes from the eight common errors that managers make when they need to implement change [20]. These 8 steps are listed and briefly described in table 3.

Table 3. Kotter's Eight Step Model for Change by Kotter, 1995

''**Step 1: Establishing a sense of urgency**''

- Top management support change when they understand why
- They are more likely to be involved and committed when there is urgency

''**Step 2: Forming a Powerful Guiding Coalition**''

- Group acting as a team is more likely to bring about change than a single person
- They facilitate better communication, knowledge sharing, stronger support and decision making

''**Step 3: Creating a Vision**''

- Creating a common vision helps channelize the change efforts
- A common strategy has to be developed on how to achieve the vision

''**Step 4: Communicating the vision**''

- This will help gain the necessary resources and also commitment from the work-force. It also helps to create the motivation and assistance to the members

''**Step 5: Empowering Others to act on the Vision**''

- Empowering employees to act on the vision will help maintain the credibility of change

''**Step 6: Planning for and Creating Short-Term wins**''

- This will help boost motivation, morale and commitment of people at all levels
- This will also prevent people giving up when they are close to the achievement

''**Step 7: Consolidating Improvements and Producing Still More Change**''

- Further improvements will be created by short term wins

''**Step 8: Institutionalizing New Approaches**''

- The change that has already been brought should be practiced and enforced everyday

5 Mapping Chen and Meng, 2010's Reasons for Success with Kotter's Eight Step Model for Change

According to Chen and Meng, it is very important for an organization to get support from leaders and involve management at different levels which corresponds with Kotter's step that says sense of urgency has to be established and there has to be guiding coalition. It is the sense of urgency that makes top management serious about the necessity of change, and make them committed to bring about this change. It may be in terms of providing resources, forming a team or prioritizing it in all of the communications.

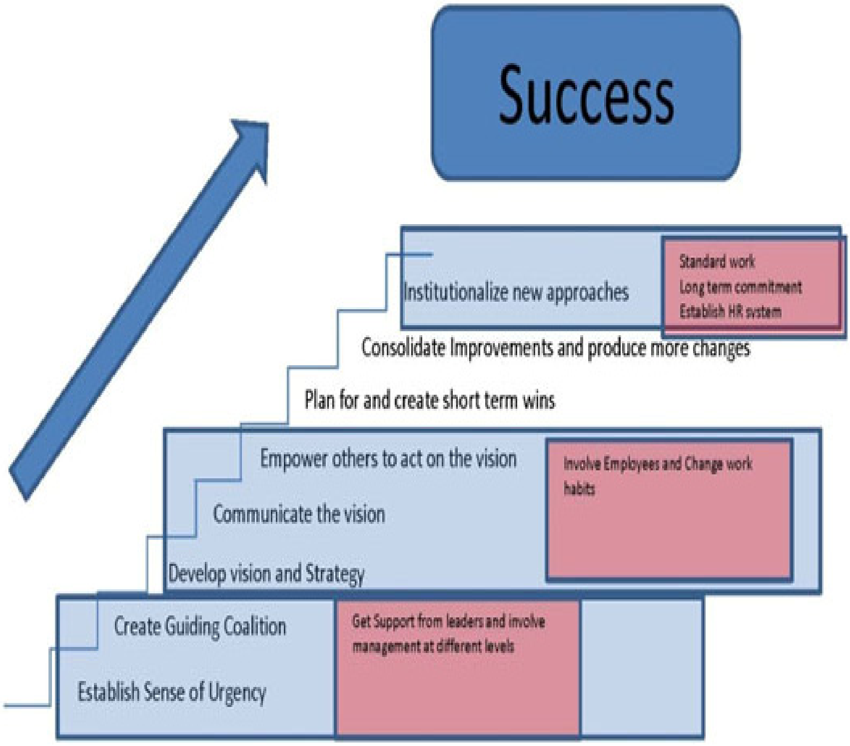

Fig. 1. Chen and Meng's reason for Success(in red) mapped with Kotter's model for change

Chen and Meng's saying that employment involvement and changing work habits could be matched with Kotter's 3rd, 4th and 5th steps.

Chen and Meng in their work also emphasized the need for standard work, long term commitments and establishing HR system which is actually 8th step of Kotter's Model. According to Kotter, change would never sustain and last till the change becomes the way of life. The right HR practices that motivate an employee who follow the standard work and penalize or take corrective action with those who do not will help institutionalize the change. And in the long run, the change may sustain.

6 Mapping Scherrer-Rathje et. al. (2009)'s Reasons for Success with Kotter's Eight Step Model for Change

According to Scherrer-Rathje et. al for lean to be implemented successfully, there has to be visible management support. Kotter's model says management commitment becomes visible when the sense of urgency is established and there is a critical mass of people who strongly believes in the necessity to bring about this change. They form a guiding coalition to work as a team and support every way possible to make it happen. Scherrer-Rathje emphasizes the need for open discussion of short term and long term goals which can be matched with Kotter's 3rd step. A vision and clear strategy help communicate the desired picture and also the ways to achieve it. Similarly Scherrer-Rathje et. al's formal Communication, formal mechanism for autonomy, communicate wins, evaluate changes and long term sustainability could be mapped with Kotter's Step 4, step 5, Step 6, Step 7 and Step 8.

Fig. 2. Scherrer-Rathje et. al's reasons for success(in red) mapped with Kotter's Eight Steps Model

7 Need to Modify Kotter's Eight Steps Model for Change to Implement and Sustain Lean

Changing from any production system to Toyota Production System could be one big change which would affect entire value stream and everyone working in an organization. Following Kotter's eight steps for change could help successful implementation of lean. But as lean involves continuous improvement, it is expected for an organization to have to deal with changes continuously. So it is more important for lean organization to be change ready and have an established culture to change.

The need for change in any lean organization may come from customer (internal or external), competitive position, potential gain or loss, threats or potential threats or technological changes. Hence there has to be continuous evaluation of the organization, departments, and business units. Creating urgency all the time in order to reduce waste and improve continuously may be challenging, but this could be driven by continuous evaluation and need assessment based on organizational performance with respect to the global competition. Hence incorporation of continuous evaluation of performance, continuous improvement, and need assessment is recommended.

8 Conclusion

Based on the factors for successful lean implementation and comparing it with Kotter's model for change; following eight steps model to implement lean could help successful implementation. Implementing lean based on the sole focus on lean tools could be very challenging. Several studies in the past have shown that lean can fail even with the sufficient knowledge about lean tools [22, 23]. In addition to the tools, successful lean implementation requires change management tools and techniques. It might be more practical for lean engineers to be trained in managing change. This study uses only one change management model and two cases of lean implementation successes or failures among many that have been published. More extensive study, which would include larger number of cases of lean implementation experience and also larger number of applicable change management models, is suggested. The study then could further be used to develop lean implementation model and guidelines to prevent failures of lean implementation.

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Determinants of Smart Energy Demand Management: An Exploratory Analysis

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Abstract. The unprecedented rise of population with increasing energy consumption has necessitated the stabilization of dwindling energy resources to secure the provision of energy. Electricity production and distribution through smart grids is a key component in delivering reliable, efficient, and low-carbon energy for a sustainable development of the society, and to meet the growing demands of electricity. Smart electricity grid is a complex system of systems that requires sophisticated collaboration tools and intelligent techniques with active participation from all its connected users. A dynamic role and a pro-active participation of consumers and societies with the integration of distributed energy resources are highly anticipated for the long-term sustenance of these grids. This paper discusses and identifies key determinants of the demand side sustainable collaboration in a smart way (resulting as what we address as smart energy demand) through the involvement of pro-active consumers.

Keywords: Smart demand, collaboration, sustainability, intelligent systems, sustainable consumption patterns, energy demand management.

1 Introduction

Cultural, social, and economic factors are increasingly modifying the consumption patterns, shifting the consumers' behaviors from a mere individual attitude to satisfy personal needs to a more collaborative process, resulting in a sustainable value creation. Thanks to a growing impetus in promoting sustainable consumption patterns, individuals are more conscious of their role in their communities, and are aware that their direct and collective participation can affect the current and future life of their society. Conversely, many sustainability strategies and corporate social responsibility (CSR) practices mainly address environmental aspects [1], neglecting the impact of global over-consumption [2], and overlooking the role of the consumer and the societal involvement.

In our understanding, a holistic approach is required to effectively deal with the current challenges posed by the sustainable development principles: consumers (and

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their communities at large) should be explicitly encouraged to be directly engaged through a more participative and collaborative behavior, factually realizing a collaborative consumption strategy, that is a technology-enabled sharing of goods and services between consumers that requires enhanced forms of collaborations [2–4].

Dealing with sustainability challenges finds its roots in a shift of mindset towards the achievement of more efficient consumption patterns. The support provided by properly designed collaboration platforms would increase the possibilities for producers and consumers to establish a mutual collaboration, seeking an equilibrium between supply and demand both in time (e.g. finding a customer when products are available, finding suppliers when demand upsurges) and space (e.g. finding a supplier close to a customer, or vice versa). Moreover, these common platforms can support pro-active consumers in acting interchangeably as users or providers of goods or services in their relation with other consumers according to the specific contexts and needs (i.e. privates that sells extra energy produced via photovoltaic panels installed on the house's roof).

As a result, changing the consumption patterns, moving towards a collaborative and sustainable process involving different participants, with distinct requirements and interests, requires a completely new approach to demand management. Under this premise, the nature itself of the demand changes, requiring a different connotation. Therefore, we refer to such a demand with the term *Smart Demand*, that is a demand signal coming from a collaborative process (see Section 2 for a detailed description).

The purpose of this paper is to provide a ground definition of smart demand, illustrating its main components. Along this, it analyzes the importance of active demand side participation in the case of energy demand management as result of the uprising role of smart electricity grid systems. Further, the paper highlights the key challenges under different dimensions. Attaining the benefits of smart grid technologies requires increased collaborative efforts between utilities and its connected customers. The smart grid concept supports the functioning of such energy systems with the integration of proactive consumers that contribute to the energy generation through their own systems, and share the excess with other consumers and utility grids.

The paper is structured as follows. Section 2 discusses the Smart Demand concept and the main components. Section 3 illustrates the smart demand applied in the energy sector, under the smart grids concept. Finally, Section 4 reports the conclusions, emphasizing some key challenges to be addressed by leveraging the smart demand concept.

2 Defining Smart Demand

The demand resulting from a collaborative consumption process differs substantially from the traditional forms of demand as usually conceived. For our purpose, we deem the term *Smart Demand* as a simple yet comprehensive term expressing the main characteristics of the demand signal expressed in a collaboration environment. In this environment, the individual demand can be shifted in time and/or compensated through other participatory efforts of the community. The "smartness" of the demand depends upon the smartness of the actions undertaken to reduce/shift/redistribute its profile under the collaborative systems by considering the mutual gains. We envision three main dimensions along which we characterize a smart demand:

Sustainability: Traditionally, much of the attention has been given to promote the sustainability design for production related impacts. Extensive efforts are also being made towards promoting those technologies and designs that can play an important role for moderating the overall consumption level and its related impacts [5]. However, a systematic and holistic approach to address a social nature of consumption (such as promoting collaborative consumption) is still lacking in the user-centered and behavioral related design efforts. In view of this, there is a growing interest in accommodating the social-technical dimension towards consumption by applying social practices in the technical-design process [6]. To get the detailed insights, about users and their behaviors under user-centered approaches, different research methods and the ways of approaching users are being adopted from multi-disciplinary fields. With the efforts, based on cognitive and environmental psychology, behavior-based approaches include applying the persuasive designs, intelligent technologies, and design scripts [6].

Collaboration: Collaborative consumption is not limited to the communal use of products and services, but the primary objective is to promote and encourage active role of consumers towards sustainable communities. These communities collaborate to foster a sustainable development in different sectors such as infrastructure, mobility, energy, waste and food [7]. By adopting such consumption patterns, people get the ownership benefits with less personal burden, cost savings, and lower impact on environment, hence showing more captivating alternative to standard and traditional buying and ownership styles. Consumers, as well as their communities, need to be empowered with adequate collaborative platforms to play their dynamic role for such transformation. For such platforms, three primary systems are created that are redistribution markets, collaborative lifestyles, and product service systems [4]. To achieve vast cultural and commercial implications, a trust and user experience plays a vital part in the platform of collaborative consumption [3]. This participation yields benefits not only related to the environment; it also generates social (improved quality standards, improved health conditions, employment generation) and economic benefits (such as new products/service innovations, more choices to customers and financial incentives).

Intelligence: The literature proposes different terms regarding intelligent products that are often associated with the smart products, smart objects and can be used interchangeably [8]. Further, concept realization of smart products also varies according to the number of terms used to describe or relate to them [9]. Accordingly, in this paper, smart products and intelligent products are used as interchangeable. McFarlane et al. [10] defined intelligent products as the products that are able to represent their physical (locations) along information based (conditions) characteristics. Smart products can be defined as the products having the following characteristics [8-10]: (i) have its distinctive identity; (ii) sensing and storage ability towards measurement of systems; (iii) ability to identify and sense other relevant attributes of external entities; (iv) can have an interconnection and communication power with other smart objects; (v) have decision power (i.e. make the decisions about themselves and external objects). Smart and intelligent products play a central role towards enabling a platform for system integration through a collaborative sustainable process. Smart products and services can assist consumers in using the collaborative platforms and can help them to analyze their consumption and demand patterns [11].

By this vision, Smart Demand is a sustainable collaborative demand sensed through embedded product/system intelligence, under the network of information and communication technology. Such a demand, with the help of information technology network and smart/intelligent objects, provides the sensing ability to observe the collaborative demand shifts/variations.

By highlighting the importance of consumers, and their pro-active participation in a community, we emphasize the fact that individuals' demand are smartly connected (through intelligent products and systems) towards a collaborative demand which may provide substantial benefits for a sustainable development.

3 Smart Demand for Energy Demand Management

Electricity production through *Smart Grids* is a key component in delivering an efficient and low-carbon energy for the sustainable economic infrastructure [12-13]. Smart Grids can be defined as a cost effective electricity delivery infrastructure, enhanced with information and communication facilities (including technologies that facilitate the efficient integration of renewable energy sources) to enable more efficient, reliable and secured grid operations with an improved customer service and a cleaner environment [12,14-15].

Energy sustainability has a key influence in the domain of sustainable developments. It requires a shift from traditional energy sources towards renewable energy ones. A smart grid vision facilitates the development of sophisticated collaboration tools and intelligent techniques for increased member participations and for incorporating the decentralized and fluctuating energy sources. It can assist in reducing the excessive burden on the grid by creating a balance between supply and demand [15]. This balance can be established through an effective demand side management (DSM) and proactive participants' efforts. DSM, an essential part of smart grids, is a cost effective tariff program for managing the electricity load that generates benefits both for utilities and consumers. Normally, under these programs consumers play a passive role because most decisions and actions are taken by utilities whilst consumers have little or no control. In addition, utility grids support the functioning of such energy systems with the integration of proactive consumers (also termed as *prosumers*) that contribute to the energy generation through their own systems, and share the excess with other consumers and utility grids. The proactive energy participants transform their passive role into the active role in the electricity generation and share the responsibility of reducing and optimizing the energy consumptions.

To achieve the true capability of a bidirectional flow of energy and information between utility grids and users, consumers along with their communities need to be encouraged for their involvement. It is estimated that their contribution (through demand response and renewable sources) will constitute from one-third to one-half of total smart grids benefits for sustainable energy [16].

Efficiency in energy sustainability refers to a curtailment in energy consumption without following the reduction in energy supply [17]. As referred above, adopting the social nature of consumption that is from a product-based approach to a practice-oriented approach (for collaborative systems) can also considerably strengthen this energy consumption.

Seeking energy sustainability in a broader societal perspective with the support of proactive consumers requires consumption modification along socially connected efforts. These community efforts enforce sustainable practices leading to sustainable behaviors. Consumers should actively participate to achieve the sustainability targets (with mutual gains consisting of economic, social and environmental benefits) through collaboration (creating the demand flexibility) with the help of intelligence (as intelligent products and systems).

Smart demand for energy demand management is envisioned as based on a tripod of sustainability, collaboration and intelligence (as shown in Fig. 1). An increased level of collaboration through highly intelligent tools and techniques reflects improved efforts toward a sustainable development. A prosumer-to-prosumer collaboration through collective decision-making (against divergent interests and perspectives) may seek energy autonomy / self-sufficiency in sustainable energy communities [7].

The more consumers enter into the dynamic prosumers' domain, the more significant impact they can have on the smart grid infrastructure. In views of Vogt et al. [18] a grid becomes smart when all endpoints contribute to its operations. Where endpoints should not be restricted only to generators but must also include power users (consumers along prosumers). A smart demand can ensure that the amount of energy generated is equal to the amount of energy demanded.

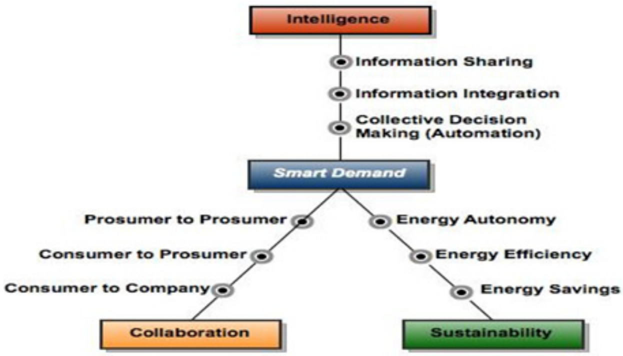

Fig. 1. Smart demand for energy demand management (Source: Authors)

Along with the tripod vision, collaborative arrangements in the energy context are strongly intertwined with the expected level of sustainability and the form of intelligence required. Such integrated consideration is highlighted in Table 1.

However, thorough implementation of smart demand management into a specific system model requires its comprehensive analysis in terms of tangible and intangible determinants (such as behavioral, motivational and cognitive aspects in consumer collaboration towards energy sharing). Such contextual determinants can generate mutual gains in the societal coordinative efforts towards achieving the sustainability.

Whereas most work related in this perspective overlooks the comprehensive analysis and hence partially comments these dimensions in collective way as a peak load saving strategies. Such as [19–20] focus only on the collaboration as a collective energy purchasing by overlooking the consumers proactive participation and other determinants such as behavioral factors in creating the demand flexibility under energy sharing perspective.

Table 1. Energy demand management through smart demand

Collaborative arrangements	Integrated considerations
Consumer to company	Consumers collaborate through their energy demand information sharing with the utilities to avoid consumption during peak hours, being beneficial for customer (as savings) and for utility (as low production costs). Both foster the sustainability as energy savings / conservations.
Consumer to prosumer	Collaboration that seeks energy efficiency (i.e. efficient usage of energy and / or opting alternative supply sources). For such DSM, participants integrate the network information (e.g. supply constraints) into their decision making towards consumption alterations.
Prosumer to prosumer	Collaboration for DSM by involving and promoting the role of prosumers in the network towards incremental capacity of the supply side leading to energy autonomy. It requires intelligent automation systems that enable fully autonomous decision-making against diverse self-interests.

4 Concluding Remarks and Future Challenges

Leveraging on the smart grids concept, we posit that a pro-active participation of consumers through a collaborative process may provide substantial benefits for the long-term sustenance of the electricity infrastructure. Transferability of this process can also be envisioned in other contexts, as for example for the transportation demand management, which requires strong collaborative arrangements towards managing the travel / traffic demand (as modification and/or redistribution).

However, this potential role is determined by various factors (briefly highlighted in Table 2), ranging from self-interest layers to exogenous conditions that can induce the coordinated efforts of the users towards energy demand management. Smart demand illustration as energy demand management emphasizes the relationship of consumers along societal efforts towards energy sustainability. Such a relationship is heavily dependent on the self-interested participants, which may have an impact on the smart demand. Considering this, the same table provides a guideline for our future research

Table 2. Future challenges to smart demand

Intervention	Challenges
Sustainability	Consumers' limited knowledge regarding their energy usage patterns and its sustainability impacts can limit consumers' proactivity level.
	Embedded social practices, lack of societal pressures, lack of self-efficacy awareness level and existing satisfaction level do not allow them to pursue a change in their demand patterns.
	Investment costs regarding renewable energy sources, storage devices and system implementation costs.
Collaboration	Non-availability of tools to evaluate demand flexibility against technical and economic benefits and costs [21]
	Electricity market structures, legislative, administrative and regulatory barriers that suppress consumer participatory efforts.
	Consumer response fatigues and required attention to individual products / electrical appliances could also have adverse impacts.
	Collaboration among participants raises the information security and data privacy concerns. Such unauthorized access of data can hinder successful implementation of collaborative platforms.
Intelligence (products and systems)	Costly access and overload of information with its required processing efforts can create hindrance for the participation.
	Lack of user-friendly technologies that can monitor real time usage and supply patterns assisting consumers to create demand flexibility.
	Technology costs and their financing options (such as smart meters) and without these consumer participation is not possible.

to investigate about the most efficient coordination mechanisms by considering the optimality among dimensions of smart demand.

This paper raises some important aspects along different requirements, being the antecedent for building up the smart energy demand management model. The designing of this model does not only depend on the technological factors but also on those intangible factors that are related to consumers energy consumption and generation activities under the energy sharing context, being enabled by smart grids. Collectively absorbing these requirements into the system modeling for the demand side management may help to design proactive consumers' efficient energy management decision support system. Such system development can augment the smart grids economic impact.

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Process Alignment for Sustainable Product Development: The Essential Role of Supplier and Customer Involvement Processes

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Abstract. Sustainable product development (SPD) has received increasing attention by scholars and practitioners recently. This paper explores two essential organizational processes to support SPD: supplier and customer involvement. The empirical study in six discrete manufacturing firms shows that various types of sustainability innovations (e.g., recycling or energy efficiency) imply discontinues change in the supply chain and/or customer context, and that these themes only can be implemented when the supplier and customer integration process is sufficiently supported. The results suggest that SPD requires alignment between the type of SPD innovation and the type of SPD organizational processes.

1 Introduction

During the past decade, sustainability has become increasingly popular in new product development (NPD). Various pressures and incentives to improve sustainability are mentioned in academic literature, such as laws and regulations, customer demands, cost reduction, improvement of quality, mitigation of risks, and improvement of image [1-5]. While its importance is more and more acknowledged in corporate mission and strategies of firms, sustainability oftentimes remains a lip service of motivated individuals working in operational levels of firms [6]. Many firms face difficulties in the management of sustainable product development (SPD) due to its far-reaching impacts on the organization, and the firms' business model, supply chain and operations [9-13]. Besides these practical complexities, the meaning of sustainability and its implications remain ambiguous in both literature and practice. Preliminary work reveals two conceptual complexities that can impede firms to manage SPD effectively. First, firms can regard sustainability as a homogeneous objective with a 'one size fits all' set of organizational practices. Instead, sustainability covers multiple objectives, and a wide array of sub-themes that consequently require tailored practices and aligned business models [15]. Secondly, firms can approach SPD as traditional NPD complemented with several design for environment (DfE) approaches (e.g., [17], [18]). SPD however shows increased complexity compared to traditional NPD, and therefore requires specific managerial approaches [6 - 9].

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Given its importance and its problems, we seek to provide a more nuanced understanding of the relations between various types of sustainability, the organizations' business model (e.g., value proposition, infrastructure), and organizational processes (i.e., in this paper, supplier and customer integration). To accomplish this research aim, we conducted a multiple case study in which we investigate the type of sustainability that is currently pursued by the SPD function in a firm in relation to the type of supplier and customer integration in the early stages of SPD.

2 Research Questions and Background

The research focusses on three perspectives: (1) the types of sustainability innovation, depending on the firm's business model and sustainability focus; (2) the type of SPD organization with the specific focus supplier and customer involvement; and the ultimate aim, (3) SPD performance. These perspectives are reflected in three research questions:

- Can SPD innovations be categorized based on their type of sustainability focus and business model?
- What types of SPD organizational processes[1] are required for what type of SPD innovations?
- How does the interaction between SPD innovations and SPD organizational processes[1] contribute to SPD performance?

In the first part of this section we will explain how sustainability can be characterized in different themes and business models. Then, we will explain the process management perspective that is used to characterize different types of SPD organizations. Finally, we will elaborate on some prior literature related to supplier and customer involvement in product development.

2.1 Sustainability Focus: Sustainability Themes

Sustainability has various meanings in business settings, and can be achieved or improved in product development in various ways. This section provides an overview of types of sustainability innovations in discrete manufacturing. The overview is the result of analyzing sustainability themes associated with products as reported in CSR reports of discrete manufacturing firms, and is subsequently supplemented with Design for Environment strategies. The details of the theoretical underpinnings and methodology can be found in [16].

Peters et al. [16] identify three levels to describe types of sustainability innovations in discrete manufacturing, namely 1) object level, 2) life cycle stage(s) and resource or release level, and 3) solution or measure level. In this paper, the object is a product, whereas other object foci can be e.g., packaging or production plant. For a product,

[1] In this paper the focus in on the investigation of the supplier and customer integration processes.

sustainability themes and solutions concern one or more (or all) product life cycle stages, and one or more resource and release categories: 1) materials/parts, 2) energy and CO_2 emissions, 3) (other) greenhouse gasses (GHG) emissions, and 4) hazardous and toxic substances. The combination of object + life cycle stage + resource or release, can be improved by various types of measures or solutions that product developers can implement through one or more Design for Environment (DfE) strategies, as described next. Table 1 presents an overview of sustainability themes with the related DfE strategies.

Table 1. Sustainability Themes with DfE strategies (see also Peters et al., [22])

Resource / release	Sustainability themes with DFE strategies	
	Measure category	DfE Strategy
Materials	Dematerialization	**Material use optimisation (*linear system*)** (Design for resource conservation; Avoidance of waste; Reduction of material use; Design for durability)
		Material and component reuse (*circular system*) (Use recycled and recyclable materials; Design for recycling; Design for disassembly; Design for re-use; Design for remanufacturing)
	Substitution	**Sustainable material use** (Use renewable material; Use bio degradable materials)
Energy & co_2	Dematerialization	**Energy efficiency (*product/function*)** (Use of lower energy content material; Design for energy efficiency; Reduce weight of the product (transport)/design for efficient distribution)
		Energy efficiency (*system*) (Design for energy efficient system; Design for use CO_2 in other functions in system)
	Substitution	**Sustainable energy** (Design for cleaner use; Design for renewable energy sources)
Ghg/ Hazardous Substances	Dematerialization	**Cleaner use** (Minimize GHG and toxic or hazardous substances; Design for re-use)
	Substitution	**Clean substances and emissions** (Avoid GHG, and toxic or hazardous substances; Design for use GHG in other functions in system

DfE strategies are design principles and procedures to develop environmentally conscious products [19], [20]. The measures, solutions and DfE strategies can subsequently be divided in two categories, namely dematerialization strategies and substitution strategies [21], [22]. Dematerialization concerns increased resource productivity and/or less waste, e.g., design for durability or design for energy efficiency. In addition, we discern where the system boundaries of the solutions or measures are drawn. Dematerialization can be achieved by solely looking at the product (e.g., using less materials, or consume less energy), but it can also be achieved by influencing the system design in which the product ultimately is used (e.g., redesign of both system and pump for energy efficiency, or use waste produced by product in different function in system, or make sure product parts are re-used after end-of-life). Substitutive measures imply a change to a substitute resource or release leading to a more sustainable product, e.g., design for renewable material and design for non-toxic and non-hazardous substances.

2.2 Sustainable Business Model

A business model is affected by the firms' strategy towards sustainability. Its effectiveness is influenced by the way customer perceive the sustainable value proposition, and its efficiency is influenced by the firm organizational processes to best encounter those desires. *"The essence of a business model is in defining the manner by which the enterprise delivers value to customers, entices customers to pay for value, and converts those payments to profit"* [23].

Literature is diverse in terms of the attributes that constitute a business model. Table 2 presents an overview of various attributes mentioned in the literature. In this study we will analyze the companies on (1) Market segment, (2) Value proposition, (3) Elements of value chain (distribution channel, customer relationships), (4) Positioned in value network (network partners), (5) Competitive strategy.

Table 2. Different business model attributes

Verhulst and Boks (2012) [24]	Chesbrough and Rosenbloom (2002) [25]	Osterwalder (2010) [26]	Crawford and DiBenedetto (2011) [27]
Sustainable design strategies	Xerox spin off business models (not SPD)	Business model building for planet, people and profit	New products management
• Value proposition • Customer interface • Infrastructure • Financial viability	• Market • Value proposition • Value chain • Value network • Cost and profit • Competitive strategy	• Customer segment • Value proposition • Customer relationships • Distribution channels • Partner network • Key resources • Key activities • Revenue stream • Cost structure	• Market focus • End-user benefit/insight • Technological focus

2.3 Type of SPD Organizational Processes

The introduction of sustainability in NPD introduces complexity e.g., [14]. Complexity can be reduced by the employment of process management techniques by the reduction of variance and the improvement of stability and repeatability [28-31]. Process management is based on a view of an organization as a system of interlinked processes. It involves concerted efforts to map, improve, and adhere to organizational processes [30]. The principle postulation of this study is that the type of sustainability innovation needs to be aligned with specific SPD processes. To illustrate this point this paper specifically investigates the role of suppliers and customers processes in relation to different types of sustainability innovations. We expect that firms need address and (re)organize supplier and customer integration processes for many types of sustainability innovations.

For example, to implement remanufacturing, a company needs to efficiently organize reverse logistics cf. [32]. For reverse logistics, customers have to be able and willing to return end of life products. The product design directly influences the effectiveness of this process, because it influences the ease of contribution in terms of size, ease of disassembly, traceability, etc. Furthermore, in order to influence the user phase in the product life cycle, a product has to be aligned not only with the customer requirements in terms of functionality, but also with the acceptance of specific sustainability functionality and the existing infrastructure at customers' sites. Therefore, alignment is required between the product design and the suppliers' and customers' infrastructures.

Previous literature has shown that early supplier involvement is an important process in supply chain design, product design and process design e.g., [33]. Petersen et al. [33] distinguish between three types of supplier integration: (1) White box – design and specification decisions are the responsibility of the company, but discussions are held with suppliers about this with suppliers; (2) Grey box – formal or informal involvement of suppliers in development, which may include information and technology sharing and joint decision making regarding design specifications; (3) Black box – almost complete supplier responsibility for the purchased item with only review on the purchased item's specifications by the buying company.

Concerning the customer perspective various authors mention the importance of customer empowerment in product development in terms of their engagement to create ideas for new product designs; and their permission to select the product designs to be produced e.g., [34]. Moreover, the type of customer involvement affects the type of engineering work that is conducted and impacts the overall product delivery strategy of a firm [35]. Customer involvement can vary from very limited involvement, to very intensively involvement, i.e., having lots of influence on the design decisions of a company. Thus, firms could operate according to *open product delivery strategies* that allow customers to specify engineering work completely (fully engineer-to-order), whereas on the other side of the spectrum, firms operate according to a *closed product delivery strategies* towards customers (e.g., make to order, assembly to order, make to stock). The above-mentioned types of supplier and customer integration will be used to categorize the cases in their intensity of supplier and customer integration in SPD.

3 Methodology

Present research is an exploratory multiple case study [36]. The cases used for this study were selected by combining two sampling strategies: homogenous sampling and (maximum) variation sampling. With regard to the homogeneity of the sample, we concentrate on companies that aim to improve the sustainability of their products in product development, and who operate in discrete manufacturing industries. With regard to variation, we selected either companies for whom the improvement concerns the first step into managing sustainability in product development, or companies for whom it concerns further developing and expanding SPD. The selection process resulted in six discrete technology manufacturers (i.e., company A, B, C, D, E, F).

Data collection and analysis comprised the following steps. Firstly initial interviews were conducted to investigate the roles of suppliers and customers in SPD. Then, literature was analyzed and a framework was constructed. Based on the operationalization, we collected generic data on the roles of suppliers and customer in SPD. Subsequent data will be collected about the roles, the processes and decisions of suppliers and customers in cooperation with the companies in the different stages of the FFE. The data was reduced and condensed by using tables and data displays following the framework.

The results of the data analyses are summarized in in two figures (Figure 1 (a), (b)). Figure 1a represents the positions of the cases on supplier and customer integration, and Figure 1b positions the sustainability themes on the required supplier and customer integration. The position of the cases and sustainability themes on supplier and customer integration are assessed based on the dimensions presented in Section 2.

4 Results

In this section we describe the case study results. For each case we will give a brief overview of their business model and sustainability theme, followed by an analysis of how the case company organized supplier and customer integration.

Figure 1(a) and Figure 1(b) illustrate together the link between the (a) position of the cases and (b) the various sustainability themes a firm can focus on given the position on supplier and customer integration. Figure 1(b) illustrates that the various sustainability themes differ in the required supplier and customer integration. For example, Materials Dematerialization: materials use optimization (linear system)' requires limited downstream integration, because the organization of a return flow is not required and the impact the customer specification is limited (see Figure 1). The 'Materials Dematerialization: materials and component reuse' theme requires more downstream integration, because the organization of the return flow and a specific consideration of remanufacturing in the product design are required.

The majority of case companies (i.e., Companies A, C, E and F) make products that have multiple sustainability characteristics, e.g., durability, safety, reliability, maintenance-free, and energy efficiency, as a result of their past en present business models. Today, these companies intend to incorporate new sustainability characteristics in their products, or bring existing qualities to a higher level. It is however questionable whether the business models of companies C, E and F enable new sustainability innovations. In order to illustrate this point, we discuss the business models of these three case companies, starting with company's C, in relation to the type of sustainability innovation each company intends to realize within SPD. Additionally, we contrast the 'problematic' cases with other cases that have been more successful in SPD, or that have an enabling business model in place.

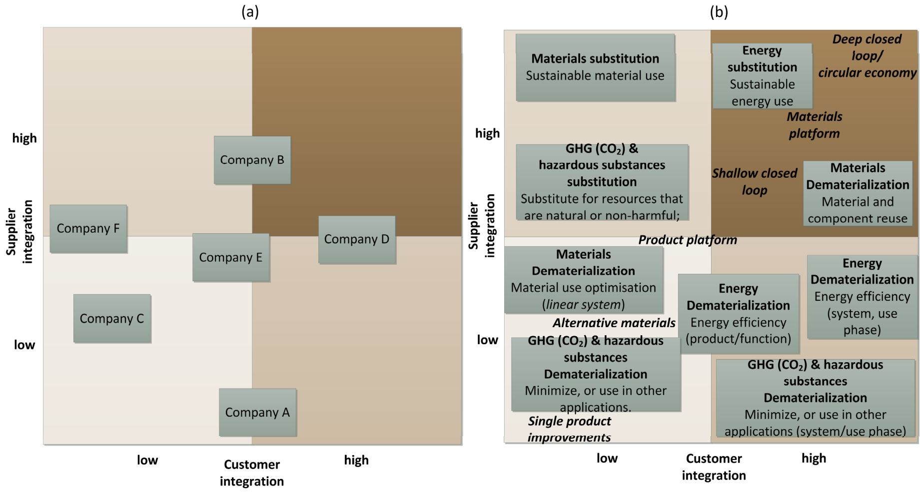

Fig. 1. Position of the cases and sustainability themes

Due to new EU law and regulation regarding the energy consumption of centrifugal pumps, Company C concentrates on energy efficiency innovations. Although Company C already studied the possibilities to increase energy efficiency, because they expected the recently implemented EU law and regulations for energy consumption, not much has changed. According to Company C's R&D manager: "the organization, and especially the sales force, do not fully embrace energy efficiency".

Company C is a traditional supplier of centrifugal pumps: based on customer requirements (i.e., usually a certain pump capacity) the most economic pump is selected and sold to the customer. The newer and more energy efficient pumps lead to a higher initial list price for the pump, but should improve the Total Cost of Ownership. But Company C's sales force are confronted with customers that do not perceive energy efficient pumps as an attractive advantage, and therefore still prioritize a lower initial cost price over energy efficiency savings or environmental advantages. This problem especially applies to Company C customers who are not end-user of the product yet, for instance original equipment manufacturers (OEM's). Another reason is the lack of information, tools and skills of the sales personnel regarding the implementation and possibilities of the pump in an energy efficient system for the customer. Thus, Company C's current business model is not yet compatible with the new sustainability focus of Company C.

Company A, also a manufacturer of pumps, employs a different business model. Instead of waiting on customers telling them what kind of pumps they want based on a few parameters as in Company C, Company A aims to be involved as early as possible in the design of the system in which their pumps will operate. In this way, Company A can ensure their customers buy pumps that function optimal in their systems from both economical as well as environmental points of view. Moreover, Company A can advise their customer to adjust certain aspects of their system, for instance piping diameters or hydraulic head, so that pumps will even function more efficient. Company A's level of integration in the value chain can be an example for Company C.

Company E supplies electric switching gear to utility companies and industries. In utility companies, CO_2 footprint and climate change are the most important sustainability themes. Company E has therefore adopted CO_2 reduction as a major theme for sustainability innovations. Moreover, unlike most switching gear equipment produced by competitors, Company E's equipment does not contain sulfur hexafluoride (SF_6), which is the most potent greenhouse gas in the world (23,900 times higher global warming potential than CO_2). Despite this unique characteristic, and Company E's other SPD efforts to contribute to the CO_2 theme of their customers, sustainable product successes are mixed. According to Company E's R&D manager: "the share of our equipment in the total customer's CO_2 footprint is marginal". Consequently, customers have better alternatives to invest in than Company E's CO_2-friendly switching gear. Innovations aimed at CO_2 reduction do not fit within the current business model of Company E. Company E is now reconsidering its type of sustainability innovations (e.g., material efficiency), and explores how this may affect their current business model (e.g., offering leasing construction).

Lastly, Company F has traditionally concentrated on offering high efficient gas-based solutions to generate hot water and heating. It has recently developed new techniques, most notable combined cogeneration technology. Yet this technology is still too expensive given current market conditions, and moreover, requires changes in the energy market (e.g., the household as a supplier of energy) that have not been implemented. Company F therefore wants to explore other sustainability opportunities, such as material efficiency. Because Company F intends to stick to its current business model, the possibilities for material efficiency improvements are very limited. In this respect, Companies B and D have shown that significant material efficiency gains can only be achieved when the business model is aligned.

The data presented in Figure 1 show that the case companies vary in their process management capability with respect to customer and supplier integration and thus their ability to implement sustainability themes. It is for example illustrated that Company C has challenges in supplier and customer integration. They produce centrifugal pumps, which have substantial impact on energy consumption in the use phase and the overall sustainability performance of the customers water management system. These customers, however, are required to be convinced, and cooperation is needed in the design of the overall water management system in order to be able to improve the 'Energy Dematerialization: energy efficiency of the system and use phase' theme (see Figure 1).

Based on the interviews, generic patterns on supplier and customer integration are found. Figure 1(a) illustrates that Companies C, A, E, and F have limited supplier and customer integration whereas Companies B and D have more integration. All in all, we found that early supplier involvement is perceived as very important for SPD with very innovative business models and/or transitions towards new business models and very ambitious sustainability initiatives. One of the key findings is that, because of the lack of supplier and customer integration, several cases have limited influence on the supply chain, which leads to challenges to implement new sustainability business models. In order to be able to reach their sustainability goals, these firms are required to align their supplier and customer integration with their sustainability focus and their sustainability business model.

5 Discussion and Conclusion

The first research question of the study is: "Can SPD innovations be categorized based on their type of sustainability focus and business model?". Present study has shown that SPD innovations can change substantially due to their differences in focus, scope, impact and type of business model. We use the sustainability themes framework developed in previous studies as a starting point [15], [16]. Further research could aim at the development of a more detailed SPD innovation typology.

The second research question is: "What types of SPD organizational processes are required for what type of SPD innovations?". In this study the focus was on the specific processes related to supplier and customer integration. The results show contribution, however this depends on the type of SPD innovation a firm focusses on. Some sustainability foci and business models require more integration then others. The authors intent to investigate in future research other types of SPD organizational processes in different SPD stages that contribute to SPD performance.

The third research question is: "How does the interaction between SPD innovations and SPD organizational processes contribute to SPD performance?". Based on the study, several generic patterns are distilled. Figure 2 illustrates the proposed relation between SPD alignment between SPD organization and SPD innovation, and SPD performance. 'SPD alignment' refers to ensuring that the 'SPD organization' characteristics are consistent with the 'SPD innovation' characteristics.

One of the most important observations is that when firms persist in the assumption that traditional NPD and engineering methods (such as traditional DfEs) deliver enough support to create sustainable products, the eventual proportion of sustainable products in the total portfolio of these companies will be limited. Instead, it is expected that solutions towards SPD performance are related to the ability of a firm to align the type of SPD innovation (e.g., type of business model, type of sustainability focus) with the SPD organization (e.g., type of SPD process, SPD stage) (See Figure 2).

The case examples demonstrate that many of the present organizational routines within NPD often do not facilitate organizational or external level activity aimed at sustainability. The unaligned cases call for process management of various processes of SPD that enable the exploration for new sustainability opportunities and business models. Future research could focus on investigating important process areas and related practices in SPD that facilitate different forms of SPD innovation. It is furthermore assumed that companies show diversity in their maturity in SPD: some of them focus on relative simple sustainability business models, while others have more advanced ambitions with the required advanced SPD organization. The area of process maturity in relation to SPD is thus promising a direction for further research.

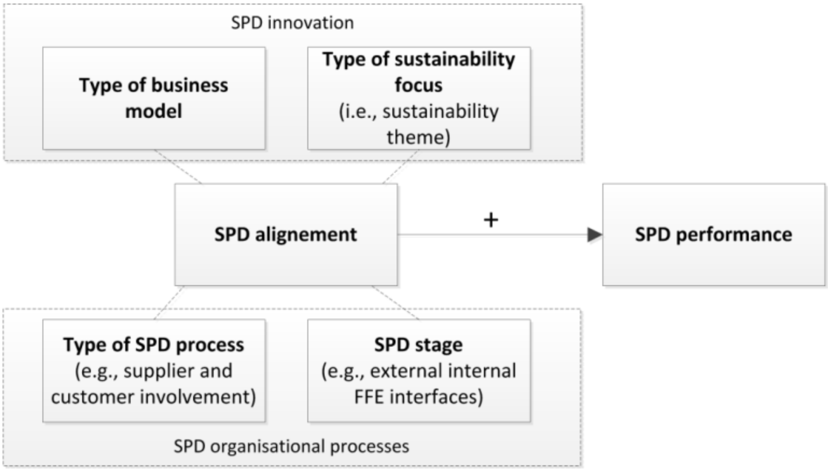

Fig. 2. Proposed Framework: SPD alignment

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Global Product Development: Organization and Links with the Supply Chain

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Abstract. The coordination of supply chain configuration with new product development process has become extremely relevant to either prevent product launch from failure or to enhance supply chain effectiveness. Recently, along with the offshoring of production activities, a new paradigm emerges: companies adopt globally dispersed teams for the collaborative development of new products. While many studies regarding new product development have been carried out, few have examined this topic in a global setting. The aim of this research is to investigate how companies are organizing and managing product development projects on a global scale. Seventeen companies working in the electro-mechanical sector participated in this exploratory study to determine what type of global product development configurations were being adopted and to identify the link between the configurations and the supply chain. In addition, the study also addressed how the selected configurations influence new product development practices and which contingent factors determine the adoption of a certain configuration.

From the data, it emerges that common behaviours were adopted concerning geographical dispersion and the management of development teams in new product development. Furthermore, the study led to some interesting implications for managers because the identified configurations can be utilized by firms for more effective planning of their global product development efforts.

Keywords: Global Product Development, Globalization of Supply Chain, Global teams.

1 Introduction

Nowadays, achieving success in an international context requires companies to develop new products and services that respond effectively to many complex and diverse market needs and characteristics. With the emergence of a global economy and the acceleration of technological dynamics, companies have not only to be able to manage globalized supply chains (SC) [1], but also to deploy a successful international new

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product development (NPD) program in order to gain a competitive edge in the market. Finally, companies should be able to coordinate supply chain management with NPD processes to either prevent product launch from failure or to enhance supply chain effectiveness [2].

Global product development (GPD) has been defined by Eppinger and Chitkara [3] as *"a single, coordinated product development operation that includes distributed teams in more than one country utilizing a fully digital and connected, collaborative product development process. This may include third parties that provide engineering or design capacity, or it may be an entirely captive, company-owned operation"*. Therefore, the new challenge for multinational companies is to achieve success in their GPD practice, and to be able to manage the relations of GPD with globalized supply chains. Despite the relevance of the topic for companies, this topic has been only marginally explored by existing literature, and a study that presents how companies manage GPD and the relations with the supply chain is missing. Thus the aim of this work is to investigate how companies are organizing their worldwide distributed product development activities, with a particular focus on the ownership of these functions, distinguishing whether these are owned by the company or by a third party. Moreover, we propose to study the existing link between the resulting configurations and the company's supply chain.

The remainder of the paper is organized as follows: first a literature review on GPD and the link between GPD and global supply chain is presented. Then the research questions and the methodology used to answer to them is described. The discussion of results follows. The paper ends with the conclusions, limitations and future research paths.

2 Global Product Development: Literature Review

The existing literature describes the new product development as "the set of activities that start from a market opportunity and end with the production, sale and distribution of the production of the product" [4]. Many generic models for NPD process have been proposed [4] [5]. Companies can involve many different actors during NPD process, ranging from suppliers to universities, with various degree of collaboration [6] [7].

Eppinger and Chitkara [3] find that in the first five years of the 21st century, companies were rapidly migrating from a centralized approach to GPD practices: they exploit highly distributed, networked development process, in which centralized functions work with resources located in other sites or regions of the world [3]. GPD practice results in establishing GPD teams comprised of individuals drawn from multiple countries and company functions [8]. This is happening in several industrial settings, ranging from computer hardware and software development to automotive development [9]. And, in the recent years, the use of GPD approach involving multiple companies that are geographically dispersed and separated by organizational boundaries (e.g., outsourcing, offshoring, alliance) to develop products has spread dramatically [10]. Globalization practices are for the most part adopted by companies in developed countries and to a lesser extent by companies in developing countries [11] [12] [13]. Moreover, firms of smaller countries have a greater need to offshore their development facilities due to the lack of available resources in their origin countries [14] [13].

Some attempts to describe the emerging organizational forms of NPD have been done. However, to our knowledge, the classifications proposed cannot capture the diversity in the GPD organizational forms being too generic. In particular, based on the concepts of outsourcing (i.e., the ownership of the resources involved in NPD activities) and offshoring (i.e., the location of the resources involved in NPD activities), Eppinger and Chitkara [3] suggest four fundamental organizational forms of NPD, i.e. centralized, local outsourcing, captive offshore and global outsourcing. Besides, PTC [15] defines a GPD maturity model composed by five levels, from a totally centralized solution, to a globally dispersed one. GPD teams assume very high importance. They are defined as "teams comprised of individuals who work and live in different countries and are culturally diverse" [16]. Global teams can be used to exploit globally dispersed competencies, without the necessity to locate all the members in the same location. The possibility to locate people coming from different countries in the same place, leads to the development of global products that can satisfy the needs of different markets [16] [17]. Even if he topic of the globalization of supply chains have been studied in depth [1], a study on how supply chain management (SCM) is integrated to GPD in the global context is missing.

3 Research Framework

In order to fill the highlighted gaps in the literature, the main objective of the paper is to investigate how companies manage GPD activities and how they integrate such activities with SCM. To study this topic, we strive to identify common patterns in the globalization of product development activities, and those contingency factors affecting companies' behaviour in terms of GPD, such as peculiar characteristics of the firm, and location and ownership of development activities. With the aim to accomplish these research objectives we developed a research framework, and a list of research questions, that were the basis for our empirical research, as described in following sections.

In particular, the research questions we developed are the following:

- *RQ1: Which are the GPD configurations adopted by companies?*
- *RQ2: Which is the link between the GPD configurations and the SC configurations?*
- *RQ3: How does contingency factors determine the choice of the GPD and the SC configurations?*
- *RQ4: Which is the link between GPD and the practices adopted by companies in the NPD process?*

Figure 1 depicts the research framework that synthetizes the main variables and relationships expected.

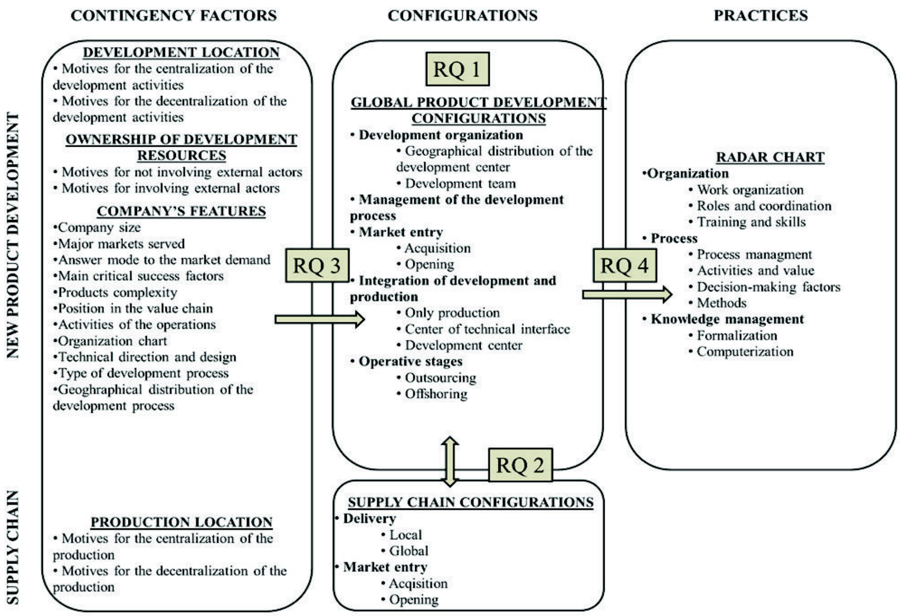

Fig. 1. Research Framework

GPD configurations describe the ways companies organize the NPD process at a global level. GPD configuration encompasses both the management of the development process [4], the market entry [18], the integration of development and production [19] [11] [13], and the operative stages [3] [20]. *SC configurations* represent the ways the SC is configured, thus we mainly focused on market entry [18] and the distribution of delivery, i.e. local or global.

Moreover, basing on prevalent literature contributions, we identified four elements to be the main *contingency factors for GPD configurations*: motives for the centralization of the development activities, motives for the decentralization of the development activities [18] [3] [19], motives for not involving external actors, motives for involving external actors [6] [19]. Additionally, two are the main *contingencies* we identified for the choice *of SC configurations*: motives for the centralization and for the decentralization of the production [21]. Moreover, company characteristics, such as company size, can affect the choice of the configuration.

Regarding the *practices adopted by the companies in performing NPD process*, we mainly refer to the model proposed by Rossi et al. [22], which groups NPD activities into three main areas: organization, process, and knowledge management [22].

4 Methodology

To explore the nature of the links between the proposed variables, we ran multiple exploratory case studies. We mainly focused on medium and big size enterprises, which are more willing to globalize their product development activities, rather than smaller firms. Moreover we decided to investigate companies' behaviour in a single sector, the electromechanical, to obtain more valuable results. The main tool used to gather data during the interviews has been a questionnaire, properly developed starting from literature review investigation. Aim and description of most relevant questions is summarized in Table 1.

Table 1. Questionnaire Description

Topic	Description/Purpose
NP	Indication of the success of new products developed
SC – Make	Level of internationalization + reasons of relocation of production facilities
SC – Source	Inbound supply chain, procurement, location, relationship with suppliers
SC – Delivery	Outbound supply chain
Offshoring	Location + property of development resources
Offshoring	Factors influencing centralization/internationalization of PD process
Outsourcing	Role + location + stage of collaboration of actors involved in NPD
Outsourcing	Criteria + motives of selection of development partner
Develop. Team	Organization of PD process + internal resources + global/local team

The number of case studies we collected from November 2012 to January 2013 is seventeen, as displayed in Table 2.

Table 2. The sample

Company	*Developed Products*	*Empl.*	*Turnover [mln€]*
1	LED Displays	250	30
2	Electric coils, solenoids, valves	400	34
3	Forks for forklifts, lifting platform..	700	115
4	Car electronic control	302500	51,5 mld€
5	Axles, transmissions gearboxes	2000	600
6	Payment/recognition coins; changer	200	30
7	Batteries for cars	10300	2,1 mld€
8	Motorcycles	250	44
9	Capacitors	670	70
10	Electronic modules, pressure sensors..	250	42
11	Electric Forklifts	5000	1,36 mld€
12	Plugs, sockets, switch, disconnectors..	163	25
13	Trucks	336	60
14	Industrial vacuum cleaners	230	35
15	Semiconductor electronic components	50000	10,4 mld€
16	Power transformers	400	145
17	Ovens, Hobs	11500	1,3 mld€

5 Results Discussion

Through the analysis of collected data we were able to answer the four identified research questions. First of all we came out with a description of possible configurations companies are adopting when performing a GPD initiative (RQ1). Main variables considered here are the geographic distribution of design sites and the location of team members, because they were better justifying and explain the differences between companies. From case studies we observed four common behaviours adopted by companies, which determine four GPD configurations, which could be named and defined as follow:

- *All-in*: the development is not globalized, but centralized in Italy (in one or more development canters).
- *One-Gap*: is the first step towards a geographically distributed development; some delocalized structures exist (center of technical interface) to customize products for local customers.
- *Blind*: the development is international, but each center works independently
- *Connector*: the development is globally distributed and the global teams collaborate for developing new product all across the world.

Different contingency factors drive the choice of companies to setup in one way rather than another (*RQ3*). Companies that decide to centralize development in Italy (*All-In*) do it to avoid the dispersion of resources, and to a lesser extent because the domestic market in which they operate is relevant. Companies that have taken the first steps in foreign territories have adopted this configuration (*One-Gap*) to respond quickly to customer requests. In fact, when a market becomes relevant, or when there are local needs, it may be suitable to bring the technical expertise close to the customer. Probably, when the need to integrate development and production becomes predominant, it may be reasonable to switch from having only a structure that is responsible to customize the product to a structure instead covers the whole process of development. Who decides instead to have a geographically distributed development (*Blind* and *Connector*) can globalize at least in two ways. They can acquire a foreign company with a development center able to meet the needs of the market in order to gain access to dispersed technology and competences (on a market or on a specific product family), owned by the acquired firm. Or they can integrate production with development activities, so that those who design the product are in direct contact with the production. We have observed that very often, when a foreign served market starts to become significant, the path followed by companies is to delocalize the production at first step, then the development.

Data demonstrate evidences that a link between the configurations of global product development and the supply chain exists (*RQ2*). We observed that similar GDP configurations have similar SC characteristics. Moreover, in term of GPD configurations and NPD adopted practices (*RQ4*), we noticed that *All-in* and *One-Gap* have some similarities, such as *Blind* and *Connector*. We then identified two main clusters: *thin* and *thick*. What has emerged is that companies in cluster *Thin*, are less structured, and for example do not have training programs for human resources nor the definition of roles and coordination are formalized process. Conversely, companies in the cluster *Thick*, implement tools, methods, rules, standards to guarantee highly formalized NPD process which is uniform across all corporate locations.

6 Conclusions

The paper analyses in detail GPD and its link with NPD practices and SC configurations, highlighting the main contingency factors affecting the choices of organizations. Some highlights, emerging from a critical elaboration of the proposed ideas, lead us to think that in its globalization process, a company, moving from a totally centralized configuration (*All-in*), to a completely globalized one (*Blind*, *Connector, One-gap*), should take into account some hints:

- Changes in the process organization and in the company's culture may be required. Thus, managers have to deploy adequate resources to achieve success in the process of globalization.
- The process must be divided into clear steps, that can hence be assigned to globally dispersed development functions.
- "Do not outsource key competences" [3] is a fundamental principle of GPD.
- Members of global teams may use different technologies, systems and specific processes. Thus, it is necessary to uniform the infrastructure and the systems used.
- Team members speak different languages and have different cultural values. This may lead to misunderstandings or misinterpretations. Because of these problems, shifting to a GDP approach should follow the adoption of new modes of collaboration between globally dispersed team members.

The relocation of production does not always follow the internationalization of development: companies internationalize design with different shades, and this is according to the needs and characteristics of each company.

The conducted research, which involves seventeen companies, doesn't have statistic value but case studies serve as a mean to better understand how GPD is managed in real cases and how common paths could be found in different behaviours, within a specific context (Italian medium and big enterprises from the electromechanical sector). Future development could be the generalization of found results involving a larger number of companies, through a proper structured survey or multiple case studies. Furthermore the comparison between the highlighted results within the Italian context could be expanded to other countries and sectors.

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A Study of Sustainability Adoption Trends in the Transportation Market

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Abstract. Due to an increasing concern for sustainability, automobile manufacturers have been introducing hybrid variants of popular vehicles in an attempt to reduce the environmental impact of vehicles. However, it is still unclear how this 'hybridization' of popular car models affects the overall success of the vehicle. This paper seeks to address these gaps in knowledge by implementing a demand modeling approach, game theory framework, and a technology forecasting model. In the demand model, it was found that the percent of hybrid cars sold, the year and the model of the car are significant predictors of the total sales. In the game theory model, all possible scenarios suggest that an increase in hybrid sales would encourage market share growth. Lastly, using the technology forecasting model, S-curves were generated to show how the energy impact score (EIS) of automobile engines decreases over time as technology improves, and provide justification for the investment in hybrid engine development.

1 Introduction

Although the hybrid electric vehicle was first developed as an alternative to traditional internal combustion engine vehicles in as early as the 1900s, it has only recently gained momentum as a core segment of the automobile industry [1]. Hybrid Electric Vehicles (HEVs) combine the conventional internal combustion engine and an electric propulsion system that that uses energy stored in a battery. This combination allows the vehicle to have same power and range as other vehicles while getting better fuel economy and lowering negative emissions since the combustion engine is reduced in size and capacity [2]. Although only comprising of a small percentage of the automobiles that are driven today, the United States is home to the largest fleet of HEVs [3], making it a significant part of any sustainability adoption consideration.

Since the HEVs are considered to be a step in the direction for a more sustainable driving future [4], an increasing number of consumers are adopting hybrid technology. Thus, automobile manufacturers are beginning to offer hybrid variations of their top selling models. Examples of this 'hybridization' of popular vehicle models include the Toyota Camry, Honda Accord, and Nissan Altima. While this strategy provides consumers with a more sustainable option for trusted vehicle

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models, it is still unclear how this 'hybridization' affects consumer adoption of HEVs. In other words, since automobile makers largely influence consumer behavior (i.e., availability can drive desirability), the increase in hybrid sales should be investigated for its impact on the automobile maker's total sales. In addition, consumer perception of a particular automobile maker's brand could be influenced by this 'hybridization', ultimately affecting the success of the vehicle. Thus, this paper seeks to examine the role of HEV adoption on the success of a model of vehicle by using a Demand Modeling framework, as has been previously done by other researchers who seek to facilitate product planning in competitive markets [5, 6].

In addition to the proportion of hybrid cars sold by a single automobile maker, the behavior of *other* automobile makers have the potential to influence overall sales. One method of analyzing the market dynamics of a few major players is through the Game Theory framework. Formally, game theory involves the study of "mathematical models of conflict and cooperation between intelligent rational decision-makers" [7]. The rational decision makers to be considered in this paper are the individual automobile manufacturers, and game theory can be used to uncover the most effective and profitable strategy to be taken by multiple players (automobile manufacturers). Thus, one of the main goals of this paper is to examine the relative payoffs (sales) for each major automobile manufacturer in when considering varying levels of hybrid car sales.

While the impact of hybrid sales and competitors' behavior can certainly affect the success of a particular vehicle, the life-cycle of hybrid technology needs to also be examined. This is important for justifying investment in HEVs, given that most all technologies are surpassed by new technologies eventually. One method of analyzing the life-cycle of technologies is through the use of S-curves that depict how the technology has evolved over time [8]. The start of the S-curve depicts "market adoption" that relates to the birth of a new market opportunity. In this specific case, Toyota Camry first introduced hybrid cars in 2006. Typically, "early adopters" are consumers that are interested in testing and trying out new products. Following this phase, the technology moves into a mass manufacturing and distribution phase. Lastly, as the market matures, at which point "late adopters" who are risk adverse, begin to purchase the product. Therefore, this paper seeks to examine the growth of hybrid technology over time and provides justification for investing in a larger proportion of hybrid sales within the next ten years.

The main objective of this paper is to explore trends in hybrid technology adoption and examine the impact of competitors' behavior on the success of different models of vehicles. Therefore, this paper seeks to address the following research questions: (1) How does the percentage of hybrid cars affect the overall sales for that model? (2) How do competitors' behavior with regards to the proportion of hybrid cars being sold affect overall sales? (3) What is the future of hybrid technology and is there justification for continual investment in HEVs?

2 Methodology

In order to answer our research questions, a method of analyzing the current trends in hybrid vehicle technology and predicting the competitive landscape is presented in this section. Since the current problem involves uncovering trends in hybrid technology, three different example vehicles are used to illustrate the process, namely, the Toyota Camry, Honda Accord, and Nissan Altima vehicles. These vehicles were chosen because of the similarities in quality (belonging to the same ‘tier’ within each brand), and the availability of sales data. In addition, all three models are available as non-hybrid and hybrid alternatives. Thus, the first step of the proposed methodology involves utilizing a Demand Modeling approach to analyze the relationship between the proportion of hybrid cars sold and the total sales. Next, a Game Theory framework is implemented in order to gain a better understanding of the impact of competitors’ behavior on sales. Lastly, the future of hybrid technology is analyzed from a sustainability perspective using Technology Forecasting. These steps are demonstrated and discussed in the following sections.

2.1 Demand Modeling of Hybrid Sales

The first step in determining the best strategy for maximizing sales is to examine the impact of various factors on the total sales of the model of vehicle. In particular, the proportion of hybrid sales is studied in this paper since it provides a normalized indication of the amount of hybrid cars being purchased for each model. In other words, we seek to determine if the proportion of hybrid sales can significantly predict total sales for the three chosen models of vehicles. Thus, the amount of sales of the hybrid variations of each model of vehicle (S_{hybrid}), as well as the total sales of each model of vehicle (S_{total}) were obtained through the companies’ sales reports. Then, the proportion of hybrid sales (P_{hybrid}) is simply computed using Equation 1 for the years that each model had a hybrid alternative available.

$$P_{hybrid} = \frac{S_{hybrid}}{S_{total}} \tag{1}$$

A linear regression analysis was then performed using S_{total} as the dependent variable, and P_{hybrid}, model, and year as independent variables. The year was included as a variable in the analysis in order to account for fluctuations in consumer behavior throughout the years. Furthermore, since the hybrid variants of the different car models were introduced at different points in time (different year ranges), the years that saw both regular gas-powered engines and hybrid variants of the same model were included in the model. For example, from the year 2007 to 2010, Toyota produced both regular gas-powered Toyota Camrys and Hybrid Toyota Camrys. Thus, the year ranges were adjusted for each car model accordingly. In addition, the model variable was included in the analysis in order to account for inherent differences in sales between different vehicle models. Since the model variable is categorical in nature (Toyota Camry, Honda Accord, and Nissan Altima), ‘Dummy Coding’ was used to analyze the variable in linear regression. The total sales for each vehicle model, the model’s hybrid sales, and the proportion of hybrid sales for each model are shown in Table 1.

Table 1. Proportion of hybrid sales computed using sales of hybrid vehicles and total sales for each model of vehicle, for each year

Vehicle Model	Year	S_{hybrid}	S_{total}	P_{hybrid}
Toyota Camry	2007	24477	418631	0.1151
	2008	6272	430345	0.0144
	2009	22887	333937	0.0641
	2010	14587	313217	0.0445
Honda Accord	2004	1061	358709	0.00274
	2005	16826	352467	0.0456
	2006	5598	348843	0.0158
Nissan Altima	2007	8388	276374	0.0295
	2008	8819	260849	0.0327
	2009	9357	194211	0.0460
	2010	6710	22253	0.0293

The results of the linear regression analysis conducted to model the impact of the proportion of hybrid sales revealed a significant relationship between total sales and the proportion of hybrid sales, model, and year variables ($R^2 = 0.90$, $p < 0.00$). This result indicates that the proportion of hybrid sales indeed affects the total sales of the vehicle. In addition, differences in the model and year of the vehicle can be said to affect the total sales of the vehicle as well. This is unsurprising since different vehicle models are bound to have different sales figures, affected by changes in consumer behavior from year to year. In particular, total sales appear to decrease following each year, but tend to increase as the proportion of hybrid sales increase, see Equation 2.

$$S_{total} = 42566452 - 20970(Year) + 323273(S_{hybrid}) - 71814.87(Model) \qquad (2)$$

2.2 Implementation of Game Theory Framework

Implementing game theory is a good way to analyze how the sales of a car will be impacted depending on which "move" or policy the competitors make. From demand modeling, it was found that overall sales were influenced by the percentage of hybrid cars the company produced. Taking this information into account, a game theory scenario was constructed where two companies were evaluated at two different levels of percentage of hybrid cars produced, out of their total number of cars. The two levels chosen were 3% and 10%. There were three pairwise comparisons performed—one for each pair of vehicles (Toyota Camry, Honda Accord, Nissan Altima). The assumed strategy of the game was to maximize market share among the competing companies, by examining all perceivable strategies and their corresponding payoffs for each manufacturer [9]. The values were obtained directly from the multiple-linear regression developed for demand modeling. A unique Nash Equilibrium point (NE) was found, which means that neither company has an incentive to deviate from this strategy, thus both companies should be at 10% hybrid in order to increase their market shares, regardless of the strategy of the opponent. This result was found when performing pairwise comparisons of all car companies, see Figure 1. This is an indication that hybrid technology is becoming a vital segment of the automobile industry, and could likely benefit automobile makers even in a competitive environment. It should be noted that Toyota Camry has the highest market share values regardless of the 'game scenario', and can be said to 'dominate' the market, possibly due to the overall brand size and popularity.

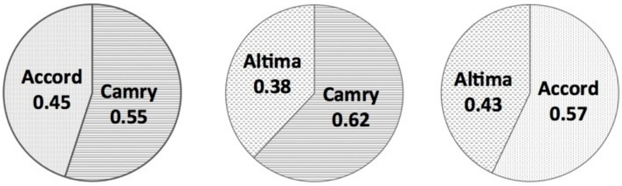

Fig. 1. Market share values for the NE point across all pairwise comparison scenarios

2.3 Technology Forecasting of Hybrid Engines

In order to analyze the technology life-cycle of hybrid engines, the Energy Impact Score (EIS) was used to measure the sustainability of the engine. This metric is used as an industry standard for measuring the number of barrels of petroleum consumed by a vehicle in one year [10]. Thus, the lower the EIS, the more sustainable the vehicle is said to be. The 'growth' of the technology, or in this case, the decrease in the EIS, provides an indication of trends in the sustainability of vehicle engines, and can serve as a method of predicting the sustainability of these engines. This trend is captured using S-curves, a mathematical function that models changes in parameters over time using a logistic form. In our study, the EIS generates a backwards S-curve, because the EIS decreases over time, as technology improves. Therefore, the logistic growth functions used in this paper are monotonically decreasing, reflecting and improvement in the EIS score, as seen in Equation 3.

$$\frac{F}{F-P} = e^{\propto t+\beta} \tag{3}$$

Where F is the Energy Impact Score, P is the saturation point (determined through optimization), and α and β are coefficients of the exponential function. Then, for every point in the data set, we compute $\frac{F}{F-P}$ as well as $\ln(\frac{F}{F-P})$. This transformed form of the exponential function is shown in Equation 4.

$$\ln(\frac{F}{F-P}) = \propto t + \beta \tag{4}$$

Values of $\ln(\frac{F}{F-P})$ are plotted to find the slope, $\propto$, and intercept, β. Equation 5 is then solved for F, treating this new value as an estimator, $\hat{F}$.

$$\hat{F} = \frac{-(P * e^{\propto t+\beta})}{(1-e^{\propto t+\beta})} \tag{5}$$

The points for $\hat{F}$ are plotted to visually illustrate the trend of this technology and how it evolves, if it continues at its current pace. The sum of square error between the actual data point (EIS) and $\hat{F}$ is then minimized to find the lowest energy impact score that a car can achieve. The S-curves is created for the hybrid car engines as well as the non-hybrid car engines and are shown in Figures 2 and 3. Based on the S-curve, the lowest EIS that hybrid cars can achieve is 6.68, around year 2065. Effectively, hybrid cars achieve 95% of their potential for sustainability around the year 2025 (EIS = 7.01). For non-hybrid cars, the lowest EIS that can be achieved is 11.86, which saturates around year 2053. Non-hybrid cars achieve 95% of this value around the year 2016 (EIS = 12.45).

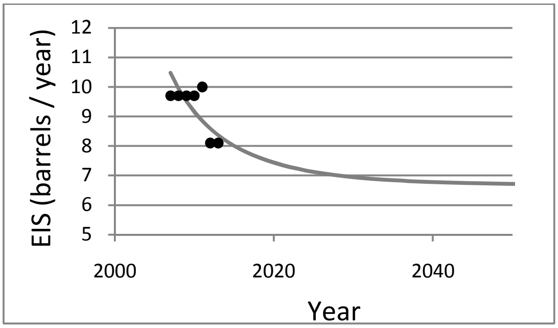

Fig. 2. S-curve of EIS for hybrid vehicles

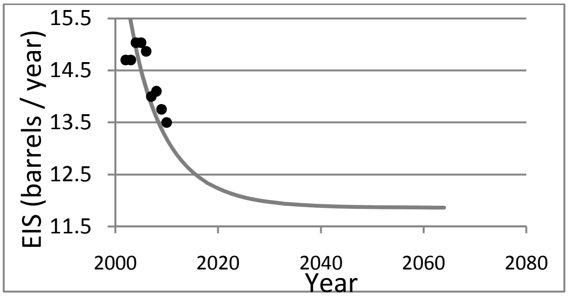

Fig. 3. S-curve for EIS for non-hybrid vehicles

To create an S-curve that combined the S-curves of hybrid and non-hybrid into one growth by means of weighted averages, a new EIS metric needed to be formulated. For the years where the hybrid and non-hybrid cars overlap (2007-2012), we compute a weighted EIS value (WEIS) for each year i, see Equation 6.

$$WEIS_i = EIS_{non\text{-}hybrid}\left(S_{non\text{-}hybrid}\right) + EIS_{hybrid}\left(S_{hybrid}\right) \tag{6}$$

Where $EIS_{non\text{-}hybrid}$ and EIS_{hybrid} correspond to the EIS values of the respective types of vehicles, and $S_{non\text{-}hybrid}$ and S_{hybrid} correspond to the sales of the respective types of vehicles. This weighted EIS score is computed for all years with sales in both hybrid and non-hybrid vehicles, for each model of vehicle. For years where only non-hybrid cars were sold, a regular average was used to compute EIS. Using these new values for EIS, the S-curve for both hybrid and non-hybrid cars was constructed and is shown in Figure 4. From this curve, the lowest Energy Impact score for weighted Hybrid and Non-hybrid cars can achieve is 10, which saturates around year 2075. Practically, 95% of the sustainability would be achieved around the year 2042 (EIS = 10.5).

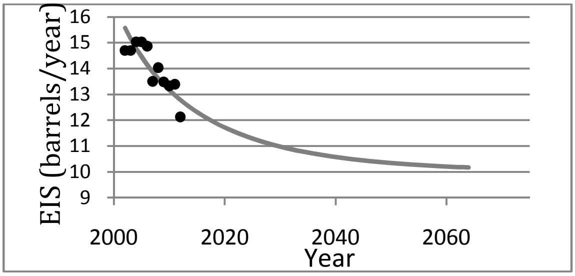

Fig. 4. Combined Hybrid and Non-Hybrids S-curve

3 Discussion

From our results, it was found that there was a significant relationship between total sales and the proportion of hybrid sales, model, and year variables. In particular, the higher the percentage of hybrid cars sold, the higher the overall sales for that model of vehicle. This result is important, because while the proportion of hybrid sales may not directly predict total sales, it indicates a positive trend between these two variables. In other words, a higher proportion of hybrid sales is *associated* with more success for a model of vehicle, encouraging car manufacturers to consider strategies for increasing hybrid car sales. This result could be attributed to the relationship between the proportion of hybrid cars produced and the success of a particular car manufacturer. From a policy-making and consumer standpoint, identifying factors that affect the overall sales of vehicles could prove useful for making decisions regarding the purchasing of vehicles.

From the game theory implementation, it was found that it would benefit all competing companies to have a higher percentage of hybrid sales. Since we found that the proportion of hybrid cars affects sales in the demand model, then we looked at different strategies that companies can make regarding the proportion of hybrid cars to produce and how it would affect their sales. For all three scenarios, the results suggest that the best strategy for all companies is to increase hybrid sales. These results show how hybrid technology is imperative for automobile companies to incorporate in order to be competitive. Further analysis could include a more in-depth analysis on the effect of brand positioning and company size on market shares.

The third step of the methodology involved technology forecasting of hybrid and non-hybrid engines. Using the sustainability metric, Energy Impact Score, we generated a total of 3 S-curves corresponding to the EIS of the Toyota Camry hybrid, the Toyota Camry non-hybrid, and a combined hybrid and non-hybrid curve. It is important to note that the backwards S-curve shown in the model represents the tail-end of the S-curve because it already passed the inflection point for the years

2002-2013. Our results showed that the saturation level of the EIS for hybrid vehicles is almost half of non-hybrid vehicles. This can be taken as justification as for why automotive makers should invest in a larger proportion of hybrid sales. That is, non-hybrid vehicles will likely never achieve the same level of sustainability as hybrid vehicles. In addition, since hybrid engines are predicted to continually improve in sustainability for the next 10 years, there is further motivation for automotive manufacturers to invest in hybrid vehicles.

4 Conclusion

This paper explored the factors that impact overall sales, and found that the proportion of hybrid sales, the year, and the type of car significantly influenced sales. It was also found that behavior of competitors' impacted the overall sales of a particular vehicle, highlighting the need for companies to consider the proportion of hybrid sales in competitive analysis. Lastly, we found justification for investment in hybrid technologies since improvement to sustainability scores are predicted to increase substantially for the next 10 years. Future work should incorporate larger databases of vehicle sales information in order to achieve a more generalizable model for predicting sales trends. In addition, we recommend that policies that encourage adoption of hybrid technologies (such as tax incentives) could benefit both automobile makers and consumers. Other measures of sustainability (such as amount of energy used to manufacture batteries) should be considered in future research regarding sustainability in order to increase the validity of the results.

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Sustainability Adoption Trend Analysis

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Abstract. The sustainability trend in the automotive market has been analyzed. A dataset of cars was elicited from select companies that have increased their market share in the United States automotive market over the past decade. In the first part, a linear regression model is developed to evaluate how the market share is influenced by key vehicle characteristics, and in particular, to evaluate the role of sustainability in that analysis. For the second part, game theory has been applied to see how market dynamics change in relation to sustainability moves of two competitors. The third part uses technology forecasting techniques to suggest which technology to invest. The results of the paper show that, in the long term, sustainability will be a significant factor in determining a company's market share. Investing in manufacturing processes that reduce the cost of battery systems can support the competitiveness of hybrid vehicles but so too can investing in research and development to reduce the energy density gap between gasoline and batteries.

Keywords: sustainability, game theory, technology forecasting.

1 Introduction

As a society, we are becoming more aware of non-renewable resource depletion. Future generations are discussing the utility and potential of sustainable resources in the current market. Behavior regarding sustainability is extremely complex as it deals with factors such as politics, beliefs versus actions, and socio-economic status. Several set-backs in industry exist in regard to producing sustainable products such as lack of clarity on how to implement sustainability in industry, and possibly most important, when to release a sustainable product into the market. Industry needs to know how the market will behave and react.

Increased awareness and education levels impact sustainable behavior; however, this is an ongoing research topic. Our objective is to research sustainability trends in terms two automotive competitors to see how the market reacts. This will be done through demand modeling and predicting market share of certain vehicles and their attributes, game theory, and technology forecasting of a sustainable vehicle attribute and how it pertains to investment. This paper is divided into background information, the perception of sustainability, a game theory application, battery technology forecasting, and conclusions.

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2 Background

The Environmental Protection Agency (EPA) has been categorizing sustainability for some time and has designated carbon dioxide (CO2) as a "... greenhouse gas that traps the earth's heat and contributes to the potential for global warming" [1]. There are many contributors to this effect from the automotive industry including the development, manufacture, transportation, use, and infrastructure required to maintain a fleet of vehicles both in the U.S. and across the globe. Omar [2] performed an energy audit of the amount of energy and CO2 generated during an energy audit of a typical light passenger vehicle over ten years and concluded that end-user use corresponds with approximately 90% of the total energy and greenhouse gas emitted during the life of a vehicle.

Manufacturing and transportation costs are a difficult metric to reduce in the abstract so a quick investigation into why material and consumer use contribute so heavily to these sustainable metrics is explored. The energy audit by [2] showed a typical breakdown of materials by weight for a typical sedan. The standout is that mild steel contributes 44% of the total weight of the vehicle. There is a trend in manufacturing to incorporate composites and plastic to reduce vehicle weight and to increase fuel economy by allowing for more aerodynamic shapes to be designed. The metalworking required to generate steel and the machine it is energy intensive and can relate to global effects.

The weight of the vehicle has a direct correlation with energy consumption for both manufacturing and consumer use. Data collected by [2] demonstrate the relationship between vehicles' energy consumption per kilometer of travel and fuel economy versus curb weight, and greenhouse emission versus energy consumption for a variety hybrid and non-hybrid vehicles. It suggests that decreases in weight of the vehicle as well as increases in fuel economy can lead to more sustainable vehicles.

Vehicles are a commodity and their influence on sustainability can be controlled by consumers through the purchase of vehicles that are lightweight *and* have good fuel economy. There are many other factors affecting the automotive industry to address sustainability, and the reader is encouraged to read through [3] for an excellent review discussing design for sustainability in the automotive industry. In the end, consumers play a large role in determining the viability of a product and so Sect. 3 discusses a method to determine if sustainability is important or even relevant to consumers during their vehicle purchasing decision.

3 Perception of Sustainability

How has the consumer-perceived value of sustainability changed across time? What is to be expected in the near future?

We first focus attention on the customer perceived value of sustainability, how this has changed across time, and how it is expected to be in the near future. The focus is on the value that sustainability has for a customer, how sustainability contributes to make a specific product more desirable, and how sustainability increasing the value of a product for a customer. The analysis presented here is based on the automotive market, but the principles can be implemented in many other different fields, and for different kind of products.

3.1 Methodology

To understand if and how sustainability contributes value for the customer, a benchmark was defined and data were collected. We focus on two car makers that have been able to increase their market share in the last decade, based on trends collected from [4], namely Toyota and Honda. These two car makers have increased from 9.1 to 14.1% for Toyota, and from 6.5 to 9.6% for Honda in this time. They are considered in our analysis as two companies that seem to be trending together and thereby making them direct competitors. A sample dataset is collected of their vehicles, including a hybrid and a gasoline vehicle. The combination of hybrid and non-hybrid is used to determine if there are synergies for the automaker via a halo effect. Two models of cars from each manufacturer have been taken into account in the dataset, the Toyota Prius, Toyota Corolla, Honda Civic Hybrid, and Honda Accord.

Since these two companies have increased in market share, they may have successful features that other companies do not have. A regression model is developed for the analysis as (1), where the dependent variable (y) is the market share. The regression is a linear model with two-factor interactions.

$$y(x) = \beta_0 + \sum_{i=1}^{n} \beta_i x_i + \sum_{i=1}^{n} \sum_{j>i}^{n} \beta_{ij} x_i x_j \tag{1}$$

The market share depends on many variables including primary (e.g., price, reputation, and fuel economy), secondary (e.g., style), etc. A subset of characteristics was chosen that could be readily gathered by consumers online. The independent variables included are as follows:

- Year – the model year of the vehicle.
- Manufacturer's Suggested Retail Price (MSRP) – nominal price of the car.
- Curb weight – total mass of the vehicle with standard equipment. It can be viewed as a surrogate metric for car dimension, perceived safety, sustainability, and reliability of a vehicle.
- Combined Fuel Economy – in miles per gallons, a well know index of efficiency performance of the engine, which can be used as an estimation of fuel consumption and expenditure for a particular kind of car.
- Greenhouses Gases Emitted – in tons per year, a direct metric of sustainability of a car. It includes carbon dioxide, methane, and nitrous oxide.

These variables are some of the most common attributes that are accessible to a consumer when evaluating a vehicle. These variables are advertised by the car makers and the metrics are well known. Other variables can be elicited for this problem, but these five attributes are simple and are common to consumers when describing a vehicle purchasing decision. These attributes were collected from [5] and [6] for 2001 through 2012 when available.

3.2 Results

A regression analysis was performed using best subset analysis, a method that examines all possible combinations of predictor variables using (1) as the model, with centered predictors. The model with the highest coefficient of determination (R^2) is selected — the generated model has an R^2 of 0.916 with 43 samples. Model coefficients and statistical measures is shown in Table 1.

Table 1. Regression Model Output

Predictor	Centroid	Estimate	Standard Error	t-Statistic	p-value
Constant (β_0)	—	1.448700	0.095081	15.237	3.20E-16
Year	2006.91	0.067261	0.027279	2.466	0.019221
MSRP	20781.70	-0.000179	0.000085	-2.124	0.041512
Weight	2864.37	0.004038	0.001299	3.108	0.003935
MPG	34.465	-0.121992	0.089362	-1.365	0.181727
Greenhouse	4.602	-0.528704	0.756184	-0.699	0.489494
Year*MSRP	—	-0.000006	0.000005	-1.227	0.228865
Year*Greenhouse	—	-0.097961	0.043220	-2.267	0.030311
MSRP*MGP	—	0.000071	0.000017	4.115	0.000253
MSRP*Greenhouse	—	0.000767	0.000187	4.095	0.000268
Weight*Greenhouse	—	-0.002912	0.000954	-3.053	0.004540

The model incorporates interactions which make interpretations more complex, but we can observe that the model suggests several features relevant to sustainability and describe them here briefly. We note that *Greenhouse* has a strong negative coefficient and, when coupled with *Year*, *MSRP*, and *Weight*, suggest that market share may decrease if it is not addressed. This is consistent with a greener perspective that has been touted in recent years. *MPG* also has a general trend of negative impact on market share implying that consumers are concerned with fuel economy in the current economy; improvement in fuel economy is expected through time. *MSRP* when coupled with *Year* has a negative coefficient, suggesting that decreases in prices over time should increase market share. *MSRP* when coupled with *Greenhouse* has a positive coefficient suggesting that greenhouses gases emitted are a metric related to engine performance or luxury, i.e., more performance tends to yield more emissions. *MPG* coupled with *MSRP* has a positive coefficient suggesting that as fuel economy increases, the more the customer is willing to pay. This can be viewed as a basic metric of sustainability; the customer may not be directly interested in environmental sustainability, but may likely be interested in saving money with fuel economy.

3.3 Discussion

The linear regression model suggests that sustainability has increased customer perceived value throughout years based on market share and a few consumer predictors. This result supports push for competitors to develop more sustainable vehicles by investing in sustainable energy systems and features. The regression describes overall market trends, but how does a company position itself to gain more market share? Game theory, described next, is a tool that can help.

4 Game Theory

How do you expect the market dynamics to change in relation to sustainability moves of the two competitors?

A game theory matrix is a game that has two players that have a finite strategy set with a specified number of elements, and the payoffs are posed in an $S_1 \times S_2$ matrix. Player 1 and player 2 independently and simultaneously choose a strategy $s_1 \in S_1, s_2 \in S_2$, respectively and receive their designated payoff, $u_i(s_1, s_2)$. Toyota and Honda are competitors in the car industry and will be represented as two players in our game.

4.1 Methodology

A model was used to predict market share for the two companies, Honda and Toyota. The model includes the same dependent variables as in Sect. 3, and the dependent variable output predicted by the model is the percentage of the market share of a hypothetical vehicle. The sustainability aspect of this model is the amount of greenhouse gases emitted. The purpose of this game is to see how market dynamics (or market share) change in relation to sustainability moves, and in particular greenhouse gases emitted from different vehicle designs.

4.2 Results

Different hypothetical designs are created for each company, and a regression model is used to predict the market share of that vehicle for each company. The application of the game theory model is presented using the scenario in which both companies use the same model to investigate interactions between one another. The method can also be applied independently to look at individual strengths.

Five car designs were chosen for each company based upon the five attributes: Year, MSRP, Weight, MPG, and Greenhouse. These car designs can be viewed in Table 2.

The Nash Equilibrium is Toyota T2, Honda H5. This indicates that if Toyota were to choose their T2 vehicle design, Honda should choose their H5 vehicle design, and vice versa. This is the optimal scenario for each company as neither company has an incentive to deviate. The game can become more complicated by inserting external factors such as competition for customers, customer loyalty, and so on.

Table 2. Hypothetical scenario vehicle builds for Toyota and Honda

Scenario	Model	Year	MSRP	Weight	MPG	Greenhouse	Market Share
T1	Toyota	2012	26900	3042	50	2.97	0.962
T2	Toyota	2012	25500	3042	50	2.97	1.459
T3	Toyota	2012	27900	3000	51	2.96	0.582
T4	Toyota	2012	26900	3000	51	2.95	0.841
T5	Toyota	2012	28000	2900	55	2.90	0.976
H1	Honda	2012	24200	2853	44	3.37	0.181
H2	Honda	2012	23000	2853	44	3.37	0.752
H3	Honda	2012	25800	2800	48	3.50	0.349
H4	Honda	2012	24200	2800	48	3.50	0.495
H5	Honda	2012	27500	2750	50	3.60	0.990

4.3 Discussion

Based upon these games, we can see that in the in the long term sustainability should increase market share, but in the short term it does not. If the company is to invest long term, a strategy can emerge that requires development time and cost now, but will have dividends later. What technology will provide the most "green" alternative? Or will better hedge against competition? A forecasting technique is now used to determine which technology might bolster a company's green appeal.

5 Technology Forecast

What is one of the technologies you are able to justify investing into? How do you expect to see the performance (and may be cost) to change of this technology?

An issue that Hybrid electric vehicles have is that their competition (gasoline powered automobiles) uses a very energy dense fuel (∼12800 Wh/kg) to provide power and range. Battery technology has yet to progress at a pace with Moore's Law [7] which states that many technologies have been doubling their performance every 18 months due to fundamental chemistry inherent to a battery's inner workings [8].

Certainly there must be a technology that can achieve a high energy density so that batteries can compete with gasoline engines. Technology forecasting is a method that uses historical data to predict future characteristics of useful technological machines, procedures, techniques, protocols, etc. The primary use of the method is to analyze the current state-of-the-art and determine, through a regression analysis, how the technology will perform in the near future.

The energy densities of various battery technologies are forecast and analyzed to determine if investing in a particular technology will become competitive or if a new technology should be invested. The following sections describe the methodology of forecasting and their interpretations.

5.1 Methodology

The technology life-cycle describes the commercial impact of a product through research and development through profitability. The "shape" of the curve describing a technology is often referred to as an S-curve because of its slow growth through its conception and introduction, its steady growth through product maturity, and its slowed growth at the end of its life-cycle at which point a newer technology assumes a similar pattern. This shape can be parameterized as (2) where: $f(t)$, performance of a metric over time t; f_0, performance offset time for introduction; S, scaling factor for total growth; α, rate of growth; β, shifting parameter.

$$f(t) = f_0 + S\frac{\exp(\alpha t + \beta)}{1 + \exp(\alpha t + \beta)} \quad (2)$$

Equation (2) is essentially a logistic regression with a scaling term S and an offset term f_0. The parameters are estimated using a nonlinear regression routine that uses historical data over time for each technology metric of interest. The data used in the analysis was taken from [9] for various primary batteries including: Zn-Carbon, Mg/MnO2, Zn/HgO, Alkaline-MnO2, Li/MnO2, Li/SO2, Li/SOCI2, and Zn/Air. Details about the batteries, their characteristics, applications, and cost can be found in [9].

5.2 Results

The nonlinear regression model described in (2) was implemented and the results are shown in Table 3. The table shows the regression coefficients (appropriate units are assumed) and the predicted performance of the technology in the year 2013 and 2020.

Table 3. Results of the regression analysis of forecasting various battery technologies

Technology	f_0	S	α	β	$f(2013)$	$f(2020)$
Zn-Carbon	55.609	41.695	0.506	-1001.820	97.3	97.3
Mg/MnO2	80.217	37.114	0.090	-177.560	116.9	117.1
Zn/HgO	38.189	101.846	0.061	-120.145	136.1	137.4
Alkaline-MnO2	62.235	102.268	0.473	-936.427	164.5	164.5
Li/MnO2	145.335	87.388	0.551	-1093.350	232.7	232.7
Li/SO2	127.233	161.985	0.316	-622.261	289.2	289.2
Li/SOCI2	17.748	305.175	0.505	-996.407	322.2	322.9
Zn/Air	77.890	301.797	0.179	-352.650	379.4	379.6

5.3 Discussion

The linear regression indicates that each technology appears to be saturated with Zn/Air being the largest at $\sim$379 Wh/kg. Zn/Air does, however, suffer from environmental conditions and would most likely deteriorate during use in outdoor settings such as driving. Li/SOCl2 is the next highest with ∼323 Wh/kg, which is still quite high when compared to current lithium-ion secondary batteries that have an energy density of ∼130 Wh/kg [9]. Li/SOCl2 currently cost quite a bit more than conventional battery systems which may diminish its utility. However, the regression performed during technology forecasting does not incorporate questions of cost – it only describes the performance over time.

6 Conclusions

In this paper, the role of sustainability in the consumer perceived value has been analyzed. From the linear regression model we can hypothesize that sustainability has increased customer perceived value throughout the years. The regression ignores contingency variables such as fuel prices and economic crisis, but as a simple model it captures the effect of sustainability in relation to market share quite well. This result of the model could leads competitors to develop more sustainable vehicles by investing in sustainable energy systems and features. Investment in "greener" technology is justified by a higher market share over years. For what concerns technology investment justification and performance expectation, two possible solutions can be under-taken: either invest in manufacturing enhancements of this battery type or to begin research and development in a different technology. Further research should focus on the impact of contingency variables and how they affect consumer purchasing habits.

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Eliciting a Mode of Transportation to Improve Product Life Cycle Performance

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Abstract. The purpose of this paper is to describe how to implement the utility theory to a supply chain problem. In this problem, two different modes of freight transportation are compared to improve life cycle performance of a mass product: trucks and trains. First, the problem is described, the criteria and attributes are introduced and the dataset for this problem is defined. Then, a description of the utility theory model is conducted, explaining the choice of the multiplicative model instead of the additive one. After that, the utility functions for each attribute are elicited, and a trade-off analysis is conducted in order to define indifference points and to calculate the scaling factors. Then, the aggregation function is formulated for this problem, the alternatives ranked, and the best mode of transportation elicited.

Keywords: utility theory, transportation, PLC, product life cycle.

1 Introduction

The utility theory is applied to a supply chain problem: eliciting a mode of transportation to improve product life cycle performance of a particular kind of product (refrigerators) on a specific environment (European continent). The problem has been drawn according to [1]. However, [1] does not directly take into account how to ship the refrigerators: there is no information about the mode of transportation used. In order to improve this shortcoming, the aim of this paper is to elicit the best alternative to ship refrigerators.

More specifically, two different modes of freight transportation are taken into account for this problem: trucks and trains. The first mode of transportation is represented by three different types of general freight truck, divided by mileage: less than 250 miles (truck type A), between 250 and 500 (truck type B), and over 500 miles (truck type C), according to [2]. Trucks are well known to be flexible, they require little time to be loaded, and they do not need railroad facilities: they can easily go wherever there is an asphalted road. Trucks' drawbacks are pollution emissions and higher cost per ton per mileage.

On the other hand, trains are reasonably flexible, less expensive than trucks and produce much less emissions. The main drawback of trains is the journey time: given that trains usually may carry a large quantity of goods, loading time is consequently longer compared to trucks. In this analysis, four different trains have been taken into account: Heavy Unit Train, Mixed Freight Train, Intermodal Train, and Double-stack Container Train [2].

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2 Criteria and Attributes

In order to rank the alternatives, three criteria have been considered relevant for this problem: flexibility, cost, and emissions. For each criterion, different attributes have been used, as follows:

- Flexibility:
  - Maximum distance that the mean of transportation can cover (max dist.)
  - Maximum load that can be carried (max load)
  - The average speed of the truck or train (avg. speed)
  - The easiness to restore, repair, and replace truck or train (eas. to R/R)
- Environmental Impact:
  - The amount of NO_X gas emitted by the mode of transportation (NO_X)
  - The amount of CO_2 gas emitted by the mode of transportation (CO_2)
  - Environmental Risk: based on the overall environmental impact and footprint (env. risk)
- Average Cost per Ton Mile (avg. cost p t-m)

Some data has been drawn by [2], others (avg. speed, eas. to R/R and env. Risk) have been calculated by using some assumptions and making estimation: for this reason the data in input is affected by some variations, and it introduces a source of uncertainty in the model. For instance, data may slightly vary depending on the driving condition, the maintenance status of the engine, the type of road and several other factors. For this purpose, utility theory has been developed for this problem. The dataset for the problem is reported as follows:

Table 1. Attribute dataset ([2], except for avg speed, easinees to R/R and env. risk)

	Flexibility (max)				Environmental Impact (max)			Cost (min)
	Max Dist. (miles)	Max Load (tons)	Avg. Speed (mph)	Eas. to R/R	NO_X (g/ mile)	CO_2 (g/ mile)	Env. Risk	Avg cost p t-m (cents)
Truck type A	350	7.26	23.68	8.5	2.390	34.88	1	21.17
Truck type B	750	14.77	27.61	10	1.88	94.62	2	8.94
Truck type C	1250	15.61	30.41	8	16.12	134	2.50	7.69
Heavy Unit train	1000	10500	9.62	1	0.257	22	10	1.19
Mixed Train	500	6300	7.81	3.5	0.322	18.60	7.5	1.20
Intermodal Train	1750	3360	24.65	5.5	0.603	17	6	2.68
Double stack	1750	6720	18.42	2	0.400	15.40	7	1.06

3 Utility Function Elicitation

In this section, the utility function elicitation is performed. First, for each attribute, it is necessary to define a function and its parameters. In this way, for each attribute, it is possible to calculate the utility that corresponds to each level of the attributes itself. The utility range goes from zero to one. The utility function gives a value of zero to the worst level of each attribute, and a utility of one to the best level. The largest or the smallest number of each attribute is considered the best or worst case depending on the minimization or maximization of that particular attribute.

3.1 Mathematical Model of the Utility Function

In this section, we first describe the method used to determine the utility function for each attribute. Among the several different types of function that can be used, the exponential function is the most popular. This is due to the fact that it is sufficient to define only one parameter (RT) to describe the curve. In this case study, we use the exponential function, which is reported as follows:

$$U(x) = A - B * EXP\left(-\frac{x}{RT}\right) \tag{1}$$

Where U(x) is the utility of consequence x; RT is the parameter that determines the curvature and it is called risk tolerance (it determines if the DM is risk adverse, risk neutral or risk seeking); EXP is the exponential function; A and B the scaling parameters. These two parameters depend on RT too, as follows:

$$A = \frac{EXP\left(-\frac{Low}{RT}\right)}{\left[EXP\left(-\frac{Low}{RT}\right) - EXP\left(-\frac{High}{RT}\right)\right]} \tag{2}$$

$$B = \frac{1}{\left[EXP\left(-\frac{Low}{RT}\right) - EXP\left(-\frac{High}{RT}\right)\right]} \tag{3}$$

In order to define the RT parameter, three points must be defined. Two points are the end points of the dataset, corresponding to the best and the worst case; the third point is chosen by the decision maker by using the certainty equivalent. This is the amount of payoff (in terms of utility) that the decision maker is willing to receive to be indifferent between that payoff and a given gamble [3]. The certainty equivalent is calculated as follows:

$$CE = -RT * LN\left[\frac{A - EU}{B}\right] \tag{4}$$

Where CE is the certainty equivalent; RT is the risk tolerance parameter (that we want to find); LN is the natural logarithm function; and EU the expected utility.
In order to estimate the correct value of RT for three given points (best case, worst case, and certainty equivalent), it is possible to use the following:

$$A - B * EXP\left(-\frac{CE}{RT}\right) = .5\left[A - B * EXP\left(-\frac{High}{RT}\right)\right] + .5\left[A - B * EXP\left(-\frac{Low}{RT}\right)\right] \tag{5}$$

Equation (5) states that the utility of CE must be equal to the expected utility of the lottery. The value of RT that verifies this equivalence should be used to describe the curve.

3.2 The Utility Function Elicitation for Each Attribute

In this section, the utility functions are elicited for each attribute. For any of them, the assessment inputs are chosen; the risk tolerance and the scaling factors are calculated; the function is drawn; and finally the utility for each alternative is reported.

Table 2. Assessment inputs and outputs for the attributes

	Max Dist. (miles)	Max Load (tons)	Avg. Speed (mph)	Eas. to R/R	NO_X (g/ mile)	CO_2 (g/ mile)	Env. Risk	Avg. cost p t-m (cents)
Assessment Inputs								
Worse Payoff	350	7.26	7.81	1	16.12	134	10	21.17
Certain Equiv.	650	1500	15	4	12	90	7.5	15
Better Payoff	1750	10500	30.41	10	0.257	15.4	1	1.06
Assessment Outputs								
Risk Tol.	465.03	2181.97	14.11	6.23	-6.89	-109.77	-4.36	-11.64
A (2)	1.052	1.008	1.253	1.309	1.111	1.514	1.146	1.216
B (3)	2.233	1.012	2.178	1.537	0.107	0.447	0.116	0.197

All the functions have been built from a risk adverse prospection. In fig.1, the utility functions for the eight attributes are reported. It is possible to notice the risk aversion in the concavity of the curves, as follows:

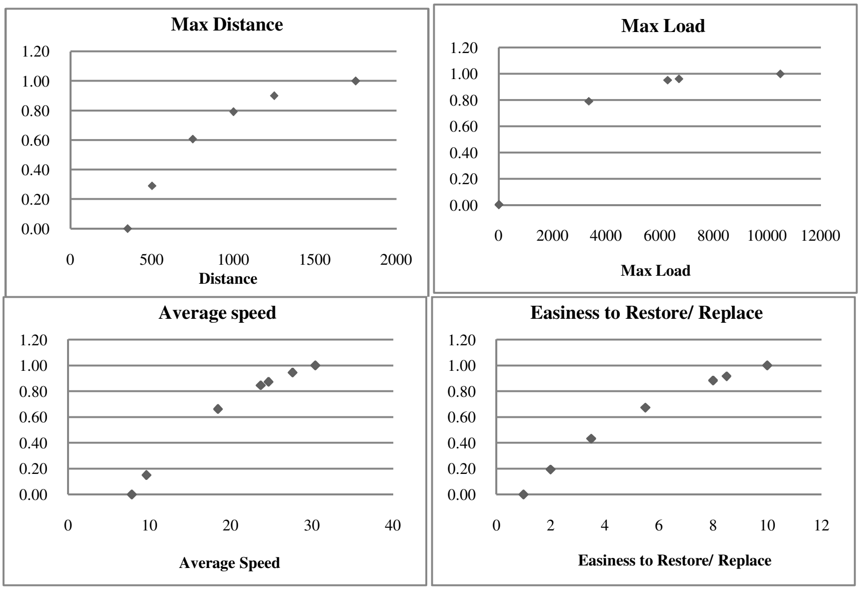

Fig. 1. Table 3. Utiliy Functions

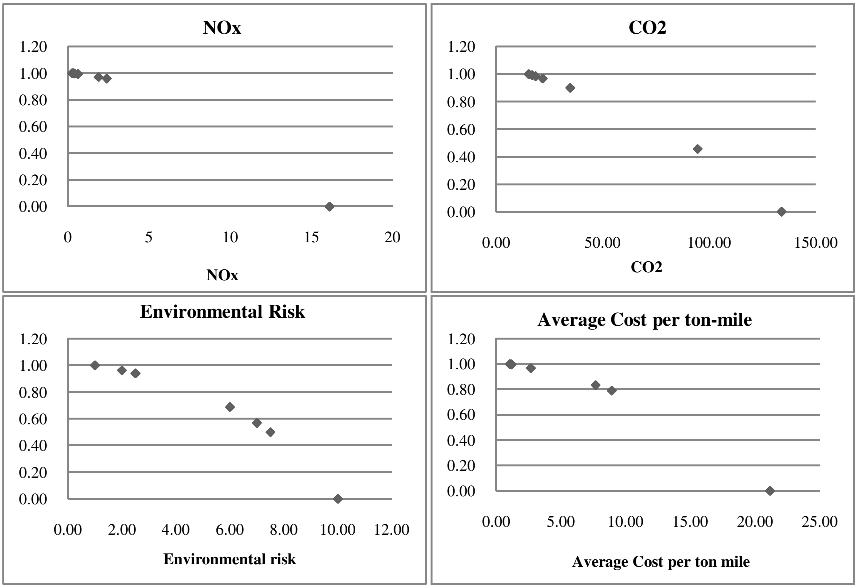

Fig. 1. (*continued*)

4 The Multiplicative Aggregation Method

The choice of the multiplicative method is required whenever the attributes involved are correlated among each other. As soon as there is at least one significant correlation among two variables, a multiplicative model must be used. In our problem, there are some strong correlations (positive or negative) among the attributes, which are reported as follows:

- Average cost per ton-mile is negatively correlated (ρ= -.72) with the maximum load: the higher is the load, the lower is the average cost per ton-mile
- The pollutant gases NO_X and CO_2 are positively correlated (ρ= .85)
- The environmental risk is highly correlated with the maximum load (ρ= .97)

Since there are some correlations among the problem's attributes, the multiplicative model has been implemented. According to [4], the overall utility is given by the following:

$$U(x_1, \dots, x_n) = \frac{1}{K}\left[\prod_{i=1}^{n}(K k_i u_i(x_i) + 1) - 1\right] \quad (6)$$

Where, u_i is the utility of the attribute x_i and it is defined by the utility function, k_i is the scaling factor of the attribute x_i, and it will be defined using a trade-off comparison analysis among the attributes, and K is a non-zero solution to the equation [4]:

$$K + 1 = \prod_{i=1}^{n}(1 + K\,k_i) \quad (7)$$

The utility function have been elicited for each attribute, and the value of $u_i(x_i)$ have been defined (by using values in Table 2). Then, the k_i are defined, throughout a trade-off comparison among the attributes.

5 Scaling Factors Elicitation

In this section, the scaling factors for the multiplicative model are defined (k_i). First, it is necessary to rank the attributes, and then, a value for the scaling factor of the most important criteria is assigned. The other scaling factors are defined by comparing them with an equivalent level of the most important criteria.

5.1 Criteria Ranking

The first step is to define the ranking of the each attribute. The criteria have been ranked as follows:

Table 3. Attributes ranking

Criteria	k_i	Attribute	Rank
Flexibility (maximize)	1	Max Dist. (miles)	2
	2	Max Load (tons)	2
	3	Avg. Speed (mph)	7
	4	Eas. to R/R	3
Environmental Impact (minimize)	5	NO_X (g/ mile)	5
	6	CO_2 (g/ mile)	6
	7	Env. Risk	4
Cost (minimize)	8	Avg cost p t-m (cents)	1

The most important criterion is cost. The maximum distance and the maximum load are both equally important and they occupy the second position of the ranking. The easiness to replace the mean of transport is in the fourth position, followed by environmental risk, and by the two pollutant gases (NO_x and CO_2). The last position belongs to average speed. As specified in the previous sections, the average speed is considered to be so relevant for this problem. Consequently, k_i's are ranked as follows [5]:

$$k_8 > k_1 = k_2 > k_4 > k_7 > k_5 > k_6 > k_3 \quad (8)$$

5.2 Determination of the Indifference Points

The third step is to determine the scaling factors for all of the attributes. One method is determining the indifference points by comparing the best level of any sub-criterion (x_i) to an equivalent trade-off level of the most important criterion (x_8). According to

(8), the most important scaling factor is average cost per ton mile, and its value has been assumed equal to the following:

$$k_8 = 0.4 \tag{9}$$

The trade-offs for the other attributes have been assumed equal to the following:

$$(x_1 = 350, x_8 = 4.5) \approx (x_1 = 1750, x_8 = 21.17)$$

$$(x_4 = 1, x_8 = 5.5) \approx (x_4 = 10, x_8 = 21.17)$$

$$(x_7 = 10, x_8 = 8) \approx (x_7 = 1, x_8 = 21.17)$$

$$(x_5 = 16.12, x_8 = 10) \approx (x_5 = 0.257, x_8 = 21.17)$$

$$(x_6 = 134, x_8 = 13) \approx (x_6 = 15.4, x_8 = 21.17)$$

$$(x_3 = 7.81, x_8 = 18) \approx (x_3 = 30, x_8 = 21.17)$$

The trade-offs lead to:

$$k_1 = k_2 = .343, k_4 = .316, k_7 = .265, k_5 = .224, k_6 = .245, k_3 = .116 \tag{10}$$

5.3 K elicitation

In order to calculate the value of K, it is necessary to plug-in the values of the k_i's that have been determined by the trade-off comparison, and substitute them in (7), where K is a non-zero solution of the equation (7). Among all the roots of the equation, the expert choice is to choose the largest one. The highest non-zero K value of the equation is K = -0.90974.

6 Aggregation Utility and Results

In this section, the utility function is finally calculated. Using (6), it is possible to plug in the data we have for each alternative, calculate the overall utility for each alternative, and rank them according to it. The result is the following:

Table 4. Utility and ranking for each alternative

Alternative	Utility	Ranking
Truck type A	0.732657	7
Truck type B	0.866891	5
Truck type C	0.815110	6
Heavy Unit train	0.874521	4
Mixed Train	0.883914	3
Intermodal Train	0.958810	1
Double stack	0.941066	2

The best alternative is the intermodal train, which scores pretty high in the three most important attributes: max distance, max load and average cost. In general, it is possible to notice that the overall utility score of the four trains is slightly higher than the three trucks. This is due to the fact that trains score higher than trucks on “maximum distance”, “average cost”, and “maximum load”. Moreover, trains have a higher score for what concerns the environmental impact’s attributes (e.g. NO_X and CO_2 emissions are lower for trains than for trucks).

7 Conclusions

In this paper all the aspects of utility theory have been covered. First, the problem has been introduced, the attributes have been defined, and the utility functions for each attribute have been elicited. Then, the multiplicative aggregation model introduced, indifference points defined, scaling factors calculated, and the K elicited. Finally, the alternatives have been ranked based on the overall utility: the best alternative is the intermodal train and the worst is the general freight truck type A. In general, trains have a higher score compared to trucks. This is due to the fact that trains have a higher utility in the most important attributes, as average cost, max load, max distance, and gas emissions.

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