J. Carlos Prado-Prado
Jesús García-Arca *Editors*

Annals of Industrial Engineering 2012

Industrial Engineering: Overcoming the Crisis

Springer

Annals of Industrial Engineering 2012

J. Carlos Prado-Prado · Jesús García-Arca
Editors

Annals of Industrial Engineering 2012

Industrial Engineering: Overcoming the Crisis

Springer

Editors
J. Carlos Prado-Prado
Jesús García-Arca
Escuela de Ingeniería Industrial
Universidad de Vigo
Vigo
Spain

Collection editors
Lorenzo Ros-McDonnell
Escuela Técnico Superior de Ingeniería Industrial
Universidad Politécnica de Cartagena
Cartagena
Spain

Luis Onieva- Giménez
Grupo de Ingeniería de Organización, Dpto. de Organización Industrial y Gestión de Empresas
Escuela Técnica Superior de Ingenieros, Universidad de Sevilla
Seville
Spain

ISBN 978-1-4471-5348-1 ISBN 978-1-4471-5349-8 (eBook)
DOI 10.1007/978-1-4471-5349-8
Springer London Heidelberg New York Dordrecht

Library of Congress Control Number: 2013919803

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

Welcome to CIO 2012—6th International Conference on Industrial Engineering and Industrial Management and XVI Congreso de Ingeniería de Organización—that has been developed in Vigo (Spain) under the motto *Industrial Engineering: Overcoming the Crisis*.

CIO 2012 gives continuity to the series of annual Conferences initiated in September 1986 in La Rábida (Huelva, Spain). This conference is a very significant scientific event in Business and Operations Management and related areas. Researchers, academics, scientists, and managers of diverse parts of the world have the opportunity to exchange experiences, new ideas and topics, in those fields related to Industrial Engineering.

The 6th International Conference addresses the great multidisciplinary field formed by Industrial Engineering, from an international point of view.

This book contains a selection of the papers that were accepted at the CIO 2012 International Conference, covering consolidated and emerging topics of the conference scope and they may help readers to gain a deeper understanding of how Industrial Engineering could contribute to overcome the economic crisis.

This selection has been organized in six parts:

- Business Administration and Economic Environment
- Technological and Organizational Innovation
- Logistics and Supply Chain Management
- Production and Operations Management
- Management Systems and Sustainability
- Papers Prize–Award

We would like to express our gratitude to all the authors, reviewers, and the Organizing Committee for their enthusiastic work and magnificent support during CIO 2012.

J. Carlos Prado-Prado
Jesús García-Arca

Contents

Part I
Business Administration and Economic Environment

Chapter 1
A Characterization of Types and Determinant Factors for Corporate Entrepreneurship: A Case Study Based Analysis

Eneritz Onaindia Gerrikabeitia, Unai Goyogana Quesada and Carlos Ochoa Laburu

1.1 Conceptual Model

The interest in "business creation" (entrepreneurship) and its protagonists (entrepreneurs) are a classic issue in economic literature and in Management literature specifically. This issue is specially recurrent and relevant in economic crisis times. Beginning with the illustrious examples of R Cantillon and J.B. Say in XIX century and Josef Schumpeter (1934), currently it is an academic field perfectly established, with high impact specialized publications that produce a fair amount of literature. Since 1980 decade Intrapreneurship and Corporate Entrepreneurship are also a most relevant field of study

As a synthesis of some of the more relevant models to explain the Corporate Entrepreneurship process (Guth-Ginsberg 1990; Covin-Slevin 1991; Lumpkin-Dess 1996; Narayanan et al. 2009) propose a new model that we can see in Fig. 1.1.

The model logic is:

1. The basic concept as presented in Covin-Slevin (1991) was the Entrepreneurial Orientation of the company. A positive Entrepreneurial Orientation has a positive effect on the outcomes of the company especially in the economic outcomes (profitability, sales increase, market share). The cause-effect relationship between them may be reversible. Good outcomes may favour the Entrepreneurship.
2. There are a set of Factors/Agents, External and Internal to the company that may determine the Characteristics of the new activities and by extension, the outcomes of them. The cause-effect relationship between them as well as it intensity are contingent. That's why they do not act always the same but they depend very much on the possible combination between them.

E. O. Gerrikabeitia · U. G. Quesada · C. O. Laburu (✉)
Dpto. Organización de Empresas, UPV—EHU. Escuela Politécnica.
Universidad del País Vasco, Plaza de Europa 1 20018 San Sebastián, Spain
e-mail: carlos.ochoa-laburu@ehu.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_1, © Springer-Verlag London 2014

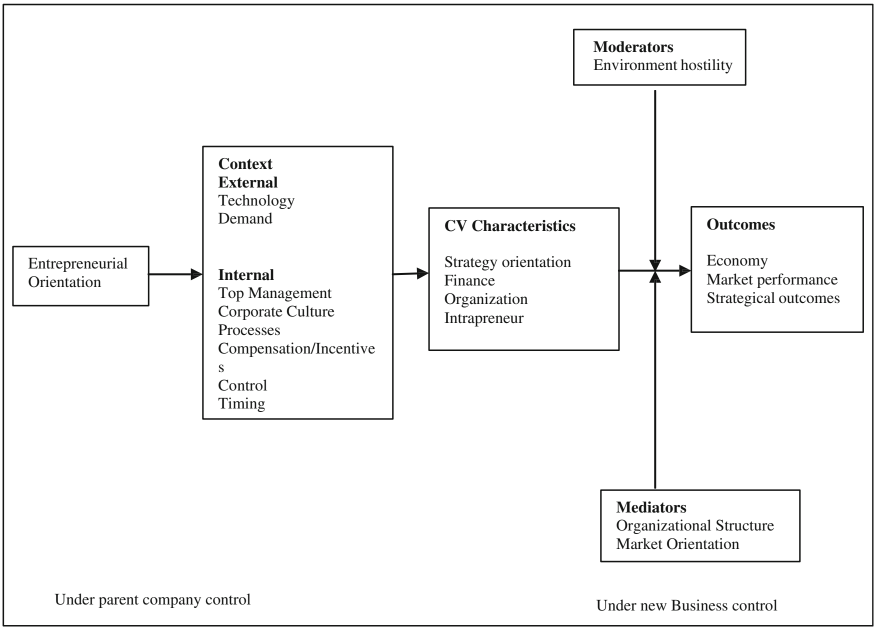


Fig. 1.1 An integrative model for corporate venturing: Narayanan et al. (2009)

Many studies on Corporate Entrepreneurship published in the last 30 years have not treated the same all elements in Narayanan, Yang and Zahra model. They have not even followed a similar cause-effect logic. Thus there is plenty of room for new research either to confirm the proposition of this model or to propose new factors.

As a starting point, we analyse in our work companies with strong experience in Corporate Entrepreneurship (CE) that have obtained positive outcomes of them. Hence the phocus of our study is:

- The types of CE: development of new business related or no related to the current activities of the company (technology, markets, customers), development of external new business (Corporate Venturing) or internal new activities (Strategic Renewal of the company), financing of these new business/activities (only parent company capital or partnership with different agents as customers, suppliers, competitors, research centres including universities, venture capital).
- The "Context", this is the factors that help or prevent Corporate Entrepreneurship that can be **External** to the company (technology, the characteristics of the industry demand, the competitive structure of the industry or **Internal** to the company (Top Management involvement, corporate culture (proclivity to changes, situation of labour relations, level and type of communications vertical and horizontal), the organizational control systems, the compensation and

incentive systems. The former have been much more studied than the latter. But there is a fair number of issues that have been neither much nor conclusively studied.

1.2 Research Methodology: Case Studies

A qualitative research design employing multi-case holistic study approach (Yin 1994) was used to investigate six technology based companies in the complex and underexplored area of CE. The data collection was made through semi-structured interviews. The paper uses data from several interviews and diverse secondary sources to enhance the validity and reliability of the study. The collection data was transcribed and categorized in order to be examined and interpreted by adopting and analytic inductive approach.

1.3 Characterization of the Companies in the Study

We have analyzed six companies with a medium-high technological base: medium-high rates of assets/employee, sales/employee, added value/employee. Although they are in very different industries: design of electric power generation utilities, public building construction, computer interactive graphics applications, four of them are mature companies, more than 30 years old, so there is a second or third generation in the company management. The other two are quite young, less than 10 years old, and the first generation, the entrepreneur is in the company management (Table 1.1).

Their size is also very different, from 30 to 5,000 employees. All of them (but company F) have a high percentage of employees with a university degree. All of them devote an important effort to R + D, either internally or in collaboration with technological centres.

Two of them (computer interactive graphics and multimedia and precision equipment for science) are in very emergent industries with increasing markets, not consolidated neither demand nor competitors. The other four are in consolidated or mature industries but exposed to very important technological and competitive changes. In any case, the duration of the life cycle of product or activity lines is decreasing to less than 10 years and companies are forced to set new activities, at least, every five years. This is why Corporate Entrepreneurship is so important for them in both aspects: new product development and new companies development based on some of the former products.

Table 1.1 Characterization of the companies in the study

Company	Industry	Age (years)	Size (no. of employees)
A	Electric power generation (utilities design and operation)	60	5.000
B	Building construction (structures design and construction)	40	70
C	Computer interactive graphics	5	50
D	Bicycle manufacturing	150	250
E	Engineering services (precision equipment for science)	5	30
F	Small and medium domestic appliances	90	80
Technology intensity	*Low*	*Medium*	*High*
Assets/employee (€)	<100.000		>200. 000
Sales/employee (€)	<100.000		>200.000
Added value/employee (€)	<40.000		>70.000
Company		C, D, F	A, B, E
R + D intensity			
% university graduates	<10 %		>50 %
% R + D (sales, employee) patents	<5 %		>10 %
Company	F	D, B	A, C, E
Internationalization			
	(<10 % sales)		(>25 % sales)
Company		B, C, F	A, D, E

1.4 Some Preliminary Results

1.4.1 Characteristics of New Activities and Ventures

For all companies Intrapreneurship—Corporate Entrepreneurship is very important in both aspects: Internal entrepreneurship, New product development that produce brand new activity lines (same or different customers in same or different markets); External entrepreneurship, New companies development based on some of the former products.

The six companies have started other companies:

1. Three of them (A, C, E) to start new business, the true Corporate Venturing.
2. Three of them (B, D, F) not for pure innovation but for administrative, fiscal or internationalizing purposes. They have developed internally the new activities. The main reason to do so is the degree of strength/appeal they give to the current brand.

Table 1.2 Types of CE

	A	B	C	D	E	F
Use of intrapreneurship?	YES	YES	YES	YES	YES	YES
New companies?	YES	YES	YES	YES	YES	YES
New internal business units?	YES	YES	YES	YES	NO	YES
Frequency (<5 years)	YES	YES	YES	YES	YES	YES
New companies EX-NOVO?	YES	NO	YES	NO	YES	NO
New companies through acquisitions?	YES	YES	NO	YES	NO	NO
Acquisition of suppliers/competitors	YES	YES	NO	YES	NO	NO
Related diversification						
Technology	YES	YES	YES	YES	YES	YES
Product/market	YES	YES	YES	YES	YES	YES
No related diversification	YES	NO	NO	YES	NO	YES
Some failures in intrapreneurship?	YES	NO	YES	YES	NO	NO
Internal intrapreneur	YES	YES	NO	YES	NO	YES
External intrapreneur	YES	NO	YES	NO	YES	NO
Drive for intrapreneurship						
I + D	YES	YES	YES	YES	YES	YES
Company board	YES	NO	YES	YES	YES	YES
Other partners			YES	NO		YES
Customers	YES	NO	YES	NO	YES	NO
Intrapreneur			YES	NO		NO
Project oriented organization (matrix)	YES	YES	NO	NO	YES	NO
Safety net for intrapreneurs	YES		NO	NO	NO	NO
Risk capital	NO	NO	YES	NO	NO	NO
Public funds and programmes	YES	YES	YES	YES	YES	YES

Four out of the six companies (A,B, D,F) at some moment, have bought other companies, some to start new business, and all of them to buy a supplier and a competitor to support current operations. It is much more common the option of buying an existing business than to start a radical new one.

The six of them have experienced failures in new activities sometimes.

The pace for creation of new activities and ventures in the three cases is about or less than 5 years, but it seems to be not intended. There does not seem to exist a planning for the launch of new ventures being them opportunistic actions. Most of the companies allow for three years to the new activities to reach “critical mass”. If not they are eliminated.

All the companies undertake new activities with diverse degrees of relation with current business: most of all different technologies for same customers/ markets or different segments of same markets but also same technologies for different markets (internationalization) (Table 1.2).

1.4.2 *Influence of the "Context": the Internal Factors*

The drive for the CE has come in most cases from Top Management. CE is a strategical issue for companies. In all cases there is pressure of the R + D department but also from external partners, mainly customers. R + D push, supported with patents, is very important in the four companies. In the other companies which also use R + D, the market opportunity is more important. Anyway there are also a certain number of failures for following too strictly the "R + D department push". They are more successful stories when combining R + D results with "demand pull" via customers or competitors alliances.

Three of the companies (B, D, F) are more "early followers" than "pioneers" although they use R + D in cooperation with applied research centres, they also use collaboration with customers or suppliers via agreements or acquisitions. Companies (C, E) rely much more on R + D although they also use collaboration with technological partners, customers and suppliers. Company A uses everything.

The capital needed, though important, has not been a critical issue although, eventually, one of the companies have asked for risk capital (C). Most new ventures (D, E, F) are 100 % owned by the mother company. (A) company uses the three possibilities 100 % proprietor, majority position with external partners and minority position with external partners and C company uses minority position with external partners.

The organizational structure of the company before developing the new venture seems to be very important. The project oriented structures seem to be more prone to develop new ventures. The level of divergence with the current business and most of all risk favour the development of new ventures.

Almost all companies have used public funds and programs to promote R + D and/or innovation and entrepreneurship. These programs are not determinant but they are important.

The entrepreneurs in the new companies created have been either internal employees or external people. More usual the former especially in the cases of acquisitions of existing companies.

Related to the personal characteristics of the Intrapreneurs the three companies have quite correctly identified the profiles they look for in the people that will promote "new business units". In general, they are much less "technical" than "commercial" people and most of all, they should have the ability to interact with and conduct other people, that is Leadership. In the three cases, they also look for people able to take risks and that show illusion, motivation and perseverance.

In one of the cases (A) the mother company guarantees the return of the Intrapreneur in case of failure, but not in the other two (C, E). But the three of them agree that a true Intrapreneur does not need this "safety net". If a candidate for Intrapreneurship is worried about this issue, he is not the right candidate.

In the three cases when asked the Intrapreneurs about their motivations, the answers were: Authonomy; Achievement spirit; the feeling of fulfilment. None of them mention the economic retribution. No company uses it as an incentive, it seems that most intrapreneurs do not even think of it when starting a new project.

1.5 Final Conclusions

Technology based companies, with intensive use of R + D, mainly SME, either in mature or emergent industries use Corporate Entrepreneurship as a strategic issue but there is a broad spectrum of types that new activities and ventures can adopt.

There is a relation between the maturity (or emergence) of the industry and the type of entrepreneurship (external or internal), and the finance of it (100 % proprietor, or partnerships in minority). There is more use of acquisitions than pure spin off.

There are some important but contingent "Context Internal factors": R + D effort, alliances. Organizational structure, strategy profile, public programs.

References

Covin J, Slevin D (1991) A conceptual model of entrepreneurship as firm behaviour. Entrepreneurship Theory Pract 16(1):7–25

Guth W, Ginsberg A (1990) Guest editor's introduction: "corporate entrepreneurship". Strateg Manage J 11:5–15

Lumpkin G, Dess G (1996) Clarifying the entrepreneurial orientation construct and linking it to performance. Acad Manage Rev 21:135–172

Narayanan VK, Yi Yang, Zahra SA (2009) Corporate venturing and values creation: a review and proposed framework. Res Policy 38:58–76

Yin RK (1994) Case study research. Design and methods, applied social research methods series, vol 5, 2nd edn. Sage Publications, London

Chapter 2
Activity Based Costing, Time-Driven Activity Based Costing and Lean Accounting: Differences Among Three Accounting Systems' Approach to Manufacturing

Carlos Rodriguez Monroy, Azadeh Nasiri and Miguel Ángel Peláez

2.1 Introduction

In the past, before 1980, accounting systems had a completely different approach. Those systems could not support management, planning and decision making (Johnson and Kaplan 1987). Such accounting systems were not fit for recent ever changing market and competitive environments any more.

At that time, in order to deal with new challenges, some companies approached Activity Based Costing introduced by Cooper and Kaplan in 1987 and some others applied the lean manufacturing concept founded on the constant elimination of waste. Lean accounting, based on lean thinking refers to efforts to develop financial management based on lean principles. In 2004, Kaplan "father of Activity Based Costing" reviewed his method and accepted the criticism that ABC requires too much work and that it is difficult for a company to maintain it over time. Therefore, Kaplan introduced Time-Driven ABC as a new solution, referring to problems recognized in the ABC method. On the other hand, in 2005, leaders in Lean Accounting reached an agreement on a document called "The Principles, Practices, and Tools of Lean Accounting" in order to develop a single and clear definition for Lean Accounting.

C. R. Monroy (✉) · A. Nasiri · M. Á. Peláez
Departamento de Ingeniería de Organización, Administración de Empresas y Estadística. Escuela Técnica Superior de Ingenieros Industriales, Universidad Politécnica de Madrid, Madrid, Spain
e-mail: cmonroy@etsii.upm.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_2,

2.2 Literature

2.2.1 Activity Based Costing

The ABC method was actually the reply to inaccurate American accounting standards (Kuchta and Troska 2007). ABC Methods were concerned with what was done in terms of activities instead of what was spent. A number of cost pools and a variety of cost drivers are the key differences of ABC and traditional costing (Don and Shannon 2008). Actually, the activity cost pool is the overall cost associated with an activity. In addition, the cost driver, which justifies changing the costs in an activity cost pool over time, is a feature that affects the cost and performance of the activity (Kennedy 1996). Firstly, it is assigning indirect costs on activities and then on cost objectives (product, service or costumer) what makes requests for these indirect costs (Cooper and Kaplan 1988b). The expenses of indirect resources are allocated to different activities via resource drivers. Besides, activity drivers represent the consumption of activities by the different cost objects (Bruggeman and Hoozee 2010). It can be said that in ABC models, the causal relationships between products and the resources used in their production traces the cost of products according to the activities through the use of appropriate cost drivers (Bogdanoiu 2009). The following stages can be concluded for Activity Based Costing: (1) Identifying activities, (2) Defining the cost of the activities, (3) Defining the cost drivers of the activities, (4) Defining the volume of cost drivers, (5) Defining unit cost per cost driver for each activity and (6) Calculating the unit cost per product or service (Cooper and Kaplan 1998; Bruggeman and Everaert 2007; Krumweide 1998).

2.2.2 Time-Driven Activity Based Costing

This method identifies the capacity of each department or process and allocates the cost of this capacity of resource groups over the cost object based on the time required to perform an activity. If the demand for work in these departments or processes declines, TD ABC can estimate the quantity of resources released (Kaplan 2006). TD-ABC captures the different characteristics of an activity by time equations in which the time consumed by an activity is a function of different characteristics. This equation assigns the time and the cost of the activity to the cost object based on the characteristics of each object. The unit cost of used resources and time required to perform an activity are two parameters for this method. The time-driven approach consists of six steps (Bruggeman and Everaert 2007):1. Identifying resource groups and the activities for which they are used, 2. Defining the costs of each group, 3. Estimating the practical capacity of each group, 4. Calculating cost per time unit, 5. Determining the required time units for each activity, 6. Calculating cost per transaction.

2.2.3 Lean Accounting

The lean concept is a philosophy where non-value-adding activities are being recognized and eliminated in lean manufacturing systems. It contains a set of principles and practices aimed to reduce cost over removal of waste and done with simplification of all manufacturing processes (Blackstone et al. 2005). Then not only non-value-adding activities in accounting processes as well as other processes have to be removed but also the accounting system itself should interpret the results of efforts in lean manufacturing. Lean Accounting methods and tools support three key aspects of a lean organization: visual management, value stream management, and continuous improvement (Kennedy and Maskell 2007).

A set of tools are used to support the five principles of Lean Accounting. A short review of the Lean Accounting framework including principles, practices and tools has been described as follows:

The first principle is "Lean and simple business accounting". This principle is applying the lean method to the accounting processes using lean tools such as value stream maps, kaizen and the Plan-Do-Check-Act (PDCA) problem-solving approach. The second principle refers to accounting processes that support the Lean Transformation. Control of production processes is done by visual performance measurement tools and box score and value stream performance board also supports continued improvement. Value stream costing tools motivates lean improvement across the entire value stream and target costing is another tool that guarantees customer satisfaction. "Clear & timely communication of information" is the third principle of Lean Accounting. Visual management is supported by visual performance boards attached to box score tools. Box score presents the operational performance and the financial performance in one sheet. This tool is also widely used for decision making purposes. Plain English income statement with- out including unclear data regarding standard costs is another tool supporting this principle. "Planning from a lean perspective" is another principle in Lean accounting. Hoshin policy deployment, Sales, Operations and Financial Planning (SOFP), value stream cost and capacity analysis, value stream maps and box scores are tools that support this principle as well. Finally, Lean Accounting must strengthen internal accounting control. This principle is supported by the Transaction Elimination Matrix which is a tool to ensure that Lean Accounting changes are made wisely process maps showing controls and Sarbanes Oxley regulations (SOX) are also, used in improvement projects to decrease the SOX risks (Baggaley and Maskell 2006).

2.3 Discussion

Here we will discuss the differences among these different accounting methods based on the three basic roles of accounting information in organizations: Financial reporting, decision making and planning and operational control and improvement (Cooper and Kaplan 1998).

2.3.1 Financial Reporting

Financial reporting which is one of the basic purposes of an accounting system has to follow Generally Accepted Accounting Principles (GAAP). Reports produced by ABC and TD-ABC are not adapted to GAAP and companies that are using these systems should have another system generating reports for external uses. Meanwhile, financial reports of Lean Accounting comply totally with GAAP. External reporting regulates internal reporting requirements (Baggaley and Maskell 2006).

2.3.2 Decision Making and Planning

The firms which were candidates for the first practice of the ABC system had several individual product lines and large numbers of products were produced in those lines. Products were served to different marketing channels. High volume and low volume products had a wide range of demand. The greater range of demand, the greater the variation of lot sizes of products for manufacturing and shipping (Cooper and Kaplan 1988a). This caused a complex management environment and complexity required more costs to be managed. Based on the ABC model overhead is not just a certain cost that has to be allocated regardless of the complexity involved. All costs of performing an activity are correspondingly allocated to cost objects based on the activity cost driver. Consequently, a more realistic view of products was provided to support decision making. ABC systems enabled managers to recognize marginal, low-volume, complex products and any other elements that could charge the companies with additional cost on products. Under this recognition, they could make the decision to stop producing these types of products. Companies began to regulate their decisions and strategy according to what they had learned from ABC. They recognized that they are more competitive on high-volume and low complex products than they had thought before. There are many other management decisions made on the basis of information gained from ABC. For example, "If batch costs such as setups, orders, or shipments were high, they would try to negotiate with their customers to reduce frequency of these activities or obtain payment to make up for the cost" (Grasso 2005). The new and accurate information on each product and costumer cost enables companies to re- move products involving extra activities that cause supplementary costs if their price do not cover the additional costs required by these activities. All the above-mentioned examples indicate that decision making takes place at the product level.

Lean Accounting based on lean thinking relies on management of the overall system. In other words: it collects costs and provides accounting information over the value stream, which is defined as all the activities for taking products or services from conception to the costumer. Total cost of all labour, machinery and facilities, materials and support services are counted within the value stream.

Cost data is typically collected weekly and there is little or no allocation of overheads (Baggaley and Maskell 2006). Financial information, such as profit and loss reports are gathered focused on value stream profitability. "The value stream income statement serves as the primary tool in providing monetary information for decision making and reflects revenues from which direct material and all workers, machine and other conversion costs are deducted to obtain value stream profit" (Moreland and Thomson 2007). Also, routine decision-making such as: make or buy, sourcing a new product, product justification, profitability, or any other, is reached by means of tools, such as Box Score, which use incremental costs for the decisions and takes advantage of the free capacity calculated on the value stream. All the above-mentioned situations emphasize that in the Lean Accounting system, although product cost might be calculated in some special cases, generally the foundation for decision making are value stream costing and Box Score which collect the required information over the value stream.

A Time-Driven ABC model identifies the capacity of each department or process and assigns the cost of this capacity on the required work done in the process. This is similar to the cost collection in the value stream in Lean Accounting. Besides that, throughout the process or product, the used and unused capacity of processes are being calculated, which is comparable to "productive capacity", "non-productive capacity" and the "available capacity" presented on the box score in Lean Accounting. Therefore, if the demands for work in these departments decrease because of process optimization or any other reasons, the capacities of resources released will be estimated. Therefore managers would be able to manage the free resources in the flow (Kaplan 2006). Or in other case, such as new market development, new product introductions or rising product and customer demands that managers might be involved with capacity shortage, they will decide about how much they will require handling increasing demands. All these examples illustrate that decision making in TD ABC takes place on both production and process level whereas traditional ABC is based on actual utilization and does not identify the vacant capacity.

2.3.3 Operational Control and Improvement

In the ABC method, Kaplan and Cooper recognize the importance of nonfinancial measures, particularly quality and time-related measures, but they maintain that financial measures must still play an important role. ABC provides a means for prioritizing improvement efforts and for assessing the performance efficiency of activities. Cooper and Kaplan also cite cases where financial measures provide powerful motivation for improvement (Cooper and Kaplan 1998).

Instead of cost data, which is usually not easy to report in real time, cost management in lean accounting method relies on direct quality, quantity and time information of activity or process in order to control the cost, since the emphasis on cost management is on efforts associated with cost planning and monitoring rather than cost control. Therefore cost planning exceeds cost control in this method. One of the other important elements of the process of cost management is continuous improvement of processes and in order to do so, critical parameters of processes must be monitored nonstop (Kilger et al. 2004). In lean manufacturing, the processes are controlled by visual performance measurement in the value stream. Charts and graphs for the main measures of process performance showing trend lines in actual performance are announced on boards in the production line. These key performance measures in lean systems are considered as a replacement for variance financial reporting generated from traditional cost accounting which motivated continuous improvement in the past. In this method, financial results are passengers not drivers (Grasso 2005). In order to support continuous improvement Lean Accounting also uses the value stream performance board which is a visual board including continuous improvement projects. PDCA projects are being initiated and the progress of these projects is being monitored. Finally "Lean Accounting motivates long-term lean improvement through lean focused information and measurements. Lean performance measurements are cornerstones of control in the value stream, and in the overall plant or company" (Baggely and Maskell 2006).

The practical capacity is a key element in the TD-ABC method because inevitable and unused capacity in conventional ABC overestimates product and costumer costs. The Time-Driven ABC approach was an attempt to avoid this distortion. After identifying practical capacity for resource groups, the other key element in TD ABC is unit time for activities performed by this group, so cost generation in TD ABC is based on time consumption and unit time has to be calculated. The unit time is usually being used by manager for strategic visions and for this purpose a rough estimate is enough, but the point is that gross inaccuracy in unite time will be ended to unexpected surpluses or shortages of committed resources (Anderson and Kaplan 2004). It is obvious that unit time can be the centre of attention for improvements. Now analysts need to monitor closely the resource requirements, quality and cycle times of activities and processes to motivate and capture improvements. Moreover, TD ABS accounting can be applied using only unit cost and unit time, and time consumption is the only cause that generates cost in the TD-ABC accounting method. Both of them, somehow, are representing the efficiency of business processes. Therefore companies can focus on high cost and inefficient processes for improvement efforts. According to all the above-mentioned reasons it seems that cost is not a driver for improvement and TD-ABC does not emphasize financial measures as a driver for improvement.

2.4 Conclusions

In this paper, we have analyzed, ABC, Time-Driven ABC and Lean Accounting with respect to three main roles of information generated by accounting systems. The result of this analysis has been summarized in Table 2.1.

Table 2.1 Different approaches for information generated from each accounting system based on financial reporting, decision making and operational control and improvement

	Activity based Costing	Time-driven activity based costing	Lean accounting
Financial reporting	Not accepted by GAAP	Not accepted by GAAP	Accepted by GAAP
Decision making	Takes place at product level	Takes place at product and process level	Takes place at value stream level
Operational control and improvement	Emphasis on financial measures	Emphasize on nonfinancial measures	Emphasize on nonfinancial measures

References

Anderson SR, Kaplan RS (2004) Time-driven activity-based costing. Harvard Bus Rev 82:131–138

Baggaley BL, Maskell BH (2006) Lean accounting: what's it all about? Target magazine, vol 22(1)

Blackstone JH, Cox JH, Cox JF (2005) APICS dictionary, 11th edn, APICS, Alexandria, VA

Bogdanoiu C (2009) Activity based costing from the perspective of competitive advantage. J Appl Econ Sci 1(7):5–11

Bruggeman W, Everaert P (2007) Time-driven activity-based costing: exploring the Underlying model. Cost Manage 21(2):16–20

Bruggeman W, Hoozee S (2010) Identifying operational improvements during the design process of a time-driven ABC system: the role of collective worker participation and leadership style. Manage Account Res 21(3):185–198

Cooper R, Kaplan RS (1988a) How cost accounting distorts product costs. Manage Account

Cooper R, Kaplan RS (1988b) Measure costs right: make the right decisions. Harvard Bus Rev 66:96–103

Cooper R, Kaplan RS (1998) Cost and effect. Harvard Business School Press, Boston

Don H, Shannon LC (2008) An evaluation of activity-based costing and functional-based costing: a game-theoretic approach. Int J Prod Econ 113(1):282–296

Grasso L (2005) Are ABC and RCA accounting systems compatible with lean management? Manage Account Q 7(1):12–27

Johnson HT, Kaplan RS (1987) Relevance lost: the rise and fall of management accounting. Harvard Business School Press, Boston

Kaplan RS (2006) The competitive advantage of management accounting. J Manage Account Res 18:127–135

Kennedy A (1996) ABC basics (activity-based costing). J Manage Account (Br)

Kennedy FA, Maskell BH (2007) Why do we need lean accounting and how does it work? J Corp Account Finance 18(3):59–73

Kilger W, Pampel J, Vikas K (2004) Introduction: marginal costing as a management tool. Manage Account Q 7–28

Krumweide KR (1998) The implementation stages of ABC and the impact of contextual and organizational factors. J Manage Account Res 21(3):18–25

Kuchta D, Troska M (2007) Activity based costing and customer profitability. Cost Manage 21(3):18–25

Moreland AV, Thomson J (2007) The lowdown on lean accounting. J Strateg Finance 26–55

Chapter 3
Operational Characterisation of a Micro-SME Producing Farmhouse Cheese in the South of Venezuela

C. Rodríguez Monroy, E. Cardozo, W. Guaita and M. Pelaez

3.1 Introduction

Venezuelan cheeses like many Latin American cheeses have their origin in Europe but because of its regional and provincial peculiarities have been labelled as different. Their production, though on a smaller scale, has much in common with those of countries with a cheese-making tradition like in Latin America, United States and some European countries. The production systems to be found in these Micro-SMEs are basically family-run businesses with a low level of technological and organisational development. They extend to regional contexts and may be considered as farmhouse production (Aragón and Marin 2003; López and Castrillón 2007; Espinosa 2009). In many cases, the producers concentrate on exotic products that have a short shelf-life, focused on a restricted regional market, which is the case being researched in this paper.

Cheese, according to the FAO, can be classified according to the percentage of fatfree moisture it contains. It can be denominated as extra-hard, hard, semi-hard, semi-soft or soft. Soft pasta filata cheese is a category recognised by the Codex Alimentarius (FAO 1978). Mozzarella cheese is placed inside this category. Guayanes telita cheese, which is a soft unmatured cheese that is ready for consumption soon after production, has also been classified in this category.

Guayanes telita cheese is mainly made in the traditional way and owes its name to the region of Guayana. It is characterised by its soft flavour, creamy appearance, low salt content, having medium fat and its soft texture (Márquez and García 2007). Because of its popularity its production has become extended to different parts of the country. Bolivar State is still the leader with production being concentrated in the rural municipalities of Piar and Padre Chien. Both municipalities

C. Rodríguez Monroy (✉) · E. Cardozo · W. Guaita · M. Pelaez
Departamento de Ingenieria de Organización Administración de Empresas y Estadística, Escuela Técnica Superior de Ingeniers Industriales, Universidad Politécnica de Madrid, Calle José Guatierrez Abascal 2, 28006 Madrid, Spain
e-mail: crmonroy@etsii.upm.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_3, © Springer-Verlag London 2014

belong to the south-east livestock corridor of Venezuela and are acknowledged for their livestock tradition.

The small enterprises producing this exquisite regional product have grouped together in the Guayanes Farmhouse Telita Cheese Producers Network. As a whole they process over 30,000 L of raw milk every day and produce almost 6,000 k of cheese. They have an employment capacity of over 600 direct and indirect jobs.

The medium term goal of this Network is to obtain a Quality Certification and, in the future, the indication of origin label for the entire product cycle. This is a challenge that will force the enterprises to implement a strategy of improvement and self-regulation in their processes. In addition, Venezuela's future membership of the Southern Common Market (MERCOSUR) will also bring challenges that can only be taken up from a standpoint of competitiveness and quality.

The research has focused on the product so far. In this respect, various studies have been made to determine the level of food safety of Guayanes telita cheese. Although most studies have concentrated on the physical-chemical and organoleptic qualities of the product (Márquez and García 2007; Colina and Xiquez 2007; Rodríguez et al. 2009), researchers have observed weak points in the internal systems.

3.2 Methodology Aspects

The purpose of this research was to undertake an operational characterisation of the small production units associated in the Guayanes Farmhouse Telita Cheese Producers Network. The population is made up of 45 units and, at the time of this study, 38 were active. Of these units, 8 contributed no information. Therefore, the final sample consisted of 30 production units that represent 66.67 % of the population, which can be regarded as a significant sample.

A questionnaire based on good food production practice was used as a data gathering technique. The questionnaire included: employment capacity, raw material handling, environmental conditions of the production process, sanitary aspects, work area, workers' personal protection system, laboratory analysis and production capacity in kilos. Version 15.2 of STATGRAPHICS computational software was used for data processing.

3.3 Results

These micro-SMEs possess the features of a family-run business (Acosta and Rodríguez 2006). Due to their size, their production process is basically horizontal. Their value chain comprises three major stages: raw material supply, collection and processing, which, in turn, comprises the operations of curdling, designing the mixture and the end product (cooking-moulding-packaging). For the purposes of this study each stage of this value chain was characterised.

By taking the results of the questionnaires, from a micro-SME size-related theoretical perspective, four layers were found for classification purposes. They are based on production capacity as a relevant criterion; that is, the volume of milk processed and the production in kilos. When the variable regarding the number of workers was analysed, two criteria were chosen during the layering process attending to the classification provided by the authors attempting to define an SME (González 2005; Saavedra and Hernández 2008; Aragón-Correa et al. 2008; Herbane 2010; Hillary 2000). Table 3.1, shows how the enterprises were classified.

The small enterprises studied receive between 160 and 3,700 L of milk per day for processing. The highest daily production of cheese recorded is 740 k and the lowest, 38 kg. The unit employing the most staff amounts to 9 people per enterprise, while the least amounts to only one worker.

As to the layers identified: 73.3 % of the enterprises are to be found in layer 4, which is the smallest layer, while 20 % are in layer 3, and 6.7 % in layer 2, the largest layer. No production units were found to be in layer 1. However, if the amount of product produced is taken as a classification criterion, then one of the enterprises can be positioned in this layer.

From what is stated above, it can be said that, taken one by one, they fit in the context of micro-enterprises or micro-SMEs.

To analyse the operational characteristics every stage and its categories were considered. Each category was broken down into variables to facilitate data processing (see Table 3.2).

Since the data were categorical data, they were encoded for processing. The variables were tabulated one by one using the STATGRAPHICS version 15.2 statistical software package.

During the raw material supply stage (reception of raw milk from the different supply farms), it was observed that 100 % of the enterprises measured the temperature, an aspect that can be considered as standardised. Regarding the type of container for milk reception, 83 % use polyethylene containers. These containers are usually recycled ones coming from other production systems which have been recovered for this specific use. Once the milk goes on to the collection stage, the containers are again recovered to be used in subsequent processes.

The collection stage is vital. The milk received is mixed together and prepared for cheese production. This stage must include filtering, temperature standardisation and its pouring into the containers where the mixture is prepared. According

Table 3.1 Enterprise classification

Type	Workers	Processed milk (litres per day)	Quanity of product (kilos)	% of enterprises (two criteria)
IV	Up to 3	Up to 1,500	Up to 200	73.3
III	4–6	Between 1,501 and 3,000	201–400	20.0
II	7–9	3,001–4,500	400–600	6.7
I	10–13	4,501–6,000	600–800	0

Table 3.2 Category and variables

Stage	Raw material reception	Collection	Production process				
Categories	Raw material handling	Raw material preparation	Environmental conditions (production process)	Sanitary aspects	Work area	Personnel protection system	Laboratory analysis
Variables	Reception temperature	Milk filtering	Gas	Mains water	Work table	Gloves	Temperature
	Container type	Milk collection container	Refrigeration System	Drainage systems	Moulds	Cap	Acidity
				Sanitary licence	Vat/tub	Clothes	Density
				Waste handling	Floors	Boots	Pasta texture
					Walls	Mouth mask	Rennet type
					Windows	Health certificate	

to the data obtained, 76.7 % of enterprises filter the milk, while 23.3 % did not respond, which would suggest that they do not do so. As for the container used to collect the milk after filtering, 56.7 % use stainless steel containers, 20 % use poly- ethylene containers and 16.7 % use wooden ones, while 6.7 % provided no information.

The production process stage is the stage where the cheese is actually produced. It is the most complex stage where the following categories were analysed for this study: environmental conditions of the production process, sanitary aspects, work area, personnel protection system and laboratory analyses.

Under normal environmental conditions 80 % use gas canisters for cooking while 20 % provided no information.

43.3 % possess a refrigeration system while 43.3 % do not and 13.3 % provided no information.

As for the sanitary aspects category, 70 % have no mains water supply, 43.3 % use the public drains network, 23.3 % throw the waste into the open without any processing, and 30 % provided no information. While 26.7 % have a health licence the rest do not or provided no information and only 26.7 % process the waste.

In the work area category, it was observed that 76.7 % use cement or ceramic work tables and 20 % stainless steel tables, while 3.3 % provided no information. Regarding the use of moulds, the most significant was: 23.3 % use silicone rubber moulds, 16.7 % stainless steel ones, 16.67 % wooden ones and 23.3 % combine different types of material in their moulds. Regarding the vat or tub used for mixing, 63.3 % possess a stainless steel vat or tub, 16.7 % a ceramic one and 10 % were made of polythene, while the rest provided no information. In respect of the flooring in the work area, 53.3 % had it covered, of which 43.3 % was granite or cement, while the rest provided no information. 73.3 % of walls were covered while 6.7 % were bare and 20 % provided no information. Regarding windows, 40 % had none while 50 % provided no information but the rest had windows.

The personnel protection system category produced the following results: 56 %, provide gloves for staff, 43.3 % provide caps, 43.3 %, provide working clothes, 40 % provide safety shoes and 70 % provide mouth masks while 63.3 % do not request staff to have any Health Certificate.

In the Laboratory Analysis category that was performed during the first and last stage, it was found that 16.7 % took no temperature measurements during the production process, 56.7 % analysed the acidity of the mixture, 63.3 % made density checks and 83.3 % checked the type of rennet.

3.4 Conclusions

The results obtained agree with the studies made that confirm the inability of these small production units to guarantee the food safety of the product (Márquez and García 2007; Rodríguez et al. 2009).

The enterprises reveal operational situations that require improvements. The necessary conditions to meet the requirements of quality certification for the product and obtain the indication of product label need to undergo adaptation processes. This study is an attempt to learn more about the micro-SMEs that are grouped together in the Guayanes Farmhouse Telita Cheese Producers Network. It provides relevant information that can be used to plan future improvement strategies that will lead to become more competitive. If the product is to achieve certification and a future indication of origin label, it will have to meet international quality standards for the entire cheese-making cycle. In this respect, this study can be a starting point for achieving these goals.

We need to consider implementing a continuous improvement model based on the principles of lean production that will be measured by control systems at every stage of production. It must include all the inspection-correction-handling stages, as well as productivity indicators.

The analytical process and the procedural basis used can be applied to similar small enterprises.

The new lines of research are directed towards an analysis of the regional production system, with emphasis on the dairy sector to establish the levels of differentiation of the micro dairy enterprises in rural municipalities and how it impacts on their development.

References

Acosta LA, Rodríguez MS (2006) En busca de la agricultura familiar en América Latina. Oficina Regional de la FAO para América Latina y el Caribe, Disponible en:http://www.rlc.fao.org/prior/desrural/busca.htm

Aragón SA, Marín SG (2003) Orientación estratégica, características de gestión y resultados: un estudio en las PYME españolas. Tribunal de Economía, publicación de Información comercial española, Ministerio de Economía 809:169–187

Aragón-Correa JA, Hurtado-Torresa N, Sharmac S et al (2008) Environmental strategy and performance in small firms: a resource-based perspective. J Environ Manage 86(1):88–103

Colina P, Xiquez A (2007) La producción artesanal de queso guayanés en los municipios Piar y Padre Chien, estado Bolivar. Revista Autana. Departamento Hombre y Ambiente. Universidad Nacional Experimental de Guayana. Ciudad Guayana 1:54–60

Espinosa AE (2009) La competitividad del sistema agroalimentario localizado productor de quesos tradicionales. Tesis doctoral de la Universidad Autónoma del Estado de México. Disponible en:http://www.eumed.net/tesis/2010/eea/index.htm

FAO-CODEX (1978) CODEX STAN 283. Norma general del CODEX para el queso. Organización de las naciones unidas para la agricultura y la alimentación. Codex Alimentarius. Disponible en:www.codexalimentarius.net/download/standards/175/CXS_283s.pdf

González AT (2005) Problemas de la definición de la microempresa. Revista Venezolana de Gerencia 10(31):408–423

Herbane B (2010) Small business research: time for a crisis-based view. Int Small Bus J 28(1):43–64

Hillary R (2000) Small and medium-sized enterprises and the environment: business imperatives. Greenleaf publishing limited, Shefiel

López MF, Castrillón P (2007) Teoría económica y algunas experiencias latinoamericanas relativas a la agroindustria. Libros EUMED. Disponible en:www.eumed.net/libros/b2007/304

Marquez JG, Garcia RCE (2007) Efecto de la nisina sobre la microflora patógena del queso blanco artesanal tipo “telita” elaborado en una quesera de Upata, Estado Bolívar, Venezuela. Revista de la Sociedad Venezolana de Microbiología 27:108–111

Rodríguez C et al (2009) Calidad sanitaria en queso artesanal tipo “telita”. Upata, estado bolívar, Venezuela. Revista de la Sociedad Venezolana de Microbiología 29(2):98–102

Saavedra GML, Hernández CY (2008) Caracterización e importancia de las MIPYMES en Latinoamérica. Un estudio comparativo. Actualidad Contable FACES 11(17):122–134

Chapter 4
Analysis of the Operating Efficiency of Mobile Operators During the 2002–2008 Period

Félix Roux Martínez, Felipe Ruiz López and Santos Eguren

4.1 Introduction

First, the Spanish mobile telephone market, including its structure, competitive dynamics and evolution, is presented. Then the efficiency of operators present in Spain and comparable European markets is analyzed. This comparison includes the analysis of the effect of the number of operators in the different countries, since it can alter competitive dynamics (Gagnepain and Pereira 2007).

We analyze how the changes in revenues are translated into operating gross margins and EBITDA. The latter is used because it eliminates the influence of factors not derived from operations, such as financial structure or tax environment. The statistical method used is linear regression, with revenues as the explanatory variable and EBITDA as the dependent variable. To analyze the quality of the results, percentage of the variance explained is used (Pena 1987).

The 2002–2008 period corresponded to years of stability in the industry because (1) digital mobile technology had already reached maturity (GSM/UMTS), and GSM technology, had consolidated (De la Pena Aznar and Moreno Rebollo 2001), (2) in Europe, the increase in both mobile telephone users and use of services was relatively stable, resulting in a steady growth of revenue, (3) the number of operators in European markets did not change significantly, and (4) It was a period of relative economic stability, with moderate inflation rates, 2.1–3.3 % in Europe (Eurostat 2009).

It is worth to mention that the only operators considered in the case are those which owned frequencies, and therefore were able to develop their own networks.

F. Roux Martínez (✉) · F. Ruiz López · S. Eguren
Escuela Técnica Superior de Ingenieros Industriales, Universidad Politécnica de Madrid, C/José Gutiérrez Abascal, No. 2, 28006 Madrid, Spain
e-mail: froux@etsii.upm.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_4,

Table 4.1 Mobile phone total revenues in Spain (in millions of Euros)

Q3 (2009)	Subscr. fees	Voice traffic	Mess (SMS)	Data	Other	Total
Million EUR	264	2,698	379	384	31	3,756
Percentage/Total	7 %	72 %	10 %	10 %	1 %	100 %

Source CMT Quarterly Report, Industry Statistics, third quarter 2009
Percentage/total is the percentage of renevues of each service over total market revenues (all services aggregated)

4.2 The Spanish Mobile Telephone Market

4.2.1 Structure and Market Size

The mobile telephone market behaves as a pure oligopoly, consisting of a few firms that produce the same type of product (Kotler and Keller 2006), with an imperfect pattern of competition since only a few companies are able to offer the specific product (Samuelson and Nordhaus 1986).

There is a reduced number of players due to structural and regulatory elements in the industry, including the fact that the radio electric spectrum is a scarce resource, whose allocation is regulated (by 32/2003 Law). There are only four operators managing frequencies: Telefonica, Vodafone, Orange and Yoigo.[1]

There is low differentiation on services, as shown in Table 4.1, 72 % of the revenue comes from voice services in which differentiation is nonexistent.

4.2.2 Market Evolution During the 2002–2008 Period

During the 2002–2008 period, the Spanish market grew from 33.5 to 50.9 million users and the penetration among the population reached 107.6 % (CMT; Annual Report 2009a), the use of voice services increased from an average rate of 62 min per month to 119. The price of services decreased progressively at a 6.9 % annual rate, from 25 c€/min to 16.3 c€/min in 2008.

The market has matured and also migration from fixed to mobile networks happened, mobile networks as they mature substitute fixed networks (Vogelsang 2010). In this sense, Gruber and Verboven (2001) show that there is a negative relationship between the number of fixed lines and mobile penetration.

[1] Yoigo is not considered because its market share was negligible.

4.3 Analysis of the Spanish Case

4.3.1 Evolution of Operating Gross Margin in the Spanish Market

From 2002 to 2008 the revenues of the three mobile operators have progressively increased (Fig. 4.1).

The evolution of the operators' EBITDA margin (Fig. 4.2) shows that Vodafone's was stable at 40 %, and both Telefonica's and Orange's suffered margin erosion.

In Fig. 4.2, three clearly differentiated ranges can be seen, Telefonica is in the 50–60 % ranges; Vodafone, as the second operator, maintains a stable middle range around 40 %; and Orange is in the lower 34–24 % range. These shows:

1. The existence of economies of scale, since the higher volume operators generate higher margins which are sustainable over time. In addition, different EBITDA ranges are observed as a function of operator size.
2. The existence of differences in operating efficiencies, since different operators undergo diverse margin evolutions as the market grows and matures.

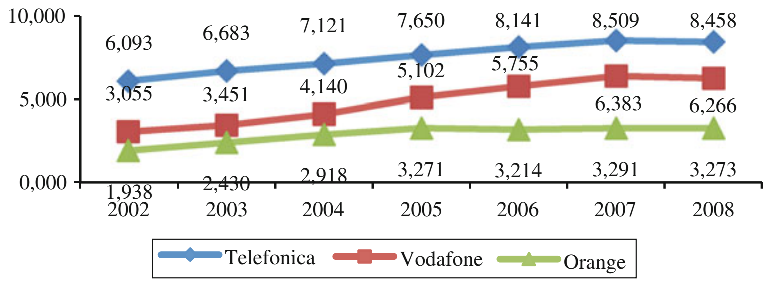


Fig. 4.1 Evolution of revenues of Spanish mobile operators, 2001–2008 period (in million €) (*Source* Global wireless matrix 4Q 2009)

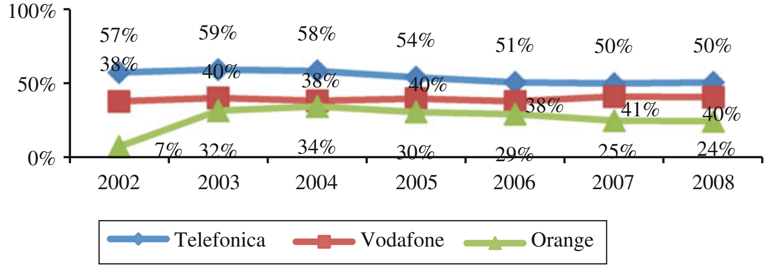


Fig. 4.2 Spanish operators EBITDA, as a percentage of revenues, 2002–2008 (*Source* Global wireless matrix 4Q 2009)

4.3.2 Relationship Between Revenue and EBITDA Margin: Quantifying Efficiency Through Linear Regression

Comparing the EBITDA margin versus revenue in absolute terms, there is a significant correlation. This confirms our previous hypothesis concerning the existence of economies of scale, as it is shown in Fig. 4.3.

To quantify the operating efficiency in revenue pass-through to margin, a regression analysis is performed. The relationship between revenues and EBITDA margin is described through a straight regression line, in which the dependent variable represents the EBITDA margin, and the independent variable represents revenue in a given year.

The regression analysis is performed both for each individual operator and for the aggregated industry (Table 4.2).

4.3.3 Conclusions from the Spanish Market

1. The aggregated industry revenue increase pass-through to margin increase was performed at an average rate of β_2 0.353, and with an $R^2 = 0.915$.
2. The existence of differences in operating efficiency is confirmed at the individual operator level, (1) Vodafone, being the highest revenue growth operator,

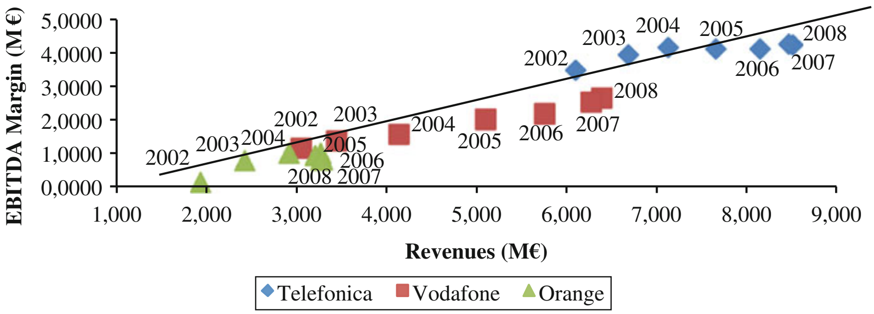


Fig. 4.3 Relationship between EBITDA margin and revenue during the 2002–2008 period (*Source* Global wireless matrix 4Q 2009)

Table 4.2 Spanish market regression analyzed by individual operator and aggregated industry

Operator	Regression line $Y_i = \beta_1 + \beta_2 X_i$	R^2 Value
Telefonica	$Y = 2162.1 + 0.251X$	0.75560885
Vodafone	$Y = -118.3 + 0.419X$	0.98783301
Orange	$Y = -561.0 + 0.461X$	0.67321737
Industry	$Y = 449.0 + 0. 353X$	0.91547621

presents the highest correlation level between revenue and EBITDA, with $R^2 = 0.9878$. Its revenue pass-through to margin has a $\beta_2 = 0.419$, and (2) Telefonica, with a lower $R^2 = 0.7556$, has a revenue pass-through to margin at $\beta_2 = 0.251$, therefore, its EBITDA margin erodes from 57 to 50 %.

This shows that the cost of gaining clients is compensated by higher volumes.

4.4 The European Environment

The structural elements of the European industry such as regulation, number of operators, and low differentiation, do not change. Therefore, similar results should be expected. To confirm this, the two markets most resembling Spain are analyzed.

4.4.1 France

In France there are three operators: Orange (France Telecom), SFR (Vodafone) and Bouygues. The revenues of all three have grown progressively. Orange and SFR jointly lead the market, whereas Bouygues is smaller (Fig. 4.4).

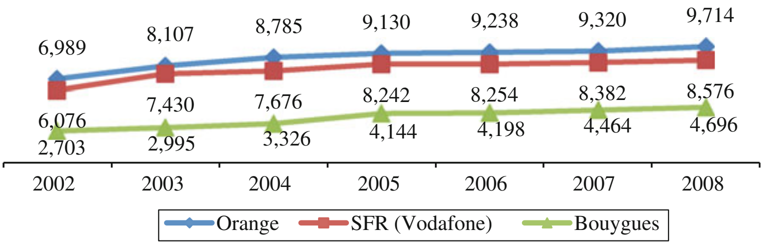
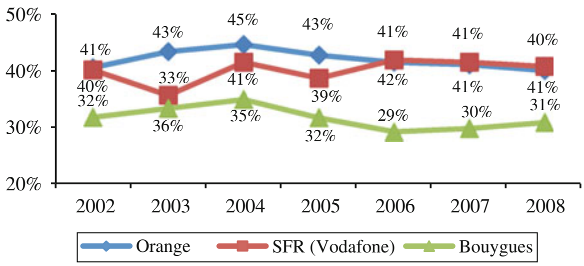


Fig. 4.4 Revenues of French mobile phone operators 2002–2008 (in millions €) (*Source* Global wireless matrix 4Q 2009)

Fig. 4.5 Evolution of French operators EBITDA Margin, 2002–2008 (in percentage) (*Source* Global wireless matrix 4Q 2009)



The two larger operators have higher EBITDA margins (Fig. 4.5), stabilizing during the last years. However, the margin of the third, smaller operator lies around ten percentage points below its larger competitors, at approximately 30 %.

The above-indicated analysis confirms: (1) the existence of economies of scale, as operators with higher revenues generate higher stable margins over time (in addition, different EBITDA margins, in line with operator size, can be observed); and (2) the existence of operating efficiency differences, since margin evolves differently as the market grows and matures. The relationship between revenue and EBITDA margin is presented in Fig. 4.6 (Table 4.3).

Conclusions in the French case are (1), the aggregate industry revenue pass-through to margin has a rate of $p_2 = 0.379$, with a high $R^2 = 0.9477$, and (2) all three operators present high R^2 values, over 0.849. Vodafone has the highest, $p_2 = 0.453$, and thus higher efficiency.

4.4.2 Germany

There are four operators in Germany: T-Mobile (Deutsche Telecom), D2 (Vodafone), E Plus (KPN) and 02 (Telefonica), (Fig. 4.7).

The two largest operators enjoy high margins 45–50 %, regardless the evolution of their revenue. The two smaller achieve lower margins, (Fig 4.8).

In this way, is confirmed: (1) the presence of economies of scale, since operators with higher revenues generate higher stable margins over time, and (2) the existence of operating efficiency differences among the different operators, since they undergo diverse margin evolution as the market grows and matures (Fig. 4.9, Table 4.4).

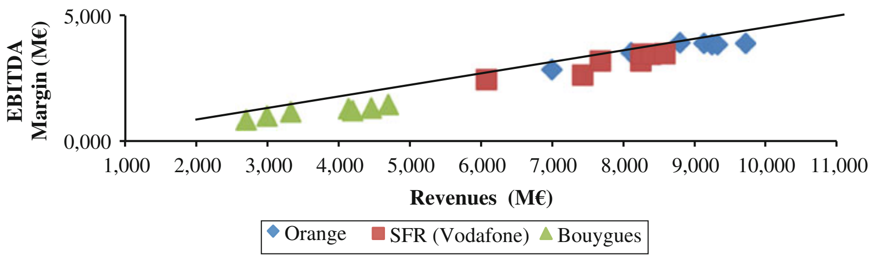


Fig. 4.6 Relationship between EBITDA margin and total revenues in France, 2002–2008 (*Source* Global wireless matrix 4Q 2009)

Table 4.3 Regression analysis for individual French operators and total French industry

Operator	Regression line	R^2 Value
Orange (FT)	$Y = 212.5 + 0.396X$	0.86575885
SFR (Vodafone)	$Y = -406.5 + 0.453X$	0.84963423
Bouyges	$Y = 229.6 + 0.254X$	0.92595216
Industry	$Y = 92.2 + 0.\ 379.X$	0.94772637

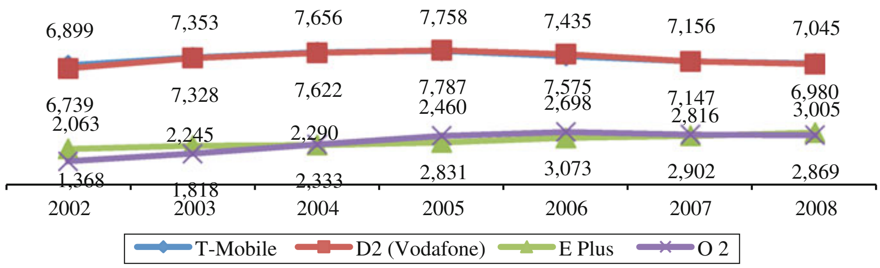


Fig. 4.7 Revenue German mobile phone operators during the 2002–2008 (in millions of €) (*Source* Global wireless matrix 4Q 2009)

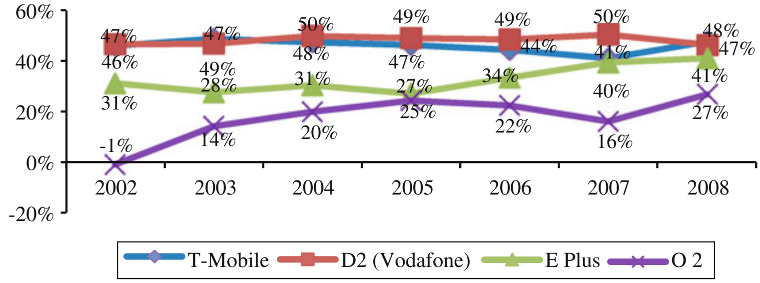


Fig. 4.8 Evolution of the EBITDA margin in Germany, during the 2002–2008 period (in percentage) (*Source* Global wireless matrix 4Q 2009)

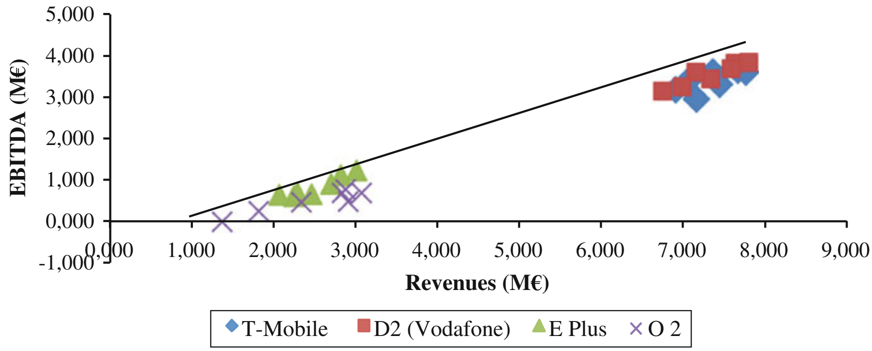


Fig. 4.9 Relationship between EBITDA margin and total revenue in Germany, 2002–2008 (*Source* Global wireless matrix 4Q 2009)

Conclusions for the German market are (1) the industry as a whole presents a high R^2 value of 0.89. This is lower than those obtained for Spain and France reflecting stronger competition, (2) with the sole exception of T Mobile (more

Table 4.4 Regression analysis by operator and industry in Germany during the 2002–2008 period

Operator	Regression line	R^2 Value
T-Mobile (DT)	$Y = -862.9 + 0.578X$	0.49215351
D2 (Vodafone)	$Y = -1333.9 + 0.666X$	0.87788377
E Plus (KPN)	$Y = -880.9 + 0.685X$	0.8044696
02 (Telefonica)	$Y = -508.4 + 0.401X$	0.86894361
Industry	$Y = -195.5 + 0.468.X$	0.8901184

affected by competition) operators present high correlations, with R^2 over 0.86, and (3) there are differences in operating efficiency, and E Plus, with the fastest growth in revenue also achieved the highest growth in efficiency during the period.

4.5 Conclusions of the Study

1. There is a strong correlation between revenue and margin in the industry, this shows the existence of significant economies of scale, and this correlation diminishes when the number of competitors increases (Germany).
2. Those operators which have reached higher revenue increases, also have maintained or increased their EBITDA margin, not being penalized by investing in growth. On the contrary, the economies of scale outweighed the required investment and growth-derived costs.
3. Through the methodology used, the more efficient operators, those able to revenue pass-through to margin, can be easily identified.

References

CMT (2009a) Informe Anual 2008, Comision del Mercado de las Telecomunicaciones (CMT). http://www.cmt.es/cmt_ptl_ext/Select0ption.do?nav=publi_anuales&detalles=09002719800868c6&pagina=1

De la Pena Aznar J, Moreno Rebollo A (2001). Presente y futuro de las telecomunicaciones moviles. Econ Ind 337, I

European Economic Statistics (2009) Edition, Eurostat Statistical Books, European Commission. http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-31-09-001/EN/KS-31-09-001-EN.PDF

Gagnepain P, Pereira P (2007) Entry, costs reduction, and competition in the Portuguese mobile telephony industry. Int J Ind Organ 25:461–481

Global Wireless Matrix 4Q (2009) Bank of America and Merrill Lynch, 13 december 2009

Gruber H, Verboven F (2001) The diffusion of mobile telecommunications services in the European Union. Eur Econ Rev 45:577–588

Kotler P, Keller KL (2006), Direction de Marketing, 12[a] Edicion. Pearson Education S.A., Madrid, cap 11

Pena Sanchez de Rivera D (1987), Estadistica Modelos y Metodos. 2 Modelos lineales y series temporales, Alianza Universidad Textos, Madrid, cap 12

Samuelson PA, Nordhaus WD (1986) Economia,12[a] Edicion. MacGraw Hill, Mexico, cap 23

Vogelsang I (2010) The relationship between mobile and fixed-line communications: a survey. Inf Econ Policy 22:4–17

Chapter 5
Challenges in Data-driven Hotel Infrastructure Assignment Decisions

Rajesh Natarajan, Esmeralda Giraldo and Alfonso Duran

5.1 Introduction and Related Work

The hospitality industry is extremely competitive due to industry factors such as over capacity, perishable hotel rooms, low barriers to entry, supplier fragmentation and long lead times for capacity change. Further, external challenges such as the economic downturn, cost pressures from new forms of intermediation, demanding and discerning customers have increased competitive pressures (Rutherford and O'Fallon 2007). In addition to high levels of operational effectiveness and efficiency, a hotel also needs to customize its products and services on the basis of pro-active anticipation of changing customer requirements (Minghetti 2003). Design of guest rooms, conference rooms and other customer facilities are typical examples of long-term resource assignment decisions (Rutherford and O'Fallon 2007). These, involving dedicated long-term resources, are based on long-term demand forecasts (Noone et al. 2003; Sigala et al. 2001). The fixed hotel infrastructure sets the context that defines the hotel-decision making environment. However, the resultant operational decisions, that involve short-term assignment of fixed hotel infrastructure to individual customers referred to as *Hotel Infrastructure Assignment Decisions* (*HIADs*), is the focus of the current work.

Within the framework of a research project on simulation-based enhancement of hotel decision making, this paper focuses on the design of a framework to support *HIAD*s. Hotels need to optimize their *HIADs* since improvement in their quality would ensure both operational efficiency and customer satisfaction. After

This work stems from the participation of the authors in a research project funded by the Spanish National Research Plan, reference DPI2008-04872, title "Optimizacion de la asignación de infraestructuras de servicios mediante simulación—sectores hotelero y sanitario".

R. Natarajan (✉) · E. Giraldo · A. Duran
Area de Ingeniería de Organización, Universidad Carlos III de Madrid,
Avda. de la Universidad, 30, 28911 Leganés, Madrid, Spain
e-mail: rajesh.natarajan@uc3m.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_5,

discussing a few typical features of *HIAD*s, we identify its two fundamental challenges namely, customer behavior prediction and management of interaction complexity and customer reactions. We can view a customer's lifecycle as a sequence of related hotel-customer decision dyads. On analysis, we conclude that sequential assignment of hotel infrastructure to customers may not be optimal because of limited incorporation of implications of customer reactions in the decision process. This leads us to propose a parallel infrastructure assignment design i.e. assignment to the most promising of the likely subsets of potential customers competing for identical hotel infrastructure at the same time slot. Finally, we discuss one possible data-driven decision support approach for *HIADs*. This, based on the integration of data mining techniques with micro-simulation, leverages the rich customer data that hotels collect during their routine operations.

5.2 Hotel Infrastructure Assignment Decisions

A hotel has to make many short-term infrastructure assignment decisions while providing services to its customers, e.g. room allocation. Although the impact is limited to the period of the stay, allocation can be made considering other factors like current availability, future demand for the same period, customer value and others. *HIADs* take place within the hotel's existing infrastructure context that has a fixed capacity in the short-term. For example, the hotel cannot change the number and type of available rooms. In the hotel context, the customer lifecycle is defined as a series of phases that a customer passes through when he/she avails the services of a hotel. Typical phases include information search, enquiry, booking, check-in, stay, check-out and feedback (Natarajan and Duran 2012). From the customer's perspective, the hotel's infrastructure assignment decisions set the context which influences his/her choices. In some cases like room allocation for a stay, the customer's request lead to the setting of room rate depending on whether the assignment is likely to maximize the hotel's efficiency and profitability parameters. Some aspects considered here include the customer's willingness to pay, probability of repeat stays, likely demand for the room between the booking-time and actual time of stay and others. In other situations like ancillary services, the hotel may offer a choice to the customer with respect to the available services. Customer satisfaction and revenue generation may be maximized if the hotel's decisions incorporate customers' likes, dislikes and preferences. Sometimes an initial infrastructure assignment decision can have a cascading effect on the later decisions of the customer. For example, personalization of services may increase the customer's possibility of engaging other hotel services leading to additional revenue earning opportunities.

5.3 Challenges in Hotel Infrastructure Assignment Decision-Making

High quality *HIADs* can have a positive impact on efficiency, effectiveness and ultimately profitability. Many challenges in *HIADs* are related to the dynamic nature of the decision-making environment. The hotel's environment that consists of series of interactions between the hotel (represented by its employees) and its customers, can be viewed as a series of decisions that each entity makes in response to other's decision. Consider a scenario during the check-in period where the employee at the reception has to make a decision regarding which of the hotel's ancillary services should be highlighted to the customer for consideration. The customer decides on the services on the basis of choices communicated by the hotel staff. Once the customer has made his/her decision, the hotel may assign certain infrastructure to fulfill these services. Then, the ancillary services offered to the next customer may differ depending on the new customer's preferences, availability of required infrastructure and hotel's updated estimation of likely demand from other customers. In other words, the hotel's decision sets the context for the customer's decision. The customer's decision in turn modifies the environment for the next round of hotel's decisions and so on. Two fundamental challenges that hotels face are accurate prediction of customer behaviour and management of interaction complexity and customer reactions.

Customer Behaviour Prediction: *HIAD*s set the context and choices for the customer's decisions. Personalization of hotel services (e.g. room rate quote, prices,…etc.), requires understanding the customer—likes, dislikes and preferences. The hotel can make a better decision if it has some idea of customer behaviour. However, this data, for the current lifecycle, would be available only after the hotel made its framework setting decisions like offering customers choices, setting room rates, etc. (Duran et al. 2011). Thus, the first challenge that hotel faces is accurate prediction of customer behaviour to the choices offered by it. For example, during the check-in period, the hotel employee should highlight only the most relevant ancillary hotel services that have the highest likelihood of being chosen by the customer.

Management of Interaction Complexity and Customer Reactions: The hotel's offer of services is constrained by its infrastructure capacity. Once a customer has made his/her decision, the hotel would assign infrastructure for the service's fulfilment constraining the choices available for other customers. Given that a hotel simultaneously serves multiple customers who may interact with each other, a hotel needs to optimize its infrastructure assignment decisions keeping into account not only its own constraints and but also the likely reactions of customers to its decisions. A hotel's restaurant capacity is limited. Therefore, the process of booking a table for a customer in the restaurant should take into account various factors such as availability of capacity, value of customer, potential reaction of customer if this service is declined/postponed, etc.

5.4 From a Single Customer to Sets of Customers

Here, we consider how a hotel can design its decision making processes to address the challenges outlined in the previous section. Figure 5.1 depicts the important elements of a *HIAD*-making environment. The customer lifecycles are depicted using a circular arrow. The lifecycle of a customer, say "C_1" can be viewed as a sequence of decisions at different points of time. Each decision (e. g. *X*) point can be viewed as a dyad of related decisions. The first is the initial framework-setting hotel decision (X_H) followed by the customer decision (X_C) (as discussed above), within each customer's lifecycle. Thus, the series *X*, *Y*, *Z*,… etc. refer to similar decisions within the current lifecycles of all customers C_1, C_2, C_3,… and others.

The customers' lifecycles may have commenced at different points of time, may have varying lengths and extents of overlap. Therefore, at any given point of time, a hotel has to serve multiple customers, say $\{C_1,\ldots,C_n\}$ simultaneously. Due to this overlap, different customers can be viewed as potentially competing for the same time slot of a given infrastructure, for example dinner or lunch at the hotel's restaurant. The hotel cannot serve all its customers due to infrastructure limitations such as limited restaurant tables, staff, etc. A possible solution is to design its service's framework in a way that maximizes its resource utilization while simultaneously minimizing the potential costs and negative implications of its

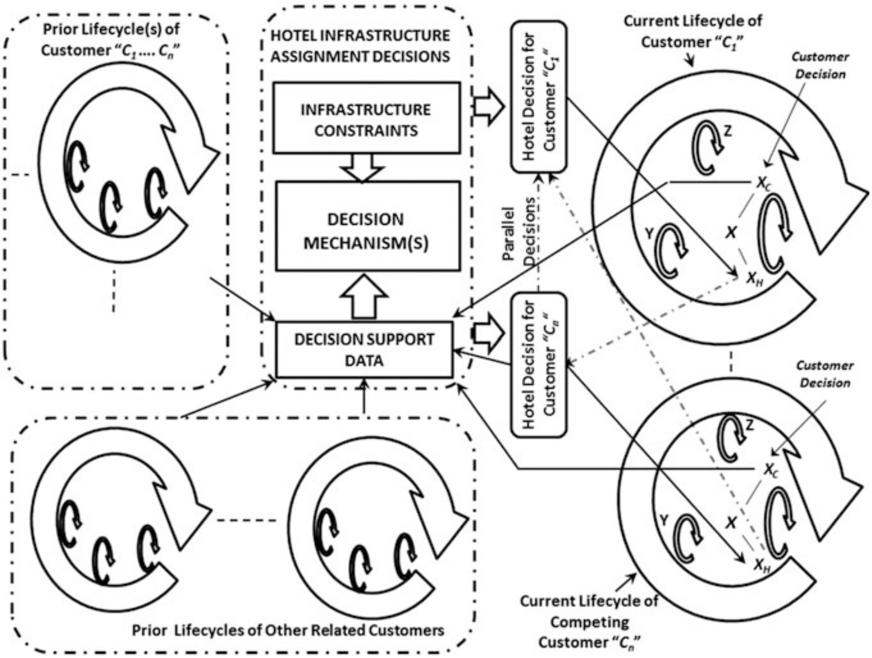


Fig. 5.1 Environment for hotel infrastructure assignment decisions

infrastructure limitations. Figure 5.1 depicts dependencies and interactions between the hotel's decision and resulting customers' decision. We assume that all customer behaviour data until the current point of time will be available to the hotel for decision support. This is depicted in Fig. 5.1 in the boxes concerning current and prior lifecycles of hotel customers.

One perspective is to view the hotel's decision-making process as a two-step process. The first step consists of the prediction of customer behaviour using data from the current and past customer stays in the hotel. This process when applied to the current set of customers predicts the hotel services that a particular customer is likely to engage. However, infrastructure assignment using customer behaviour prediction based on past behaviour, as the sole basis, is likely to prove insufficient because of failure to consider the reactions of customers to hotel decisions and interactions between customers. The second step of *HIAD* process assigns its customers to the available hotel infrastructure. As a customer's life cycle progresses, different types of infrastructure are required for the requested services. Therefore, for a given time slot and a particular assignment decision, the relevant set of customers that have to be considered as competing for the same infrastructure are those whose life cycles are in more or less similar stage of progression. The first step identifies the customers who are likely to request for a particular service. This customer set, further qualified by considering the overlap of their lifecycles, would approximately indicate the customers competing for the same infrastructure. Another important aspect is to incorporate the reactions of the customers into the hotel's assignment decisions. The final infrastructure assignment would be a subset of the above identified set of customers optimized for maximizing the infrastructure utilization and profitability parameters while simultaneously minimizing the costs of negative customer reactions and missed opportunities. This calls for parallel assignment i.e. choosing among various subsets of potential customer and simultaneous assignment of hotel infrastructure to the most promising customer subset, rather than assigning them in a sequential manner as and when a customer requests a service.

We can consider two possible situations in the case of parallel assignment decisions. In the first situation, the hotel sets the framework that influences customer choices. It assigns the total infrastructure for the set of customers by considering each one as identical to the other. For example, in the case of a "Special Menu Offer" published on the notice board, the hotel sets the framework for customer decisions by simultaneously considering the available infrastructure (kitchen capacity, supplies, etc.) and the menu that is likely to be preferred by most of the current set of hotel customers. In the second situation, the hotel can fine-tune its assignment decisions. Consider the process of room booking where the hotel can fine-tune its room rates dynamically (i.e. can modify the offer it makes to a customer based on the outcome of the interaction with the previous one) so as to maximize revenue and profitability while minimizing missed opportunities.

5.5 Supporting *HIADs* with Data Mining and Micro-Simulation

As discussed, high quality *HIADs* need a deep understanding of customers and prediction of their reactions to hotel's decisions. Further, the dynamic environment presents hotels with a limited time-window opportunity to modify/reverse their decisions. The relevance and importance of any *HIAD* support mechanism would be determined by the accuracy and timeliness of its behaviour predictions and tolerance of uncertainty with respect to customer reactions. Figure 5.2 presents one possible approach towards supporting the hotel infrastructure assignment decisions by combining data mining with micro-simulation. Micro-simulation involves simulating the behaviour of the hotel customer population using specific representative individual customers as the primary building blocks.

Customer demographic and behavioural data collected during current and previous visits to the hotel form the input to Data Mining and related predictive techniques. Attitudinal and behavioural components of customer profiles are constructed with the help of customer's past behaviour, external data and specific customer demographic and psychographic information (Table 5.1). For example, the likelihood of a customer using a particular hotel service like gymnasium services can be predicted using Data Mining techniques that include decision trees, neural networks, regression and association rules (Magnini et al. 2003). Demographic component of a customer's profile can be constructed using data collected in the previous visits or extrapolated from more representative profiles of the group

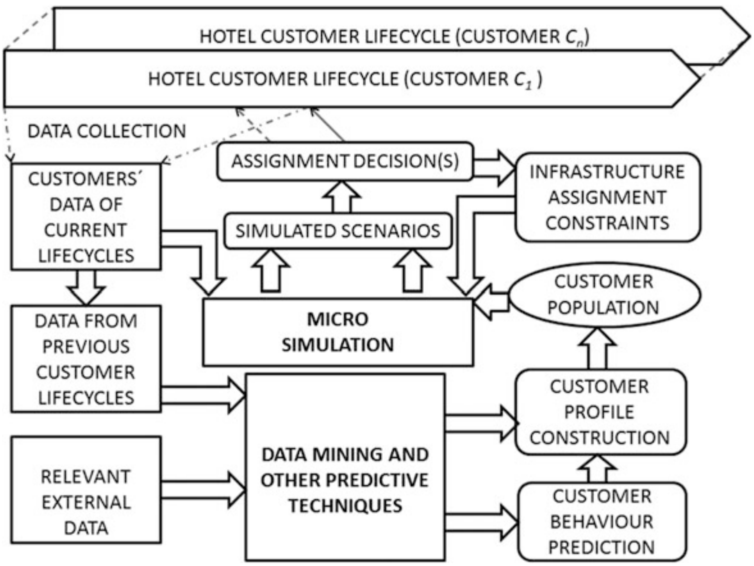


Fig. 5.2 A possible approach to support hotel infrastructure decision-making

Table 5.1 Data mining component of hotel infrastructure assignment decision support

Sub-challenges addressed	Input/required data	Applicable data mining tools/techniques	Input for micro-simulation
Customer profile construction	Customer demographics from current and past lifecycles	Clustering and classification techniques using decision trees, neural networks, etc.	Traits/ parameters of customer population
Customer preferences and behaviour prediction	Specific behavioural data from current and past lifecycles, preference data of generic customer classes	Classification, clustering, regression, association rules	Behavioural and relationship parameters of customers
Customer reaction prediction	Specific behavioural data from current and past lifecycles expressed as a sequence of hotel and customer decisions.	Sequence rules	Modeling rules for customer state transitions
Cost Implications of customer reactions	Hotel cost data, customer lifecycle value, customer behavioural data	Regression, neural networks	Modeling total cost for an assignment decision

to which the customer belongs using classification and clustering techniques. Finally, properties that control the interaction between customers and their transitions between various lifecycle stages can be mined from the past lifecycle data. Customer trait parameters and interaction information unearthed by Data Mining methods can be used to construct individual members of the customer population and transition rules for the micro-simulation bench. The simulated scenarios indicate the best set of assignment decisions considering customer preferences, likely behaviour, customer reactions to hotel decisions and hotel's cost implications as customer lifecycles progress. This information can guide the hotel optimize its assignment decisions. Further, real time feedback from actual customer behaviour and changes in infrastructure constraints when incorporated into micro-simulation reflects the actual environment evolution. This increases relevance of the supported *HIAD*s.

5.6 Conclusions

The environment of *HIADs* can be viewed as consisting of successive decision dyads—the hotel's context-setting decision followed by the customer's decision, all within the context of the customer lifecycle. Optimization of *HIAD*s requires tackling two fundamental challenges namely, accurate prediction of customer behaviour and management of interaction complexity and customer reactions. Sequential assignment of hotel infrastructure to customers does not incorporate customer reactions and its cost in the decision process. Therefore, parallel assignment, i.e. assignment of hotel infrastructure to the most promising of the likely subsets of potential customers competing for the same time slot may be a more relevant approach for optimizing *HIADs*. One possible decision support scheme is based on the integration of data mining techniques with micro-simulation. This data-driven scheme integrates the customer reactions and the interaction complexity in the decision mechanism. As a part of future research, we propose to model the interaction complexity and customer reactions using insight provided by mining dynamic customer data.

References

Duran A, Natarajan R, Giraldo E (2011) Sincronización de los ciclos de información y de gestión de infraestructuras de servicios hoteleros. Dirección y Organización 45:38–45

Magnini VP, Honeycutt ED Jr, Hodge SK (2003) Data mining for hotel firms: use and limitations. Cornell Hotel Restaurant Adm Q 44(2):99–105

Minghetti V (2003) Building customer value in the hospitality industry: towards the definition of a customer-centric information system. Inf Technol Tourism 6:141–152

Natarajan R, Duran A (2012) Aligning hotel data management for customer-related resource assignment decisions. In: Sethi SP, Bogataj M (eds) Industrial engineering: innovative networks. Ros-McDonnell L Springer, London 157–164

Noone MB, Kimes ES, Renahan LM (2003) Integrating customer relationship management and revenue management: a hotel perspective. J Revenue Pricing Manage 2(1):7–21

Rutherford DG, O′Fallon MJ (eds) (2007) Hotel management and operations, 4th edn. John Wiley and Sons, Inc. New Jersey

Sigala M, Lockwood A, Jones P (2001) Strategic implementation and IT: gaining competitive advantage from the hotel reservations process. Int J Contemp Hospitality Manage 13(7): 363–371

Chapter 6
Economic Analysis of the Renewable Energy Policies in the European Union

Roberto Rodríguez, Carlos Rodríguez-Monroy and Miguel Ángel Peláez

6.1 Energy Policies in the European Union

In January 2007, the European Commission adopted a Communication proposing a new energy policy for Europe, with the goal of combating climate change and boosting the EU's energy security and competitiveness through the development of a more sustainable and low-carbon economy. Based on the European Commission's proposal, the European Council endorsed the following targets in March 2007, namely, to:

- Reduce greenhouse gas emissions by at least 20 % (compared with 1990 levels) by 2020.
- Improve energy efficiency by 20 % by 2020.
- Increase the share of renewable energy in final energy consumption to 20 % by 2020.
- Increase the share of renewable energy sources in the fuel used by the transport sector to 10 % by 2020.

Also in the same year, the European Commission put forward a strategic energy technology plan (SET-plan) in November 2007. This aims to support decarbonizes energy technologies, such as off-shore, wind, by accelerating their development and implementation. To achieve this goal will be accurate progress in all three sectors that most affect renewable energy sources: electricity (to increase electricity production from renewable energy and authorize the production of sustainable power generation from fossil fuels, thanks in particular, to establish systems for CO2 capture and storage), biofuels, to be represented, by 2020, 10 %

R. Rodríguez (✉) · C. Rodríguez-Monroy · M. Á. Peláez
Departamento de Ingeniería de Organización, Administracion de Empresas y Estadistica, Escuela Tecnica Superior de Ingenieros Industriales, Universidad Politecnica de Madrid, C/Jose Gutierrez Abascal 2 28006 Madrid, Spain
e-mail: roberto.rodriguez.rosado@alumnos.upm.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_6, © Springer-Verlag London 2014

of fuels for vehicles and, finally, heating systems and refrigeration (Commission, Energy Policy for the European Union 2007).

By 2008, the European Commission proposed a package of measures relating to energy and the climate in order to supplement existing initiatives. The European Council, on 11 and 12 December 2008, reached an agreement on an energy/climate change package that was endorsed by the European Parliament at the end of 2008. This breakthrough should help the EU to honour its commitments and to maintain its leading role in the search for an ambitious and comprehensive post-Kyoto global agreement.

In November 2008, the European Commission put forward its second strategic energy review that contained plans designed to achieve the objectives of sustainability, competitiveness and security of supply. These included a new strategy for building energy security and solidarity between EU Member States, as well as a package of energy efficiency proposals to make energy efficiency savings in areas such as buildings and energy-using products.

It is necessary to take into account that all these directives must be transposed into the regulations of each country. But, overall, perhaps the European Union is where the greatest emphasis on energy policy is done, especially as a result of unfavourable geostrategic conditions in Europe for the supply of energy resources. Anyway, energy policies are fairly common in other regions such as Argentina subsidies to plantations to produce biodiesel or U.S. aid to production of fossil fuels.

6.2 Renewable Energy Policies

Renewable energy sources include wind power, solar power (thermal, photovoltaic and concentrated), hydroelectric power, tidal power, geothermal energy and biomass. The use of renewable energy has many potential benefits, including a reduction in greenhouse gas emissions, the diversification of energy supplies and a reduced dependency on fossil fuel markets (in particular, oil and gas). The growth of renewable energy sources may also have the potential to stimulate employment in Europe, through the creation of jobs in new 'green' technologies.

The primary production of renewable energy within the EU in 2008 was 148.1 million tons of oil equivalents (toe)—a 17.6 % share of total primary energy production (Eurostat and Commission 2009). The volume of renewable energy produced within the EU-27 increased overall by 57.0 % between 1998 and 2008, equivalent to an average increase of 4.6 % per year. Among renewable energies, the most important source in the EU was biomass and waste, accounting for 69.1 % of primary renewable production in 2008. Hydropower was the other main contributor to the renewable energy mix (19.0 % of the total).

Although its level of production remains relatively low, there was a particularly rapid expansion in the output of wind energy, which accounted for 6.9 % of the EU's renewable energy produced in 2008. The largest producer of renewable energy within the EU in 2008 was Germany, with a 20.1 % share of the EU total;

France (13.4 %) and Sweden (10.8 %) were the only other countries to record a double-digit share. There were considerable differences in the renewable energy mix across the member States, which reflected to a large degree natural endowments and climatic conditions. For example, more than three quarters (75.7 %) of the renewable energy produced in Cyprus was from solar energy, while more than a third of the renewable energy in the relatively mountainous countries of Austria, Slovenia and Sweden was from hydropower(much higher shares were recorded in Norway and Switzerland). More than one third of the renewable energy production in Italy was from geothermal energy sources (where active volcanic processes still exist); this share rose to more than 80 % in Iceland.

The output of renewable energy in Germany grew at an average rate of 13.6 % per year between 1998 and 2008, as such its share of the EU-27 total rose by 11.2 % points from an 8.8 % share in 1998. There were also average growth rates in excess of 10 % per year recorded for Belgium, Hungary and the Czech Republic, where the fastest growth in renewable energy production was recorded, averaging 14.2 % per year between 1998 and 2008. Renewable energy sources accounted for 8.4 % of the EU's gross inland energy consumption in 2008.

The EU seeks to have a 20 % share of its energy consumption from renewable sources by 2020; this target is broken down between the Member States with national action plans designed to plot a pathway for renewable energies in each country. The share of renewable in gross final energy consumption stood at 10.3 % in the EU in 2008, almost half the target that has been set for 2020.

Among the member States, the highest share of renewable in gross final energy consumption in 2008 was recorded in Sweden (44.4 %), while Finland and Austria each reported more than a quarter of their final energy consumption derived from renewable. Compared with the most recent data available for 2008, the indicative targets for Denmark, Ireland, Greece, France, Italy, Latvia, the Netherlands and the United Kingdom require each of these countries to increase their share of renewable sin final energy consumption by at least 10 % points.

6.2.1 Electricity

Directive 2001/77/EC set indicative targets for the production of electricity from renewable energy sources: according to these, 21 % of the EU's gross electricity consumption should be sourced from renewable by 2010. The latest information available for 2008 shows that electricity generated from renewable energy sources contributed 16.7 % of the EU-27's gross electricity consumption. In Austria (62.0 %) and Sweden (55.5 %) more than half of all the electricity consumed was generated from renewable energy sources, largely as a result of hydropower and biomass.

Across the member States, only Germany and Hungary had already surpassed their indicative targets for 2010 by 2008; Belgium, Denmark, the Netherlands and Finland were each within a single percentage point of attaining their targets.

The growth in electricity generated from renewable energy sources during the period 1998–2008 largely reflects an expansion in two renewable energy sources; namely, wind turbines and biomass. Although hydropower remained the single largest source for renewable electricity generation in the EU in 2008, the amount of electricity generated was somewhat lower than a decade earlier (−2.6 %). In contrast, the volume of electricity generated from biomass increased by 244 %, while that from wind turbines rose by 953 %.

6.2.2 Transport

At the end of 2008, the EU agreed to set a target for each Member State, such that renewable energy sources (including biofuels, hydrogen or 'green' electricity) should account for at least 10 % of all fuel used within the transport sector by 2020. The average share of renewable energy sources across the EU was 3.5 % in 2008, ranging from a high of 7.1 % in Austria, and more than 6 % in Sweden, Slovakia and Germany, to less than 1 % in Latvia (Eurostat yearbook 2011). The share of renewable in gross final energy consumption may be considered as an estimate for the purpose of monitoring Directive 2009/28/EC on the promotion of the use of energy from renewable sources; note, the statistical system for some renewable energy technologies is not yet fully developed to meet the requirements of this Directive.

Electricity from renewable energy sources is defined as the ratio between electricity produced from renewable energy sources and gross national electricity consumption. Electricity produced from renewable energy sources comprises electricity generation from hydropower plants (excluding pumping), as well as electricity generated from biomass/wastes, wind, solar and geothermal installations. The share of renewable energies in the fuel consumed by the transport sector is calculated on the basis of energy statistics, according to the methodology as described in Directive 2009/28/EC. Note, the contribution of all biofuels is currently included within the calculation for this indicator and that the data are not restricted to biofuels satisfying the sustainability criteria.

Directive 2009/28/EC of the European Parliament and Council on the promotion of the use of energy from renewable sources set an overall goal across the EU-27 for a 20 % share of energy consumption to be derived from renewable sources by 2020, while renewable should also account for a 10 % share of the fuel used in the transport sector by the same date. The Directive changes the legal framework for promoting renewable electricity, requires national action plans to show how renewable energies will be developed in each Member State, creates cooperation mechanisms, and establishes sustainability criteria for biofuels (following concerns over their potential adverse effects on crop prices, food supply, forest protection, biodiversity, water and soil resources).

6.3 Future Perspectives

After analysing all these studies, it appears that despite the European Union framework has been implemented from the famous White Paper of 1997; energy policy remains a local matter and not an issue at the level of the community. So, it is necessary to introduce it into the policies of the union: (a) support for technology (b) establishment of objectives in the medium and long term, and (c) provide the boundary conditions (like a system for guarantees of origin). Actual incentives for market penetration of renewable energy were hardly present.

A good way for the European Union to continue its objectives and given the times in which we are, lies in the fact that we must not reduce the budget to support European policies for the implementation of renewable energy, of course, without forgetting the future changes that will occur in the European institutions as a result of the crisis. In the proposed constitution for the European Union, makes clear that energy policy; there will be a shared competence call: “and both the Union and Member States have the power to legislate and adopt legally binding acts in that area. The member States shall exercise their competence to the extent that the Union has not exercised, or has decided to cease exercising, its competence” (Commission European Convention 2003). This makes it likely that policy initiatives for the implementation of renewable will be more and more taken at the Union level.

How would a future common system of renewable energy support look like? It is most likely that, -for the short term, -national support systems, including feed- in tariffs and tax exemptions, are still needed. However, such policies cannot be free of commitment from the side of the governments. Continuity of policies is an important prerequisite for effectiveness. As the market for renewable energy is gradually becoming more mature, it might be necessary to let the support system gradually evolve to a European support system based on renewable energy obligations and tradable green certificates (Nielsena and Jeppesen 2003). But in the short and medium term continuity seems to be more important than speed as several problems will be encountered.

If we consider briefly the main challenges that represent the three basic pillars for the future, and what you can do to solve European energy policy, we find that:

1. With regard to energy dependence and security of supply in the European market there is a clear need to diversify the energy mix where possible and efficient, both in terms of different types of energy as different geographical sources. Greater reliance on domestic energy resources (such as renewable and nuclear) will help reduce both dependence on foreign, and to promote the objective changes related to climate change. This reinforces the idea that Europe supports to some extent domestic energy sources, given the characteristics of “public good” that are both energy security and climate change and especially the use of renewable energy sources given the future perspectives that have (Commission, Energy efficiency in buildings 2010). However, in the medium term, the energy market remains dependent on gas as a key source of

flexible and relatively clean energy, to enable an efficient transition to an environment of low CO_2 (where the new nuclear energy, clean coal, and renewable energy generation will play a larger role). Inevitably, this means that security of supply and energy dependence will remain a key issue in the optimal design of the EU energy policy in the near future.

2. On the other hand referring to imports of energy, that Europe should diversify its mix of suppliers and reduce its dependence on certain countries (especially Russia). Also, the new strategic players such as China and India play an important role in this regard and now the market is global and therefore the competition is global.
3. Greater reliance on intermittent generation sources (such as renewable) will create new challenges in terms of domestic security of supply, both in electricity and in oil or gas. The periods of insufficient generation of renewable energy will create strong demand peaks generation which will require a major boost for the interconnection of Europe. In the words of Andris Piebalgs, member of the European Energy Commission: “Climate change and energy security are two sides of the same coin” (Piebalgs 2009). So will have to meet these peaks and that will require greater investment in network infrastructure, so as to guarantee delivery and security.
4. As regards climate change and related policies, data and projections that we have discussed in this article illustrate the fact that the energy market in the next 10–20 years will face a major transformation to meet the objectives required. Given the proposed environmental objectives need to ask how they can optimally be met in order to reduce the costs of reducing CO_2 (and, possibly, de-carbonization of the sector). The discussion about the best policies to achieve environmental objectives raises a number of questions and challenges as: What should promote clean technologies to minimize the overall costs of reducing CO_2 emissions, and how soon (given the necessity to reduce emissions gradually over a long period of time)? We should take into account that there are technologies that are less established and have a higher yield than others, such as wind energy above photovoltaic solar energy. Moreover, what is the best way to encourage low-emission technologies, without the owners of these technologies and who developed excessive obtain income, while providing sufficient incentives to invest in alternative sources? We can see that in some of the renewable energies, since the tariffs are regulated and the system operator is obliged to buy the energy produced, they are some imbalances in the market.

6.4 Conclusions

In summary, we believe that it should promote a common energy policy, given the externalities between countries of the EU (energy mix and environment), the necessary investments in new technologies, the need to be able to negotiate with supplier countries, and the convenience of having a single international voice of the EU on this matter. Another key aspect of the EU's energy policy is to constrain consumption by promoting energy efficiency, both within the energy sector itself and among end-users. These policies are designed to bring about a new industrial revolution that will result in a low-energy economy, whilst making the energy consumed more secure, competitive and sustainable, with the goal of the EU becoming a world leader in renewable energy and low-carbon technologies. The European energy sector will have to undertake a profound transformation if you want to meet the objectives.

References

Commission European Convention (2003)
Commission, Energy Policy for the European Union (2007) (COM 2007_1)
Commission, Energy efficiency in buildings (2010) Directiva 2010/31/CE. (n.d.), Mayo 19, 2010
Eurostat and Commission (2009) Eurostat yearbook 09
Eurostat yearbook (2011)
Nielsena L, Jeppesen T (2003) Tradable green certificates in selected European Countries
Piebalgs A (2009) Energy Security in the EU, Eufocus

Chapter 7
Analyzing the Chinese Development and Its Impacts on the Brazilian Economy

Ana Paula Lisboa Sohn

7.1 Introduction

China is the world's second biggest economy after the USA. It is the fourth biggest country in terms of size and the biggest in population rate. China's increasing importance for the world economy is highlighted by Cunha (2010) who states that despite the financial and economical crises, which emerged in 2008 and is still in recovery, it is observed a trend over the changes in the axis of development from the western to the eastern countries which are under China's leadership.

The model of liberal capitalism and its unsteady control proved to be unable to deal with the crises it has generated. Competition in global market is to suffer non-trivial adjustments. Facing the accelerated economic and social development in China Tse (2010) and Cunha (2010) highlighted the necessity for knowing and evaluating the potential and challenges of this country in global economy. Thus, the main objective of this article is to amplify the knowledge of the extraordinary trajectory of development of China since 1978 and point out the main impacts it has in Brazilian economy.

The reflexion of this phenomenon, the resurgence of China as a great global power is appropriate and necessary because since the Industrial Revolution the world has not faced such threatening experience towards the western prominence and its model of capitalism.

Regarding the knowledge Brazil has about China, authors such as Cunha (2010) and Masiero (2007) evidence that the recent experience of Chinese development and the perspective of this country to become the largest world economy have not been carefully observed by the Latin-American subcontinent whose growth rate have remained below its potential in the two last decades.

A. P. Lisboa Sohn (✉)
Universidade Federal de Santa Catarina, Campus Universitário, Trindade,
Florianopolis, SC 88040-900, Brazil
e-mail: anasohn@hotmail.com

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_7,

This article is divided into five sections. The first is related to the introduction of the theme, to its objective and to the justification for this research. In the second section we present the methodology applied to the development of the article. The third section is about the development of policies and Chinese economic and entrepreneurial structure. The impacts of Chinese development for the Brazilian economy are presented in the fourth section. The fifth section brings the final considerations and suggestions for future researches.

7.2 Methodology

This article involves theoretical and introductory work which aims to encompass a bibliography research as its main method. At first a selection of indexed scientific articles was made. Book access and statistic data, available in national and international data bank, were also assessed to make part of this research.

After the gathering of all theoretical material, the problem was fixed and the conceptual and the empirical basis of the article were built. Following the conceptual analysis, final considerations were taken in order to amplify the academic knowledge about the theme presented in this article.

7.3 China: Considerations About Development Policies and Economic and Entrepreneurial Structure

China is the largest country in Eastern Asia and the most populous in the world with 1.34 billion inhabitants, approximately one-seventh of the world's population. It is a socialist republic governed by China Democratic Socialist Party under a sole party system. Its jurisdiction ranges from 22 provinces: five of them are autonomic (Xinjiang, Inner Mongolia, Tibet, Ningxia and Guangxi), four township (Beijim, Tianjin, Shanghai and Chongqing) and two special administrative regions with great autonomy (Hong Kong and Macau) (Wikipedia 2011).

In order to proper understand the phenomenon of the Chinese accelerated growth it is necessary to acknowledge the process of modernization and starting point initiated by Deng Xiaoping in 1978. Deng's political reforms impelled China to create a market economy with special characteristics. In the 1970s, China reviewed its Sinocentric position until then exacerbated by the adoption of a socialist view focused on a centrally planned economy. Until 1978 the theoretical hypothesis of a transition from the communist organization and business operation to the capitalism did not bring about important considerations.

In the modern era, there were no experiences in the world scenario which could lead central planned policies to the opening and liberalization of the economy (Cunha 2008).

For the traditional theoreticians, the market economy is characterized by the presence of three components: (1) a price system determined by the market (2) private property and, (3) generation and appropriation of profits by private agents. As highlighted by Cunha (2008), there is no rigid default to classify the economy as a market or non-market economy. Countries differ from one another regarding the type and content of their market economy. In China, in 1978, there was a strong dominance of state-owned enterprises (SOEs) and collectively-owned enterprises (COEs), which contributed with 70 and 22 % in industrial production, respectively (Cunha 2008).

In this context in 1978, China had to decide to remain as a poor and isolated country or join the part of the world which was progressing. Opting for the second strategy, the country accepted the increasing the world integration and interdependency not only in politics but also in economy. This way, the Chinese government leadered by Deng Xiaoping defined guidelines to lead China to the economic and social development. Among these guidelines, Nonnemberg (2010) points out: (1) the process of liberalization of the price system which allows prices to be determined in free markets; (2) the liberalization of the international trade; (3) the great availability of rural labor force with very low productivity, fact that enabled the migration to cities, maintaining low salaries even with the increase of labor demand; (4) the lack of intellectual property protection; (5) the gigantic size of the Chinese population which enabled the creation of economies of scale in most industries; (6) the implementation of policies and incentives for promoting innovation and, (7) the great increase of Foreign Direct Investment, from US$ 1.4 billion in 2004 to US$ 109 billion, in 2010.

The Chinese model of capitalism implemented by Deng Xiaoping associates the dynamism of private activities with the government planning and public intervention. The success of the capitalism in China and its program of commercial opening is evidenced by the reduction of 265 million people in absolute poverty in only 17 years, from 1990 to 2007 (Cunha 2010).

According to Masiero (2007) the creation of Township and Village Enterprises (TVEs) was fundamental to the development of the modern Chinese economy. For this author Township is an administrative structure to govern towns—an urban agglomeration which is bigger than villages but smaller than cities. They are administratively subordinated to counties. Masiero (2007) observes that the definition of urban and rural area vary a lot and this fact may be a source of difficulties for foreign researchers. In the end of 2002, TVEs represented nearly 18 % of the employment rate in the country and for approximately 40 % of the industrial production in China. Masiero (2007) considered TVEs the main factor for the economic growth of the country. TVEs have innovated organizational structures, are able to maintain a great number of workers and contribute to the rapid industrialization of the Chinese rural area (Masiero 2007).

Cunha (2008) highlights that one of the signs of the economic reform was the insertion of the foreign capital to stimulate the industrial development, measurement which allowed Special Economic Zones (SEZs) to progress enabling it to become the main reason of the Chinese development, especially from 1990 on.

In the beginning of the opening process, China Deng created five Economic Zones directed to the foreign market, where, besides the adequate infrastructure to the production and goods outflow, necessary to the exportation process, foreign investments were duty-free for a five-year period.

It is important to point out that the acceptance and valorization of the private sector in China had its beginning in 1982. Up to this year there were no guarantees for the private sector and from this year on a constitutional amendment was approved. It considered the private economy supplemental to the ballast-economy in the state-owned enterprises. The process of valorization and guarantees of private enterprises, including the foreign capital, followed the gradualism idea because only after 2004 there was complete guarantee of property right (Cunha 2008).

The characteristics of the main types of Chinese companies, responsible for the generation of new Jobs are presented in Table 7.1. The analyses of the table highlights that some of the enterprises are hybrid, which means they belong to a particular economic system and political regimen which are suffering transitions; other are more similar to the western way of organization. Very complex structured companies can also be seen.

Table 7.1 The characteristics of the main types of Chinese companies

Typology	Characteristics
State, state-owned enterprises (SOEs)	Frequently controlled by relevant ministries such as the communication ministry. They have priority of access to loans and other subsides from the government
Urban collective enterprises (UCE)	Localized in big cities, enterprises are owned by communities and self-employed entrepreneurs. They are frequently enrolled in activities involving service rather than manufacturing. They are greatly influenced by regional and local control and property
Township and village enterprises	The property totally belongs to the government of the town- ship or the village; it also may belong either to the government or its stakeholders. They do not enjoy credit facilities or the support of the central government and are administered similarly as private enterprises
Private enterprises	Small enterprises with limited access to capital; they belong to individuals or private entities. Some from the technology sector when receiving foreign investments change into FIEs
Foreign-invested enterprises (FIEs)	Joint ventures with differential participations. Joint ventures from co-operative societies and foreign enterprises are legal entities from mixed property. Multinational companies generally establish FIEs after a short-term period of experience as a representative office. They cannot be characterized as private without carefully analysis due to the relation they may establish with SOEs. They have a different legislation when compared to other Chinese companies
Companies listed on stock exchange	Companies which belong to Chinese and foreign shareholders. Their stocks are negotiated in stock Exchanges. The control is carried out and the profits are shared according to the possession of stocks. The government generally own more than 50 % of the stocks or is regarded as the majority shareholder

Source Adapted from Masiero (2007) and Cunha (2007)

7.4 Impacts of the Development of China in Brazilian Economy

In the beginning of the process of the Chinese economic development, still during the 1980s decade, important entrepreneurial partnership were set with Brazil. From 2009 on, China has become the first trading partner of Brazil and the main destination of Brazilian exports to the Asian continent. Masiero (2007) cites important trading partnership between Brazilian and Chinese companies such as Companhia Vale do Rio Doce and Baogang Steel; Sinochem, companies such as WEG and EMBRACO all localized in Chinese territory.

From the twenty-first century on, the bilateral commerce between Brazil and China has presented considerable development. The bilateral trade relation between Brazil-China ended the year of 2010 with a record of trade flow, approximately US$ 56.3 billion. This amount was 56 % higher than the observed in the year of 2009. This remarkable growth was mostly due to the imports which increased 61 % in 2010 when compared with 2009. The exports also increased approximately 47 % in 2010. Even with the increasing export rates, the Brazilian trade balance with China has remained positive, a little higher than US$ 5 billion (CNI 2011). Table 7.2 presents the evolution of the Brazilian exports and imports to China.

The Chinese export high added-value products to Brazil while the Brazilian profile of exports to China is predominantly constituted of low added-value items mainly iron ore and soybeans in granular form, respectively.

Observing Brazilian imports from China it has become clear that there is evident prevalence of high added-value products. The Chinese imported products consist mainly of machines, telephony hardware, liquid crystal display, etc.

Nowadays, China is the world's second economy and the biggest exporter of goods. From 2008 on, even with the occurrence of a global economic crisis, China's investments escalated and surpassed, for the first time, 50 billion dollars. In 2009, the country held the fifth position of the rank being considered one of the biggest stakeholders in the world (Economic Commission for Latin America (ECLA) 2010).

The growing trend of FDI Chinese is motivated by the following reasons: (a) opening door policies from the current government since 2000; (b) facilitated loans of Chinese state-banks which covers the projects of investments in foreign countries. ECLA (2010) observes that most Chinese transnational companies are, with a few exceptions, state-owned.

Table 7.2 Trade relation between Brazil and China (in US$ billion)

Specification	1997 China	2000 China	2006 China	2010 China
Exports to Brazil	1.1	1.1	8.4	25.5
Imports from Brazil	1.2	1.2	8.0	30.8

Source Elaborated by author, based on Joint Statistical Publication (2011)

Nevertheless, even in the case of state-owned companies, the direct investments of China in foreign countries cannot be explained only as a consequence of the government guidelines. While the State impels international expansion, the Chinese companies are also investing in foreign trade due to its strategy of diversification and technological development. The strong growth of Chinese economy with very high savings rates, the great exporter performance and the advancements in science, technology and innovation created great capacity in plenty of companies which have been explored through external investments. In a lot of cases, Chinese companies acquired foreign companies with the objective of creating strategic measures in advanced economy and guarantee the access to sources of natural resources, especially in developing countries.

ECLA (2010) points out that the Chinese investments reveal profound changes towards some countries: Brazil which represented 3.5 % of the Chinese investments in Latin America from 1990 to 2009, in 2010 received almost two-thirds.

According to China-Brazil Business Council (2011) the amount of money invested by Chinese companies in business operations in Brazil was US$ 12.7 billion in 2010. This sum reveals the great interest of Chinese but does not represent the increase in Brazilian production capacity, once most of IDEs were allocated to the acquisition of foreign capital controls of companies already established in Brazil. With disregard of foreign exchange controls, the Chinese sum invested in Brazil is US$ 1.510 billion. CEBC highlights that the amount of money which best represents the relation between China and Brazil, with all the possible implications it may have from now on, is 12.669 billion of dollars—once it establishes the consolidation of the Chinese presence in Brazil through foreign direct investments.

7.5 Final Considerations

The Chinese model of capitalism implemented by Deng Xiaoping associates the dynamism of private activities with the government planning and public intervention. The success of the capitalism in China and its program of commercial opening is evidenced by the reduction of 265 million people in absolute poverty in only 17 years, from 1990 to 2007 (Cunha 2010).

It is convenient for countries such as Brazil to take the economic policies adopted by China as an example. It is highlighted though that Brazilian economy is at risk of being captured in the specialization of commodities, renouncing the achievement of new manufacturing segments especially in the high technological field.

The greatest challenge for Brazil is not related to conjuncture policies nor their aspects, but to define long-term outlines and strategies of development of modern infrastructure, prioritizing good quality education, science and research and adopting tax policies to stimulate industrialization and innovation of the three economic sectors, therefore modernizing the government structure.

The Beijing model has a lot to teach to the Brazilian academy, governors end entrepreneurs. As China's Gross Domestic Product (GDP) approximates the capitalist production of the USA, Brazil is to consider China a great challenge for the next 40 years and become aware that no country is protected against the inexorable Chinese capacity to conquer space in the world market as well as compete in their own national territory, prior protected against tax barriers of transportation, communication and taxes of other nature.

The Chinese market has potential to deserve continuous and growing attention. The general overview of the development process which has been happening in China since 1978 and its impact on the Brazilian economy in the near future points out to two categories of impacts: one presenting positive perspectives related to the favorable performance of the exports of commodities and to the attraction of Chinese investments in the country; and the other which will doubt the competitiveness of important segments of the industrial sector in Brazil. A research from Brazilian and Chinese Observatory (2010) points out the Chinese ascension as the world's factory, it emphasizes a reduction in Brazilian exports and advancement of China in American and worldwide markets in special in the USA, Argentina e Mexico.

This article is an introductory work which aims to stimulate other researchers about the impacts of the Chinese development in Brazilian economy. Thus, it is suggested that more theoretical and empirical studies ought to be developed in order to deepen the knowledge about the facts that underlie the success of the Chinese development.

References

China-Brazil Business Council (2011) Investimentos chineses no Brasil: uma nova fase da relação China Brasil

Confederção Nacional Da Industria (CNI) (2011) Observatório China Brasil, year 4, n 1, March 2011

Cunha IJ (2007) Governança, internacionalização e competitividade de aglomerados produtivos de móveis no Sul do Brasil, Portugal e Espanha. Chapecó: argus indústria gráfica

Cunha IJ (2008) China passado e futuro de um gigante. Visual Books, Florianópolis

Cunha IJ (2010) China passado e futuro de um gigante: notas complementares e de atualização. Florianópolis

Economic Commission for Latin America (ECLA) (2010) O investimento es- trangeiro direto na América Latina e Caribe

Joint Statistical Publication (2011) BRICS 2011, Chapter Fifteen: External Eco- nomic Relations

Masiero G (2007) Negócios com Japão, Coréia do Sul e China: economia, gestão e relações com o Brasil. Saraiva, São Paulo

Nonnemberg MJB (2010) China: Estabilidade e crescimento econômico. Revista de Economia Política 30(2), April–June 2010

Tse E (2010) Tarde demais para entrar na China? In: Harvard Business Review 88(4), April

Wikipedia (2011) China http://en.wikipedia.org/wiki/China

Chapter 8
Rethinking the Social Contract: An Agent-Based Model Approach

Marta Posada and Cesáreo Hernández-Iglesias

8.1 Introduction

Economic Theory is concerned with two issues: wealth generation and its distribution. In the last 50 years the advanced countries have been very successful in generating wealth, but not so much in its distribution. In the last decade many economists wrote about a new era where the cycle was over and prosperity was secured, because the effects of massive global trade and information technology. The distribution of wealth issue was shaded by this prosperity. The actual crisis has brought to a forefront the failure in wealth distribution. Just one example: "*Since Ronald Reagan became President in 1981, America's budget system has been geared to supporting the accumulation of vast wealth at the top of the income distribution. Amazingly, the richest 1 % of American households now has a higher net worth than the bottom 90 %. The annual income of the richest 12,000 households is greater than that of the poorest 24 million households… The problem is America's corrupted politics and loss of civic morality*" (Sachs 2010).

Business magnates as W. Buffet are showing deep concern about the lack of a proper distribution of wealth. The great destruction that is causing our recent global financial crisis has vividly demonstrated the deficiencies in our outdated current economic theories. G. Soros has just created the *Institute for New Economic Thinking* to broaden and accelerate the development of new economic thinking that can lead to solutions for the great challenges of the twenty-first

M. Posada (✉) · C. Hernández-Iglesias
INSISOC. Escuela de Ingenierías Industriales, Universidad de Valladolid, C/Paseo del Cauce, 59 47011 Valladolid, Spain
e-mail: posada@eii.uva.es

C. Hernández-Iglesias
e-mail: cesareo@eii.uva.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_8,

century. Agent-Based Modeling (ABM) has been selected as both, a challenge and a promise. Classic economists were very concerned with both sides of market properties: efficiency in wealth generation and a fair distribution. Adam Smith's, *An Inquiry into the Nature and Causes of the Wealth* and *The Theory of Moral Sentiments*. Providing answers to these questions, would strengthen civilization, by helping the poor, advancing the arts and education, thus rendering peace trough democracy.

It is worth noting that Adam Smith set on these tasks using Hume's **experimental method** (appealing to human experience) to replace the specific *moral sense*. The authors have promoted this experimental method both with human and artificial agents (ABM) since 1999: The time has come to go back to the classics with the power of resolution of nowadays social simulation (ABM).

In previous works (Posada and López 2008; Posada et al. 2008) we have addressed the questions linked with the market as an spontaneous efficient way to coordinate agents to solve problems of scarcity an choice that are common to both Economics (wealth generation) and to Management Engineering (job shop coordination and holistic manufacturing). The market capability to achieve coordination and wealth generation can be hindered by transaction costs. We have shown that ABM can also help to understand this issue.

Adam Smith was well aware of the last and more relevant question: Does the market achieve a fair distribution of wealth? And he advanced the core of a proper answer: "*A regulation which enables those of the same trade to tax themselves, in order to provide for their poor, their sick, their widows and orphans, by giving them a common interest to manage, renders such assemblies necessary. An incorporation not only renders them necessary, but makes the act of the majority binding upon the whole.* **In a free trade, an effectual combination cannot be established** *but by the unanimous consent of every single trader, and it cannot last longer than every single trader continues of the same mind*". Trade is a non-zero sum game, but the share of wealth can not be solved by the game itself.

In ABM, the influence of alternative agents' behavior on market efficiency can be evaluated because the agents' behavior can be controlled. However, the wealth distribution on markets has not received the same attention. In this paper, using an ABM approach, we study the sensitivity of wealth distribution to the agents' learning on Continuous Double Auction markets. We find that both the market efficiency decreases and the inequality on wealth distribution increases as the percentage of *parasitic* agents grows.

The paper is organized as follows. In Sect. 8.2 we revise the role of ABM to solve the relevance of institutional market design to achieve economic efficiency under heterogeneous agent's behavior and previous work about the wealth distribution problem. In Sect. 8.3 we describe our agent-based model. In Sect. 8.4 we calibrate the model and describe the experiments and the main results. In Sect. 8.5 we report the main conclusions of the paper.

8.2 ABM and Market Behavior

We choose as market the Continuous Double Auction (CDA) because there is a lot of previous experience in both experimental economics and artificial economics. CDA is a double sided auction where buyers and sellers announce and accept bids and asks at any time. The information is held separately by many market participants (in the form of privately known reservation values and marginal costs). The analytical game approach has been unable to explain its properties. Other alternative approaches have been Experimental Economics (EE) and ABM. These approaches analyze CDA distinguishing the following three dimensions (Smith 1982): the institution (I) (the exchange rules, the way the contracts are closed, and the information network), the environment (E) (agent endowments and values, resources, knowledge) and the agents' behavior (A).

Observing the agents' behavior (A) dimension, EE has established that fast price convergence and the allocative market efficiency is almost 100 %. Smith (1962) first demonstrated these properties, and subsequent researches have replicated them under alternative environment's conditions.

A major limitation of EE is the lack of control for the human participant's behaviour. Why don't we take a step further and replace human traders by soft agents that could allow us to control the A dimension?

Controlling the A dimension, ABM has established that high market efficiency (closed to 100 %) can be achieved even if the artificial agents are zero intelligent (Gode and Sunder 1993; LiCalzi and Pellizzari 2008). Price convergence and individual surplus depend on the agents' learning have been shown by the authors (op.cit) explaining the paradox that a perfect market does not preclude intensive agents competition.

However, little attention has been paid to the wealth distribution on CDA markets. Bersini and van Zeebroeck (2011) first evaluated it using Zero-Intelligent agents. The purpose of this paper is to study the wealth distribution on CDA markets when alternative agents' learning is considered. We show how the invisible hand can lead to disastrous outcomes in the wealth distribution when, for example, there are too many *parasitic* agents in the market.

8.3 Our Agent-Based Market Model

We describe our model in terms of the essential dimensions of any market experiment: I $\times$ E $\times$ A.

8.3.1 The Institution: CDA

There are several variations of the double auction exchange rules to simplify its implementation. However, simplifications of the CDA rules matter (LiCalzi and

Pellizzari 2008). We consider that traders randomly place offers on the books. Orders are immediately executed at the outstanding price if they are marketable. Otherwise, they are recorded on the books and remain valid until either the end of the trading session or the agent improves its offer (to buy or to sell).

8.3.2 The Environment

There are 12 sellers and 12 buyers in the market. Each agent has fifteen units to trade and their valuations are those reported in Noussair et al. (1998). The result of their aggregation are the following demand and supply: $D(x) = 1535-10x$ and $S(x) = 35 + 10x$, respectively. Competitive equilibrium exists at any market price between 780 and 790 and a quantity of 75. The total surplus is 57,105 which is the sum of the consumer (27,375) and the producer surplus (29,730).

8.3.3 The Agents' Behaviour

Traders in CDA markets face three non-trivial decisions: How much should they bid or ask? When should they place a bid or an ask? And when should they accept an outstanding order? Bidding strategies corresponds to particular answers for these decisions. Learning has a relevant role in market efficiency and price convergence in CDA markets (Posada et al. 2008; LiCalzi and Pellizzari 2008).

Submit an order. Traders learn to decide on how much should they bid or ask following the GD bidding strategy (Gjerstad and Dickhaut 1998), and they submit their orders 25 times the percentage. Each agent chooses the order which maximizes his expected surplus, defined as the product of the gain from trade and the probability for an offer to be accepted. The main point is to estimate this probability. GD agents estimate and modify this probability using the history of the market (the last 8 rounds).

Accept an order. Traders can use either the GD bidding strategy or the K bidding strategy (Rust et al. 1993). When traders follow the GD bidding strategy, they accept an outstanding offer to sell if it is less than its calculated offer to buy (submitted or not) and they accept an outstanding offer to buy if it is greater than its calculated offer to sell (submitted or not). The K bidding strategy consists in: "wait in the background and let others negotiate. When an order is interesting, accept it". An order is interesting when both the ratio between the outstanding bid and the outstanding offer is less than a percentage range between 1.25 and 3.75 %, and the surplus achieved in the transaction is greater than a percentage range between 1 and 3 %. Nevertheless, if the time is running out, any order (which provides benefits) is interesting. The K agents are *parasitic* on the intelligent agents to trade and to obtain profit.

8.4 Simulations and Main Results

We analyze CDA market efficiency and wealth distribution performance in the following six scenarios, where different percentage of two kinds of learning agents (GD and K) are considered, and *parasitic* agents are always in the demand side: 100 % GD–0 % K, 75 % GD–25 % K (buyers), 66.75 % GD–33.3 % K (buyers), 58.3 % GD–41.7 % K (buyers), 54.2 % GD–45.89 % K (buyers), and 50 % GD–50 % K (buyers). Each run consists of a sequence of ten consecutive trading periods, each one lasting 100 time steps.

8.4.1 Market Efficiency

We define allocative market efficiency as the total profit actually earned by all the traders divided by the maximum total profit that could have been earned by all the traders (i.e., the sum of producer and consumer surplus) (Smith 1962). We have obtained that the market efficiency is closed to 100 % when all traders in the market use a GD bidding strategy (see Fig. 4.1). Market efficiency decreases as the percentage of K bidding strategy increases. However, the market accepts some *parasitic* agents (around 40 %) without a relevant decrease of market efficiency. If all traders in the market are K agents no trade will take place and market efficiency is zero.

8.4.2 Wealth Distribution

We use the Lorenz curve and Gini index to quantify the wealth distribution. The Lorenz curve is a graphical representation of the cumulative surplus distribution function. It shows for the x % of market traders, what percentage y % of the total surplus they have. The Gini coefficient is the area between the line of perfect equality and the observed Lorenz curve, as a percentage of the area between the lines of perfect equality and inequality. The higher the coefficient, the more unequal the distribution is. A Gini coefficient of one expresses maximal inequality. It is calculated by Eq. (8.1):

$$G = \left| 1 - \sum_{i=1}^{N} \left(\sigma Y_{i-1} + \sigma Y_i\right) \left(\sigma X_{i-1} + \sigma X_i\right) \right| \tag{8.1}$$

where N is the number of traders, σY is the Y accumulated percentage of the surplus, and σX is the X accumulated percentage of the population.

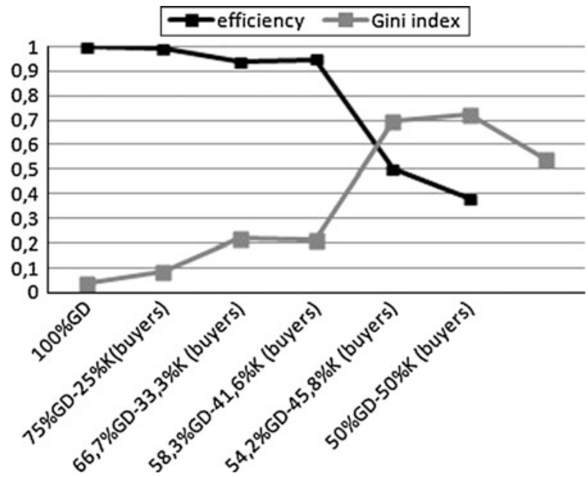


Fig. 8.1 Market efficiency and Gini index for different populations

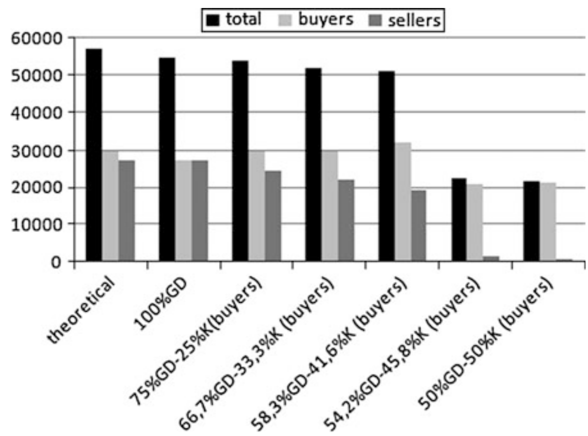


Fig. 8.2 Total surplus, buyer surplus, and seller surplus for different populations

The wealth distribution is near the perfect equality when all traders in the market use a GD bidding strategy. The Gini index increases (inequality) as the percentage of K bidding strategy increases (see Fig. 8.1). Moreover, as the inequality wealth distribution increases, the total surplus which is shared, decreases (see Fig. 8.2). The inequality in wealth distribution has a big jump when the percentage of *parasitic* agents is greater than 40 % (see Fig. 8.3).

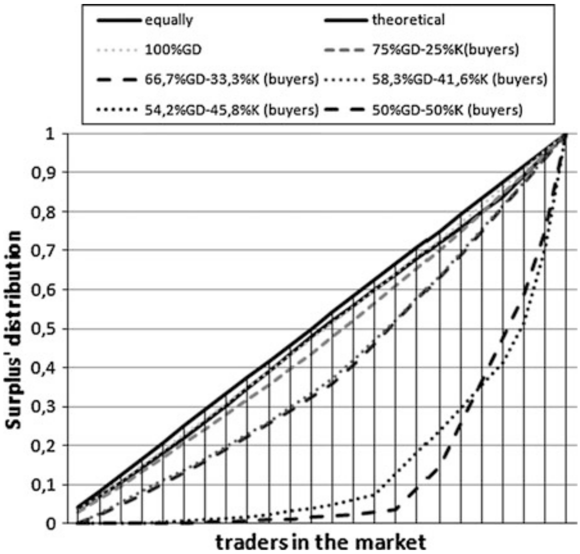


Fig. 8.3 Lorenz curves for different populations

8.5 Conclusions

The crisis has vividly demonstrated the deficiencies in the outdated current economic theories, calling for rethinking Economics. One should try alternative Economic approaches such Experimental Economics with humans or artificial agents. Not relying only in the full rational citizen or on his moral sentiments.

To this end, we have tested with artificial agents, the fact observed with human experiments: *the invisible hand* can lead to undesirable outcomes in terms of wealth distribution. Market efficiency does not imply fair wealth distribution. We have illustrated the origin of the problem and consequently how to avoid it, by introducing parasitic agents with free riding behaviour. We observe that both market efficiency and wealth distribution decrease as the percentage of *parasitic* agents increases. This result holds for different values of the model parameters.

To assure a fair distribution and market efficiency one has to properly design the institution (I) (the exchange rules, the way the contracts are closed, and the information network), the environment (E) (agent endowments and values, resources, knowledge) and the agents' behavior (A). ABM helps to design the triplet (I × E × A).

The paper is a sample of ongoing research to develop an ABM frame to serve Institutional Economics and to rethink economics. A suitable Social Contract that will achieve wealth generation (market) and fair distribution (democracy) is imperative and feasible. ABM can provide guidance to achieve this social goal.

References

Bersini H, van Zeebroeck N (2011) Why should the economy be competitive? Lect Notes Econ Math Syst 625:117–128

Gjerstad S, Dickhaut J (1998) Price formation in double auctions. Games Econ Behav 22:1–29

Gode D, Sunder S (1993) Allocative efficiency of market with zero-intelligent traders: market as a partial substitute for individual rationality. J Polit Econ 101:119–137

LiCalzi M, Pellizzari P (2008) Simple market protocols for efficient risk sharing. J Econ Dyn Control 31:3568–3590

Noussair C, Robin S, Ruffieux B (1998) The effect of transaction costs on double auction markets. J Econ Behav Organ 36:221–233

Posada M, Lopez A (2008) How to choose the bidding strategy in continuous double auctions: imitation versus take-the-best heuristics. J Artif Soc Soc Simul 11(1):6, http://jasss.soc.surrey.ac.uk/11/1/6.html

Posada M, Hernández C, Lopez A (2008) Testing Marshallian and Walrasian instability with an agent based model. Adv Complex Syst 11(2)

Rust J, Miller J, Palmer R (1993) Behaviour of trading automata in computerized double auctions. In: Friedman, Rust (eds) The double auction markets: institutions, theories and evidence. Addison-Wesley

Sachs J (2010) America's political class struggle. The project syndicate

Smith VL (1962) An experimental study of competitive market behavior. J Polit Econ 70:111–137

Smith VL (1982) Microeconomic systems as an experimental science. Am Econ Rev 72:923–955

Part II
Technological and Organizational Innovation

Chapter 9
The Importance of Strategic Alignment in Enterprise Collaboration

Alix Vargas, Andrés Boza, Llanos Cuenca and Angel Ortiz

9.1 Introduction

The aim of this paper is to approach as closely as possible the concepts of IS/IT and business strategic alignment to the business collaboration, as well as to perform a deep analysis of articles that has combined these two concepts. In an effort to gain a better understanding of the concepts and to provide a basis for future research, a broad review of some existing research on the topic has been presented. This paper is organized as follows. In next section, the methodology used in the selection of scientific articles. Secondly, we present a conceptual and comparative analysis of selected articles regarding to strategic alignment and enterprise collaboration. Then, a conceptualization and joint analysis between enterprise collaboration and strategic alignment, and finally, the conclusions and directions for further research.

9.2 Methodology

The search process was carried out with scientific-technical bibliographic databases, as well as web sites related to these themes. The following search criteria were applied: strategic alignment, business strategy and integration (in the strategic alignment field), and strategic collaboration, enterprise integration and collaborative planning (in the enterprise collaboration field). The main selection criteria of articles were: the number of times cited and the most recent year of publication (after 2007), without leaving aside the articles prior to this date that form the theoretical basis on the issues investigated. The majority of the citations

A. Vargas (✉) · A. Boza · L. Cuenca · A. Ortiz
Centro de Investigación en Gestión e Ingeniería de Producción (CIGIP),
Universitat Politècnica de València, Camino de Vera s/n Ed 8G -1° y 4° planta Acc D,
Valencia, Spain
e-mail: alvarlo@upv.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_9,

were found in journals (44 %), conference (28 %), book chapter (18 %), web documents (5 %) and PhD thesis (5 %).

9.3 Conceptualization of Enterprise Collaboration

Increasing profits and customer value generation forces enterprises to not compete individually, due to competition among SCs, so it is necessary to have a high degree of integration among partners that take part in these SCs (Plaza et al. 2010 and McIvor and McHugh 2000). This degree of integration may be achieved through collaborative mechanisms to ensure the alignment of individual plans in the search for a goal or joint plan. In this point, collaboration emerges as a tool that allows SC members to make decisions together, based on shared and exchanged information, to coordinate and synchronize activities.

According to the main elements about enterprise collaboration provide by: Stadtler and Kilger (2002), Alarcón et al. (2004), Alarcón (2005), Petersen et al. (2005), Ribas et al. (2006, 2007), Stadtler (2009), and Dudek (2009), we define enterprise collaboration, as: “A joint process between members of the SC, where the decisions are made jointly, based on the information shared and exchanged on a bilateral form, achieving coordinate and synchronize joint activities to meet customer requirements and achieve process efficiency sets to generate a mutually beneficial” (Vargas et al. 2011b).

9.3.1 Collaborative Process Description

For Kilger et al. (2008), the collaboration process consists of six activities: (1) Definition, (2) Planning in the local domain, (3) Plan of exchange, (4) Negotiating and exception handling, (5) Execution and (6) Measurement of results. However, a crucial aspect has not been taken into account in this generic process for determining efficient collaboration: this is the definition of how to share benefits equitably to ensure the stability of the collaboration (Audy et al. 2010). The solution to this aspect is provided by Stadtler (2009), which proposes a system of compensatory payments. This system may be agreed on the definition phase of the negotiation and exception handling and can be implemented when the results are evaluated. Other aspect not considered in the process of Kilger et al. (2008) is the feedback between parts once the collaboration process has been completed in the stipulated horizon, which allows reviewing and modifying the plan if it is necessary.

9.4 Conceptualization of Strategic Alignment

Nowadays, IT and IS have acquired a strategic role within organizations and this function has increased the impact on business strategy providing competitive advantages. Companies manage the technological complexity of their IS in order to generate added value to business processes. This can only be achieved if there is an alignment between business and IS/IT. This concept became stronger in the 1990s thanks to the Strategic Alignment Model (SAM) proposed by Henderson and Venkatraman (1993) although the theory suggests that there should be a strategic fit between the internal and external domains of both business and IT and also there should be a functional integration between business and IS/IT, in fact the implementation of the alignment is quite complicated to carry it out, because of the studies, models and/or frameworks developed for this purpose are scarce and often their utility have not been validated in the real world.

Several authors have defined the term strategic alignment (Luftman and Brier 1999; Luftman 2000; Maes et al. 2000; Pereira and Sousa 2005; Erosa and Arroyo 2008; Chen et al. 2008; Adaba et al. 2010; Chen 2010; Cuenca et al. 2010), according to the most important elements provided in these definitions, we suggest the following: "The strategic alignment of business and IS/IT is a dynamic and continuous process that enables integration, adjustment, consistency, understanding, synchronization and support between business strategies and strategies of IS/IT, in order to contribute and maintain the correct performance of the organization, creating a competitive advantage that is sustained over time".

However, while the concept of strategic alignment is easy to understand (Thevenet and Salinesi 2008), its application in the enterprise is not easy to carry out (Chen et al. 2008) due to a complex business environment (Hu and Huang 2006) and frequent organizational and infrastructure changes faced by enterprises.

9.4.1 Main Models and Frameworks of Strategic Alignment

The field of strategic alignment is reinforced by SAM exposed by Henderson and Venkatraman (1993), but their bases are theoretical and not practical. The alignment maturity model (AMM), by Luftman (2000), presents a practical component that SAM does not have; this model is based on the conceptual concepts treated in SAM where, practical aspects for strategic alignment are included. Proposing a model to measure the degree of business and IS/IT alignment maturity enables the company to identify, how it is, where and how to improve (Vargas et al. 2011a).

Several authors have extended or used SAM from different conceptual aspects seeking to ensure strategic alignment (Maes 1999; Wang et al. 2008; Luftman and Brier 1999; Thevenet and Salinesi 2008; Hu and Huang 2006; Marques et al. 2005; Mekawy et al. 2009; Dong et al. 2008; Weiss and Anderson 2004; Cuenca et al. 2010, 2011a; Cuenca 2009; Maes et al. 2000). Other proposal have been based on the AMM to propose practical conceptual models (Luftman 2003; Adaba et al. 2010; Chen 2010; Erosa and Arroyo 2008; Bagher et al. 2010). However, all these previous models can only be applicable to the individual business, but it is clear that the atmosphere of competition in the market is quickly changing towards a more collaborative environment, in this sense, some authors have proposed models or frameworks for alignment in the inter-enterprise context (Derzsi and Gordijn 2006; Santana et al. 2008), or have been taken into account the social factors of alignment (Lee et al. 2008; Pijpers et al. 2009).

9.5 Conceptualization and Analysis of Enterprise Collaboration and Strategic Alignment

Although the need for collaboration among members of an SC is evident to lean on IS/IT to support the joint business, very few studies have been tackled these issues together: Derzsi and Gordijn (2006) address the issue of strategic alignment in supply chains or networks, although the issue of collaboration has not been addressed specifically, it is considered an intrinsic part of the structure of the current SC; Pijpers et al. (2009) address the strategic alignment from the design of the company and they take into account the inter-organizational relationships that the company and its partners should have; finally, Santana et al. (2008) deal with the alignment by defining a maturity model for collaborative networks alignment.

In order to perform a conceptual analysis of the aspects that are taken into account in strategic alignment models in collaborative environments, we have identified the components of the previous researches of alignment, and checked which are covered by these models. Table 9.1 shows the required components defined by Cuenca (2009), Henderson and Venkatraman (1993) and Luftman (2000). The nomenclature used is explained below: The "+" means that the alignment component is covered by the model using the same or similar name, "–" means that the component is not covered by the model and the "/" means that the component is not defined in the model explicitly but it is defined implicitly. According to this analysis, all models include, explicitly or implicitly defined alignment components of Henderson and Venkatraman (1993), the components defined by Cuenca et al. (2011b), are not completely covered by these models, and the AMM of Luftman (2000), is only used in the model of Santana et al. (2008).

On the other hand the Table 9.2 shows the relationship between the phases of the collaborative process discussed in Sect. 9.3.1 and models of alignment of business and IS/IT in collaborative environments, in order to identify which aspects of collaborative process covering these models, the conventions used are the same as in the Table 9.1.

The phases for collaborative processes are not covered by any of the models, only implicitly the planning in the local domain and the exchange program are covered in the three models. This means that models of alignment in collaborative

Table 9.1 Analysis of the components of strategic alignment and strategic alignment models in collaborative environment

Research	Component strategic alignment	Author, year		
		Pijpers et al. (2009)	Santana et al. (2008)	Derzsi and Gordijn (2006)
Henderson and Venkatraman (1993)	Business strategy	+	+	+
	Organizational and processes infrastructure	+	+	+
	Infrastructure information systems	+	+	+
	IS/IT strategy	/	/	/
Cuenca et al. (2011b)	IT conceptualization	/	/	/
	Application and services portfolio	–	–	–
	Alignment heuristics	–	–	–
	Strategic dependencies model	–	–	–
	Alignment maturity model	–	+	–
Luftman (2000)	Alignment maturity model	–	+	–

Table 9.2 Analysis between the process of collaboration and strategic alignment models in collaborative environment

Phase of the enterprise collaboration process	Author, year		
	Pijpers et al. (2009)	Santana et al. (2008)	Derzsi and Gordijn (2006)
Definition and collaboration agreement	–	–	–
Planning in the local domain	/	/	/
Plan of exchange	/	/	/
Negotiation, exception handling and compensation system	–	–	–
Execution	–	–	–
Measurement of results and implementation of compensation plan	–	–	–
Feedback and review of the plan	–	–	–

environments have been more concerned to conceptualize alignment in collaborative environments, which propose methodologies to ensure the effectiveness of these concepts within complex collaborative processes.

9.6 Conclusions and Future Lines of Research

Few studies have addressed the issues of enterprise collaboration and strategic alignment together. They have proposed conceptual models or alignment frameworks in collaborative environments. However, in most cases, they lack empirical evidence and practice of the effectiveness of these models.

There are more similarities than differences between the three alignment models proposed in collaborative environments, all components of conceptual models of collaboration are common to each other, agreeing the three models in the conception of the need for integrated objectives between partners collaboration, to facilitate joint value creation through the definition of integrated objectives that are supported by IS to achieve interoperability of the joint business and integration of individual processes.

The three models of alignment in collaborative environments have been comparatively analyzed from two different perspectives: the relationship of the models with the theories of alignment and relationship of the models with the collaborative process. The results of this analysis show that the models take into account in their structure all the conceptual aspects of strategic alignment, but the methodological aspects of the collaborative process are sorely lacking. This fact generates a possible line of research, seeking to extend the conceptual models of alignment in collaborative models that provide not only theoretical aspects but also practical aspects such as generating methodological proposals to guide the implementation of the alignment models in collaborative environments.

References

Adaba G, Rusu L, Mekawy M (2010) Business-IT alignment in trade facilitation: a case study. Organ Bus Technol Aspects Knowl Soc CCIS 112:146–154 Springer, Berlin

Alarcón F (2005) Desarrollo de una Arquitectura para la definición del proceso de Comprometer Pedidos en contextos de Redes de Suministro Colaborativas. Aplicación a una Red compuesta por Cadenas de Suministro en los Sectores Cerámico y del Mueble. Doctoral Thesis, Universidad Politecnica de Valencia

Alarcón F, Ortiz A, Alemany M, Lario F (2004) Planificación Colaborativa en un contexto de varias Cadenas de Suministro: ventajas y desventajas. VIII Congreso de Ingeniería de Organización, pp 857–866, Leganes

Audy J, Lehoux N, D'Amours S (2010) A framework for an efficient implementation of logistics collaborations. Int Trans Oper Res, pp 1–25

Bagher H, Gardesh H, Shadrokh S (2010) Validating ITIL maturity to strategic business-IT alignment. In: 2nd international conference on computer technology and development (ICCTD), pp 551–556

Chen L (2010) Business–IT alignment maturity of companies in China. Inf Manage 47:9–16

Chen R, Sun C, Helms M, Kennyjih W (2008) Aligning information technology and business strategy with a dynamic capabilities perspective: a longitudinal study of a Taiwanese Semiconductor Company. Int J Inf Manage 28(5):366–378

Cuenca L (2009) Marco arquitectónico para la propuesta IE-GIP. Extensión de la arquitectura CIMOSA. Aplicación a una empresa del sector cerámico. Tesis Doctoral Universidad Politecnica de Valencia

Cuenca L, Boza A, Ortiz A (2010) Enterprise engineering approach for business and is/it strategic alignment. In: 8th international conference of modeling and simulation—MOSIM'10, 10–12 May 2010, Hammamet, Tunisia, pp 1–10)

Cuenca L, Ortiz A, Boza A (2011a) Architecting business and IS/IT strategic alignment for extended enterprises. Stud Inf Control 20(1):7–18
Cuenca L, Boza A, Ortiz A (2011b) An enterprise engineering approach for the alignment of business and information technology strategy. Int J Comp Integr, 1(19)
Derzsi Z, Gordijn J (2006) A framework for business/IT alignment in networked value constellations. In: Latour T, Petit M (eds) Proceedings of the workshops of the 18th international conference on advanced. Belgium, pp 219–226
Dong X, Liu Q, Yin D (2008) Business performance, business strategy, and information system strategic alignment: an empirical study on Chinese firms, 13 (3):348–354
Dudek G (2009) Collaborative planning in supply chains. Supply Chain Manage Collaborative Plan, pp 5–24. Springer, Berlin
Erosa V, Arroyo P (2008) Technology alignment under two strategic contexts. PICMET, pp 9–16
Henderson J, Venkatraman N (1993) Strategic alignment: leveraging information technology for transforming organizations. IBM Syst J 32(1):472–484
Hu Q, Huang D (2006) Using the balanced scorecard to achieve sustained IT-business alignment: a case study. Commun Assoc Inf Syst 17:181–204
Kilger C, Reuter B, Stadtler H (2008) Collaborative planning. In: Stadtler H, Kilger C (eds) Supply chain management and advanced planning—concepts, models software and case studies. Springer, Berlin Heidelberg, pp 263–284
Lee S, Kim K, Paulson P, Park H (2008) Developing a socio-technical framework for business-IT alignment. Ind Manage Data Syst 108(9):1167–1181
Luftman J (2000) Assessing business-IT alignment maturity. Communications of the Association for Information Systems, 4
Luftman J (2003) Assessing IT/business alignment. Inf Syst Manage, pp 9–15
Luftman J, Brier T (1999) Achieving and sustaining business-IT alignment. Calif Manage Rev 4(2):109–122
Maes R (1999) Reconsidering information management through a generic framework. Retrieved Mayo 22, 2011, from Universiteit van Amsterdam: http://primavera.fee.uva.nl
Maes R, Rijsenbrij D, Truijens O, Goedvolk H (2000) Redefining business—IT alignment through a unified framework. Retrieved Mayo 21, 2011, from CiteSeerXbeta: http://www.citeulike.org/user/cortex/article/2049717
McIvor R, McHugh M (2000) Collaborative buyer supplier relations: implications for organization change management. Strateg Change 9:221–236
Mekawy M, Rusu L, Ahmed N (2009) Business and IT alignment: an evaluation of strategic alignment models. Best Practices Knowl Soc: Knowl Learn Dev Technol All CCIS, vol 49, pp 447–455, Springer
Pereira CM, Sousa P (2005) Enterprise architecture: business and IT alignment. In: Proceedings of the 2005 ACM symposium on applied computing, pp 1344–1345, ACM.
Petersen K, Ragatz G, Monczka R (2005) An examination of collaborative planning effectiveness and supply chain performance. J Supply Chain Manage 41(2):14–25
Pijpers V, Gordijn J, Akkermans H (2009) Aligning information system design and business strategy: a starting internet company. Pract Enterp Model LNBIP, vol 15, pp 47–61, Springer
Plaza J, Burgos J, Carmona E (2010) Measuring stakeholder integration: knowledge, interaction and adaptational behavior dimensions. J Bus Ethics 93:419–442
Ribas I, Companys R (2007) Estado del arte de la planificación colaborativa en la cadena de suministro: Contexto determinista e incierto. Intangible Capital, pp 91–121
Ribas I, Lario F, Companys R (2006) Modelos para la planificación colaborativa en la cadena de suministro: contexto determinista e incierto. Congreso de ingeniería de organización, Valencia, pp 1–10
Santana R, Daneva M, van Eck P, Wieringa R (2008) Towards a business-IT aligned maturity model for collaborative networked organizations. In: 12th international conference on advanced information systems engineering, Munich, pp 276–287
Stadtler H (2009) A framework for collaborative planning and state-of-the-art. OR Spectr 31:5–30

Stadtler H, Kilger C (2002) Supply chain management and advance planning: concepts, models, software and cases studies. Springer, Heidelberg
Thevenet L, Salinesi C (2008) Aligning IS to organization's strategy: The INSTAL method. In: 19th international conference on advanced information systems engineering, LNCS, vol 4495, pp 203–217
Vargas A, Boza A, Cuenca L (2011a) Lograr la alineación estratégica de negocio y las tecnologías de la información a través de Arquitecturas Empresariales: Revisión de la Literatura. XV Congreso de Ingeniería de Organización, Cartagena, pp 1061–1070
Vargas A, Boza A, Cuenca L (2011b) Towards Interoperability through Inter-enterprise Collaboration Architectures. In: Meersman R, Dillon T, Herrero P (eds) OTM 2011 Workshops. LNCS, vol 7046, pp 102–111. Springer, Berlin
Wang X, Zhou X, Jiang L (2008) A method of business and IT alignment based on enterprise architecture. IEEE international conference on service operations and logistics, and informatics, pp 740–745
Weiss J, Anderson D (2004) Aligning technology and business strategy: issues and frameworks: a field study of 15 Companies. In: Proceedings of the 37th Hawaii international conference on system sciences, pp 1–10

Chapter 10
Infrastructure Assignment Reference Metamodel

Miguel Gutierrez and Alfonso Duran

10.1 Introduction and Objectives

In some infrastructure assignment problems there is a barrier to the adoption of the allocation algorithms, stemming from the intrinsic linkage between these algorithms and the specific design of the business processes involved. This paper focuses on a particular subset of these problems, the efficient allocation of fixed cost, perishable (e.g., which can't be stashed for future use) infrastructures among alternative, heterogeneous users (e.g., pricing and reservation process in a hotel).

To tackle that barrier we lean on the flexibility potential offered by the metamodeling technique. This potential has been demonstrated in the development of enterprise management software based upon the database implementation of an enterprise metamodel as opposed to the traditional model-based implementation approach (Braun and Winter 2005; Malhotra 2010; Maslianko and Maistrenko 2012). Lagerström et al. (2009) point out the advantages in terms of cost and flexibility of a metamodel-based enterprise architecture. Gutiérrez et al. (2006) illustrate the benefits of the metamodeling technique, particularly for SMEs, in terms of flexibility, adaptability and savings in company-specific adaptations through the complete software life-cycle.

In this paper we describe the process followed in applying the metamodel approach to the aforementioned infrastructure assignment problems. The theoretical framework used will be the metamodeling architecture advocated by the Object Management Group (OMG). A hierarchy of levels is defined (Mn; n = 0,1,2,3…), in which each model of a layer is an instance of a model of the following layer, more abstract and general. Although the relation concept-metaconcept is iterative, and therefore it can extend infinitely, in the present specification of the UML (Unified Modeling Language) the OMG (2011a)

M. Gutierrez (✉) · A. Duran
Area de Ingeniería de Organización, Universidad Carlos III de Madrid,
Avda. de la Universidad, 30, 28911 Leganés, Madrid, Spain
e-mail: miguel.gutierrez@uc3m.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_10,

specifies the following four layers that encompass the fundamental concepts normally used in metamodeling: The information layer (M0) includes the data that are meant to be described; the modeling layer of (M1) includes the metadata of the data, grouped in models; the metamodeling layer of (M2) contains the descriptions which define the structure and semantics of the models, grouped in metamodels; the layer of meta-metamodeling (M3) includes the description of the structure and semantics of the metamodels; which is an "abstract language" for the definition of metamodels.

Despite the conceptual problems that have been pointed out regarding this architecture, in particular concerning the meta-instantiation (Atkinson and Kühne 2003; Shorter and Focus 2005), its simplicity makes it suitable for our purposes. Karagiannis and Kuhn (2002) give insights in the metamodeling technique basics. Within this framework, the main objective of this research is to follow a modeling generalization process, leading to the design and conceptual definition of an infrastructure assignment reference metamodel. Instead of taking a standard metamodel as starting point, e.g. UML, we use the enterprise metamodel presented in Gutiérrez et al. (2006). The purpose of doing so is twofold: on the one hand, to present a sequence of models providing gradually higher support to infrastructure assignment problems, on the other hand, to explore the flexibility rendered by the metamodel-based approach. This is accomplished through a three step process:

First, providing companies that use metamodel-based management software with infrastructure assignment functionality.

Second, supporting companies that use metamodel-based management software in the design of the infrastructure assignment process.

Third, proposing an infrastructure assignment metamodel, intended to be the core of an independent decision support system.

After a brief description of the enterprise metamodel in the next section, the third, fourth and fifth sections deal with the three methodological steps. Finally, we present the main conclusions drawn from the research work and perspectives.

10.2 Enterprise Reference Metamodel

The enterprise reference metamodel we use in our approach essentially derives from the merging of two main UML packages: the Entity Metamodel and the Relationship Metamodel (Gutiérrez et al. 2006).

The *Entity Metamodel* (Fig. 10.1) comprises a hierarchy of *Enterprise_Entity*, each of which is *characterized* through the assignment of a set of *Enterprise_Feature*, and the corresponding *Enterprise_Object* (for the sake of legibility, from now onwards we will omit the "Enterprise_" preceding the elements of the metamodel). The hierarchy is established by the *generalization* class, and allows feature inheritance from parent entities (general) to child entities (specific).

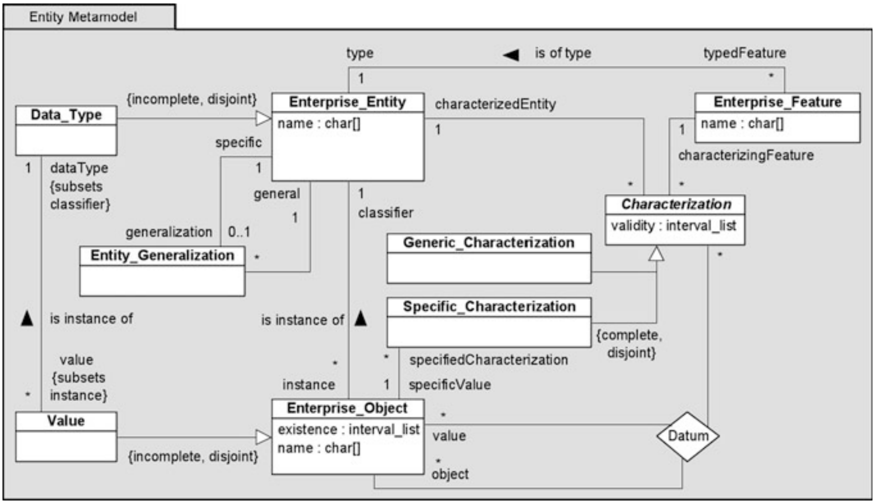


Fig. 10.1 Entity metamodel UML package

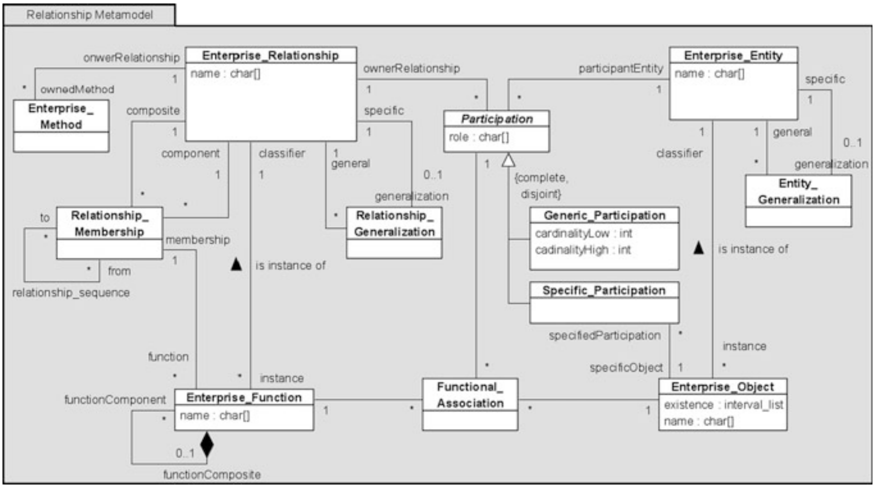


Fig. 10.2 Relationship metamodel UML package

The other essential elements of an enterprise model are the *Relationships* between entities, established with commercial or management purposes (Fig. 10.2). The *Participation* element links the *Entities* to the *Relationships*. There is also a complete classification in generic and specific participations. In the *Generic_Participation* it is possible to define cardinality. The *Relationship* inheritance tree, set through the *generalization* element, allows the gradual and intuitive definition of the enterprise activity.

10.3 Incorporating Infrastructure Assignment (IA) Functionality

One of the main advantages of metamodel-based enterprise management software development is the inherent flexibility of the resulting system that enables the necessary adaptation emerging from the changing nature of companies using it. As the company evolves, new functionalities are required. In this section we consider a fictional company that is using an enterprise management system developed upon the previously described metamodel, and we exploit the underlying flexibility to introduce infrastructure assignment functionalities in such system.

As mentioned in the introduction section, among the various IA problems, we focus on a particular, though sufficiently representative and generic, subset: procedures for the efficient allocation, to the various potential user classes, of non-storable fixed-cost service infrastructures whose value potential is dilapidated if not utilized.

The first step to model the new functionality is to define the basic entities (and hierarchies of entities) involved. Based on previous contributions we conceptualize the above mentioned IA set of problems as follows (Gutiérrez and Durán 2011): customers, grouped in customer segments, request the allocation of certain type of infrastructure through some access channel. Thus, there are three initial *Entities* to consider: *Customer Segment*, *Channel* and *Infrastructure*.

If we want to add the IA functionality, those entities as well as their corresponding objects, would typically exist in the management system prior to the definition of the new process. The combination of entities takes place in a *Relationship*, thus the triad customer segment/channel/infrastructure will participate in a relationship called *Infrastructure Access*.

In order to find the most profitable allocation of infrastructures to their potential use, some value (entity *Value*) will be assigned to each possible customer segment/channel/infrastructure combination (each infrastructure access). Besides, it will be possible to assign different values to each infrastructure access, one per each time interval (defined through the entity Time). The relationship *Allocation* will result as the participation of all the entities involved in the *Infrastructure* As*signment Process*. In order to define the specific possible *Allocations* allowed in the actual IA processes, it is necessary to create process-specific *Relationships* descending from *Allocation*. The collection of possible *Allocations* will specify how a particular type of infrastructure is assigned to one of its potential uses, thus defining an *IA Process*.

Following and complementing the conventions stated in Gutiérrez et al. (2006), we represent the IA process along with an illustrative example as shown in Fig. 10.3. Taking UML as a reference, the instances of *Entity* are represented as double-lined boxes; *Relationships* are represented as double-lined diamonds; *Participation* instances are circle-ended lines linking entities to relationships; and the *Generalization* association is represented by a line ending in a double-lined triangle. The upper side of the figure defines the *IA Process* as previously

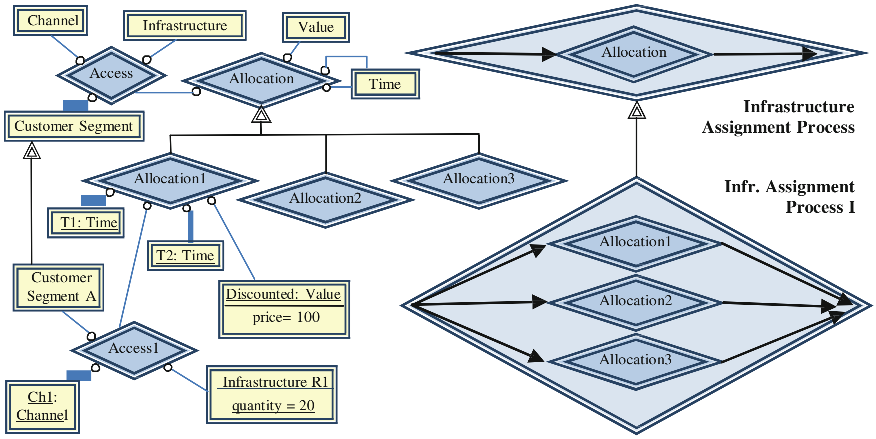


Fig. 10.3 Infrastructure assignment process

described. Diamond that represents this generic process encompasses a generic *Allocation*. As means of illustration, three process-specific *Allocations* are defined as subtypes of *Allocation*, and main details of one of them (*Allocation*1) are included. Assigning specific values for a feature at the entity level is achieved through a *Specific_Characterization* of a *Feature* (e.g. quantity) that is assigned to an *Entity* (e.g. Infrastructure R1), whereas redefining the participation of an *Entity* (Time) in a *Relationship* with an *Object* (T1) is done by defining a *Specific_Participation*. In the *IA ProcessI*, the *Membership* specifies that the *Allocations* are sequenced in parallel, since only one would take place for each execution of the process.

10.4 Incorporating Infrastructure Assignment Optimization

One step beyond supporting the current enterprise processes involves incorporating a decision-support module or optimization package, capable of aiding in the design of the business processes of the company involved. In order to do that, it is necessary to conceptualize all the specific elements involved in the business process as belonging to a higher modeling layer, i.e., to add a level of generality to all the elements of the initial model.

The way to define generic process models and specific process instances, both at the entity level, is to establish a generalization hierarchy as depicted in Fig. 10.4. To emphasize some possibilities to form the hierarchies, we represent examples of hierarchies with the entities *Infrastructure* and *Value* without the complete model (i.e., the entities will be linked with hierarchies of *Access* and *Allocation* as in Fig. 10.3). There will be (at least) three hierarchical levels. The first one, *Generic IA Process* corresponds directly with the *IA Process* of Fig. 10.3. With respect to the other two, the difference between each entity of the process model and its equivalent in the process instance stems from the level of characterization. We will be able to define a process model not dependent upon the features of the entities as well as consider generic *Times* or *Values* in the model.

Furthermore, from the functional point of view, since two *Process Instances* which differ only in the value of the quantity feature for the Infrastructures will be deemed as belonging to the same *Process Model*, we would thus be able to use the software to find the most profitable value for quantity among a set of possible values. In the same way as the model-metamodel relationship extends infinitely (see Sect. 10.1), we can extend the *Relationship* hierarchy as much as needed until grouping the process models in a suitable manner in order to obtain an efficient support for the IA process design.

10.5 Obtaining an Infrastructure Assignment Reference Metamodel

Up to this point, we have highlighted the potential of the metamodel-based enterprise software development to incorporate company-specific IA support. On the other hand, advantages in terms of flexibility have been revealed by the metamodeling approach. We can add a new level of generality to the approach and make it independent from the enterprise metamodel while taking advantage from the metamodel-based development.

The 'generalization shift' can be observed in Fig. 10.5, which follows the same schema than the one included in the UML Infrastructure specification (OMG 2011a). In the approach of Sects. 10.3 and 10.4, the Enterprise Metamodel (in layer M2) is obtained as an instance of MOF, the Meta Object Facility standard (OMG 2011b) (in layer M3), crossing the boundary of the metamodel layer. The idea behind the proposal of this section is to 'push' the IA Model up to the

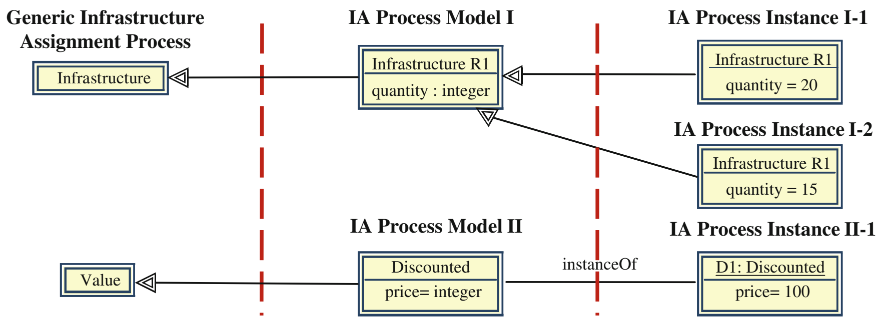


Fig. 10.4 Generalization hierarchies

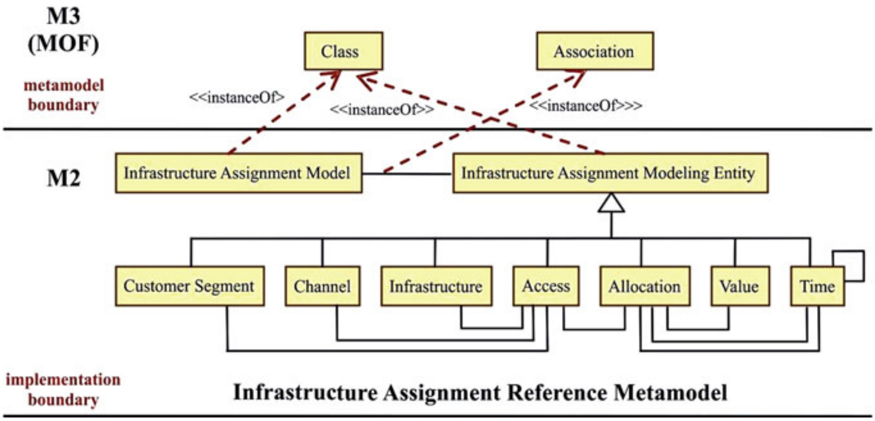


Fig. 10.5 Infrastructure assignment reference metamodel

metamodel layer, and obtain it directly as an instance of MOF. It would be intended for the metamodel-based development of an IA decision support system. Note that only few details and relationships of the model have been included for the sake of clarity. Finally, in the model layer, we would follow the same generalization hierarchy of the former section.

10.6 Conclusions

Additional flexibility is required in order to provide efficient support to some infrastructure assignment (IA) problems. With this aim, we have first explored the capabilities of the metamodeling technique in functional and design support for this kind of problems. We show that if at any given point in time a company using a metamodel-based enterprise management system identifies the need for support in some IA process, it is possible to define it just by means of instantiation of the implemented metamodel.

The inherent flexibility of the metamodel approach can be further exploited by replicating the enterprise metamodel logic to define an IA reference metamodel. This metamodel is intended to be directly implemented in a database, and to constitute the basis of the conceptual model of a decision support system. The development of this system appears to be a promising way of achieving the flexibility required for IA problems.

Acknowledgments This work stems from the participation of the authors in a research project funded by the Spanish National Research Plan, reference DPI2008-04872, title “Optimizacion de la asignación de infraestructuras de servicios mediante simulación—sectores hotelero y sanitario”.

References

Atkinson C, Kühne T (2003) Model-driven development: a metamodeling foundation. IEEE Softw 20(5):36–41

Braun C, Winter R (2005) A comprehensive enterprise architecture metamodel and its implementation using a metamodeling platform. In: Proceedings of enterprise modelling and information systems architectures, pp 64–79

Gutiérrez M, Durán A, Cocho P (2006) An alternative approach to the standard enterprise re-source planning life cycle: enterprise reference metamodeling. Lect Notes Comput Sci 3982:964–973

Gutiérrez M, Durán A (2011) Generic model base design for decision support systems in revenue management: applications to hotel and health care sectors. In: Jao CS (ed) Efficient decision support systems: practices and challenges-from current to future, Ch 10, pp 183–194

Karagiannis D, Kuhn H (2002) Metamodelling platforms. Lect Notes Comput Sci 2455:182–196

Lagerström R, Franke U, Johnson P, Ullberg J (2009) A method for creating enterprise architecture metamodels: applied to systems modifiability analysis. Int J Comput Sci Appl 6(5):89–120

Malhotra R (2010) Using a meta-modelling knowledge management layer: a new approach to designing the enterprise information architecture. Int J Data Anal Tech Strat 2(4):307–335

Maslianko PP, Maistrenko AS (2012) A system of entities for enterprise business models. Cybern Syst Anal 48(1):99–107

Object Management Group (2011a) OMG unified modeling language (OMG UML), Infrastructure V 2.4.1. Available at http://www.omg.org/spec/UML/2.4.1/Infrastructure/PDF/

Object Management Group (2011b) Meta-object facility (MOF) V 2.4.1 Core specification. Available at http://www.omg.org/spec/MOF/2.4.1/PDF/

Shorter D, Focus IT (2005) Integrating enterprise model views through alignment of metamodels. Knowl Sharing Integr Enterp, IFIP 183:21–37

Chapter 11
Innovation Infrastructures Assessment Through Knowledge Management Models

José Teba, Luis Onieva, Gerardo Jiménez and Jesús Muñuzuri

11.1 Introduction

Most authorities and professionals agree that if companies play a key role on Innovation Systems in recent years it is because of their ability to transform R&D activities in economic development and wealth. That is why most governmental innovation policies focus on the participation of companies in the innovation process as a key factor in the competitiveness of different regions and countries. Of the various innovative infrastructures developed to facilitate this type of business activities, one is the Scientific and Technology Parks (STPs). STPs act as engines of innovation, as agents for economic development, and as a crucial link between companies and university researchers. They can be considered to play an important role in innovation processes and in generating the corresponding synergies.

Taking into account the above considerations, what are the key factors in the success of STPs? Is it possible to design and implement a model to help policy-makers and managers in their decision-making process in order to predict the probability of success of these infrastructures in advance and avoid failed investments? Not many references in the literature focus on this specific issue for the Spanish case. Among them, Lopez (2003) analyzes the functional elements and the criteria for sizing, designing and managing STPs, which is eminently based on

J. Teba (✉) · L. Onieva · J. Muñuzuri
Dpto. Organización Industrial y Gestión de Empresas II,
ETSI. CM Descubrimientos s/n 41092 Sevilla, Spain
e-mail: teba@us.es

L. Onieva
e-mail: onieva@esi.us.es

J. Muñuzuri
e-mail: munuzuri@esi.us.es

G. Jiménez
Corporación Tecnológica de Andalucía, Isla de la Cartuja 41092 Sevilla, Spain
e-mail: gerardo.jimenez@corporaciontecnologica.com

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_11,

town planning aspects. Gonzalez (2004) studies business networks of technology based enterprises, focusing on research cooperation, development and innovation in the field of dissemination and technology transfer in order to obtain the factors or variables that affect the performance of such networks. Ruiz (2002) presents a theoretical model based on the concept of innovation systems. Two types of models have been proposed for regional innovation systems assessment, based on two types of analysis variables: available resources and obtained results, two factors which are closely linked (Landabaso 1997; Landabaso et al. 1999; Morgan and Nauwealers 1999). Following that trail, Heijs et al. (2002), presented a classification and characterization of the different Spanish regions with respect to their innovation systems.

11.2 Research Methodology: Proposed Model and Results

This paper seeks to provide a transversal model, future-oriented, to evaluate STPs and thus help in the decision-making process of public authorities and regional councils. Our model is based on experience, knowledge, opinions, intuition and tacit knowledge from experts in the field of STPs belonging to different areas of knowledge (managers and researchers of scientific and technological parks, business people who have worked on or have established their businesses in these parks, as well as university professors and researchers), and who have been working and researching collaboratively in such initiatives. We based our work on the following tools: (1) the European Innovation Scoreboard, in order to determine the key indicators of success; (2) the Likert scale, used for the assessment and quantification of different parameters, aspects and criteria; (3) the EFQM quality model, used to design the structure of our model; and (4) the Delphi model, crucial in the development of this work, for collecting and identifying the tacit knowledge and professional experiences of experts in this field. We collected additional data from the Territorial Statistical Analysis System of Andalusia, and processed it using the statistical software SPSS.

11.2.1 Proposed Model

In order to collect and use the knowledge, experience and intuition of experts on STPs, we directed our efforts towards the Delphi methodology against other possibilities, such as the Balanced Scoreboard, neural networks or fuzzy logic, which usually avoid or bypass the underlying intermediate processes. Table 11.1 shows the main details of our Delphi process, and Table 11.2 shows the questionnaire sent to the experts, to assess each criterion and establish the corresponding weight. The weights were set for each aspect of each criterion in a similar way. Finally, our Delphi team, in correspondence with the data gathered

Table 11.1 Description of the Delphi experiment

Panel members	No	1st round responses	% of success in the 1st round	2nd round responses	% of success in the 2nd round
Scientific experts	35	29	83	20	57
Entrepreneurs	19	16	84	9	47
Administration experts	15	15	100	10	67
Total	69	60	87	39	57

and the opinions expressed by the experts, proposed the criteria and aspects shown in Table 11.3 as the main evaluation parameters of the synthetic index. As a final result, the team proposed the model structure shown in Fig. 11.1, where the synthetic indicator is set according to environmental, technical and strategic criteria, and their weights correspond to the results of the Delphi process.

11.2.2 Application of the Proposed Model

In order to validate the model, our team applied this model to a set of STPs in different development stages: Cartuja'93 (Seville), PTA (Málaga), Geolit (Jaén), Velez-Málaga (Málaga), Agroparc (Avignon) and Bioindustry (Piemonte). The results gathered are showed in Table 11.4. In this table, for each STP, the first column shows the calculated Synthetic Index measured in percentage probability of success, and the remaining columns show the values obtained for the three main criteria conforming the Index and the aspects contemplated in the calculations for each criterion. The main aspect that requires improvement in each STP has been shown in italics.

According to the results, Cartuja'93 is a clear example of success. It was built using the infrastructure from the Expo'92, with a very favorable economic and financial plan. Its economic viability is practically assured. The model shows that only small improvements can be sought in aspects that are difficult to improve because they depend on improvements of private business networks, which can only be achieved in the long term.

In the PTA case, it is a more recent initiative, based on experience and knowledge acquired in Cartuja'93. In both cases, the government support was essential, and their strengths and weaknesses are similar. Some aspects such as socioeconomic and environmental aspects should be improved, but the main difficulty lies in their complexity. However, other aspects like transport have been recently improved (road network and railway), which will hopefully further improve the future performance level. Other clear improvements can also be seen in the recent inter-university agreements (Andalucía Tech) in search of synergies in the field of innovation.

Geolit can not be considered a success case, such as its Synthetic Index shows. It is an even more recent initiative, and with a more specialized bias towards the

Table 11.2 Questionnaire sent to the participating experts

Questions	Weight o f aspects P_{ij}… P_{ij}… P_{ij}…… P_{ij}
Interest in R&D in general	
Need to integrate new agents in the Andalusian innovation system	
Adequacy of research with industry needs	
Current availability of resources from the public administration	
Coordination between the interface, the Andalusian public administration and private agents	
Level of cooperation between business firms to develop projects of I+D I	
Knowledge by firms in the supply and demand for services	
Availability of information on business opportunities in international markets	
Appropriateness of the specialized services (logistics, reengineering, special consulting…)	
Availability of financial instruments to promote innovation	
Offer specialized technological infrastructures (science parks)	
Knowledge of the industry by tax incentives	
Existence of measures to support the creation of new technology-based companies	
Level of information received by consumers on aspects of processes	
Existence of mechanisms to inform the company on consumer preferences	
Level of attention from companies to consumers' demands	
Current presence of automation and robotic technologies in the sector	
Degree of incorporation of new conservation technologies and packaging	
Degree of implementation of information technology and communication	
Importance attached by firms to knowledge management and optimization	
Ability of firms to manage innovation projects	
Human capital capacity of firms to innovate	
Degree of implementation of environmental management (waste and byproducts)	
It is better to build PCT no focus in specific sectors	
Andalusian food industry has the capacity to have enough viability	

(continued)

Table 11.2 (continued)

Questions	Weight o f aspects P_{ij}… P_{ij}… P_{ij}…… P_{ij}
Importance of creating a network specialized in specific sector parks	
STP are considered more appropriate as multi-sector focus	
Would choose to implement these infrastructures in depressed areas	
Would choose to implement these infrastructures in dynamic areas where the viability is higher	
Importance of entrepreneurship in these initiatives	
Importance of management	
Importance of human resources available in the region	
Importance of dynamic and innovative business network for success	
Importance of territorial scope (character of the area where it is located)	
Importance of the technical proposal (plot, cost…)	
Importance of the existence of interface agents to influence the success of the CIT and research groups considered adequate agricultural region as the geographical unit of study	
Importance of the distance between SIP	
% of Weight of aspects	

Table 11.3 Main criteria and aspects chosen for the calculation of the synthetic index

Criterion	Aspect
Environmental	Socioeconomic
	Innovation
	Environmental Aspect
	I+D+I supply and demand
	Support structures
Technical	Land transport
	Supply
	Services
	Land and property law
	Plot characteristic
	Economic
	Financial
Strategic	Sector
	Science and technology
	Model

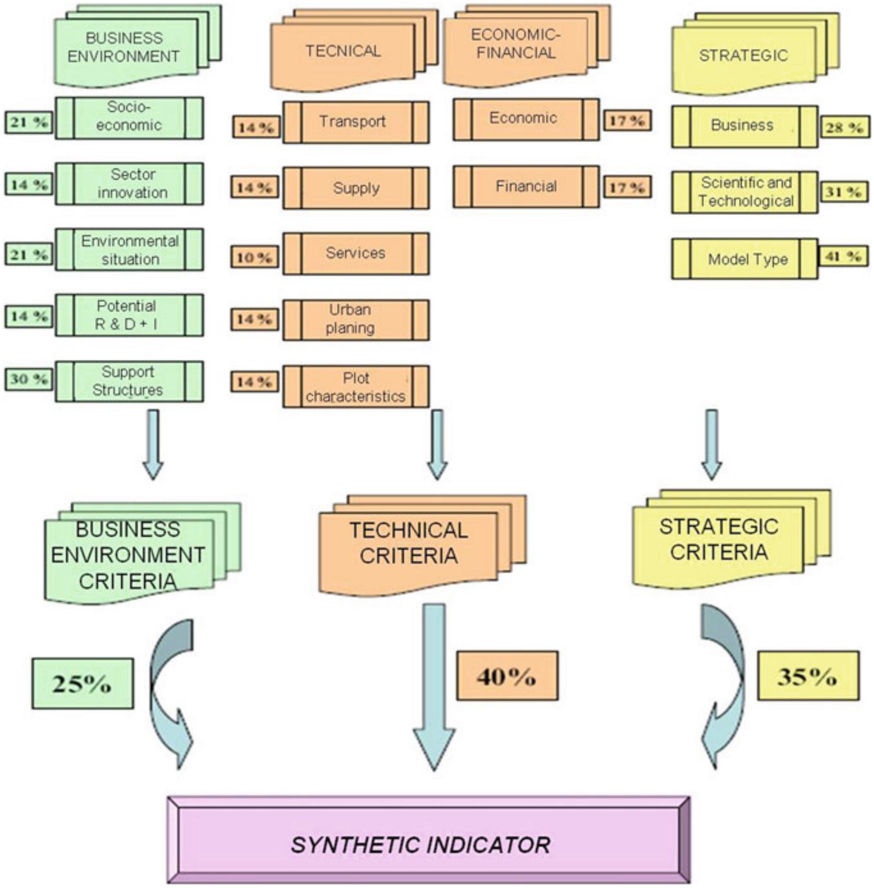


Fig. 11.1 The proposed model

Table 11.4 Results after applying the model to different STPs

	Synthetic index %	Environment criterion	Socio economic	Innovation	Ecological	I + D + i	Structural	Technical criterion	Transport	Supplying
Cartuja 93	75.0	3.90	*2.86*	*2.75*	5.00	5.00	4.00	4.02	4.00	4.00
PTA Málaga	71.0	3.65	*2.71*	3.50	*2.00*	3.50	3.00	3.44	3.50	*2.00*
Geolit Jaén	59.7	3.69	3.00	1.75	4.00	5.50	4.50	3.45	3.00	2.67
Yélez Málaga	37.0	3.27	4.17	2.75	4.00	2.50	2.75	2.62	2.50	*1.17*
Agroparc Avignon	72.6	4.16	4.14	4.71	5.00	4.17	3.33	3.16	3.00	4.50
Bioindustry Piemonte	81.3	4.51	4.14		5.00	4.33	3.33	4.07	3.50	4.20

	Services	Town planning	Ground	Economic	Financial	Strategic criterion	Business	Technical	Model
Cartuja 93	5.00	3.60	3.33	3.67	4.75	4.09	4.25	4.50	3.67
PTA Málaga	2.33	2.80	4.00	3.67	3.00	4.48	4.25	4.00	5.00
Geolit Jaén	4.00	4.00	3.67	3.67	3.25	3.13	2.50	3.00	3.67
Yélez Málaga	*2.00*	2.40	2.33	3.00	4.33	1.95	*2.00*	2.50	*1.50*
Agroparc Avignon	6.67	3.00	3.67	*2.75*	*2.00*	4.57	4.50	4.50	4.67
Bioindustry Piemonte	4.33	5.50	4.33	*3.50*	4.25	4.28	4.75	4.00	4.17

oleic sector. The regional authorities have tried to promote R&D and value-added activities oriented to manufacturing processes in the industry, but this is a complex task because the international business dealers are agents with socio-political interests far beyond the regional one. Among the weaknesses, we may highlight those related to socio-economic and finance, socio-economic conditions and the weakness relative to the entrepreneurial sector that needs a great improvement. It also has a nearby university, but with a lower potential and research capacity compared to the two previous cases.

Velez-Málaga can be considered a great failure without any doubt, according to its Synthetic Index. Its technical and strategic criteria are too low, possibly due to its proximity to the PTA. We believe that it would be necessary to change the model and reorient the concept in order to exploit the synergies of the proximity of this successful initiative (PTA) and its potential.

The Agroparc D′Avignon is a great success, as shown by its Synthetic index. Its main weaknesses are those concerning economic and financial aspects, but these can be considered secondary problems. It is, as its name implies, a STP focused on the agribusiness sector, and this is a key criterion in the success of the park because it is installed in a region with a clear commitment to the food industry where there is a great tradition in the R&D sector.

The Bioindustry Park is without any doubt the greatest success among the analyzed STPs. The results obtained after applying the model to it present a very high score for the synthetic index and the rest of criteria and aspects. This STP does not really need any specific improvement, since the lowest values, basically related to economic and financial aspects, are significantly high.

11.3 Conclusions

We have developed a transversal model for the evaluation of the success of STPs, following a Delphi process involving a relevant number of experts in the field. Innovation processes represent a rupture with the past trend, in the way of seeing and/or perform the different processes, activities, etc. Therefore, the use of historical data to validate models concerning future expectations should be avoided when possible, and use instead the previously mentioned "future data" based on the knowledge, experience and intuitions of the different knowledge stakeholders mentioned above, for the validation of such models.

According to our Delphi team, other professionals involved in the project, and other users who have used the model (Technological Corporation of Andalusia, regional and national authorities), the results of the evaluation provided by model, as applied to the different parks analyzed, present a fair and sound assessment. They all agree in considering it a valuable tool to analyze the possible future implementation of a STP or to assess the current status of existing STPs.

Another interesting aspect highlighted by its users is the ease of use and understanding, and the reliability shown by the model. Users believe that having access to information of the intermediate levels of the model allows them to interpret this information in order to suggest improvements or carry out simulation processes which would result from the modification of the input data.

In this model, tacit knowledge and experiences and personal views of expert professionals are embedded in its structure and relative weights, which were obtained according to the different criteria and aspects proposed by the experts. This limits the possible sensitivity analysis, since this structure and weights should not be modified because the essence of the knowledge of the expert group would be lost. A correct application of a sensitivity analysis should be limited to possible changes in some of the input data [e.g. what would be the result if a particular initiative improves technological infrastructure (cable network) or access infrastructure?], without affecting the model structure.

Others analytical and more conventional approaches used in the past, based on economic and financial viability, represent in our opinion a narrower framework. Our model tries to take into account all the relevant factors, incorporating criteria and aspects concerning the environment, technical and strategic issues, that we consider are more complete and demanding from the perspective of the expert group knowledge that permeates the model structure.

References

González B (2004) Análisis de las redes de cooperación en innovación y tecnología entre empresas de los Parques Tecnológicos. Universidad de Vigo

Heijs JJ, Martinez M, Baumert T, y Buesa M (2002) Los sistemas regionales de innovación en España: una tipología basada en indicadores económicos e institucionales. Economía Industrial 347:15–32

Landabaso M (1997) The promotion of innovation in regional policy. Entrepreneurship Reg Dev

Landabaso M, Oughton C, y Morgan K (1999) Learning regions in Europe: theory, policy and practice through the RIS. In: International conference on technology and innovation policy, Austin USA

López C (2003) Un nuevo equipamiento territorial: Los Parques Científicos y Tecnológicos. Análisis de la experiencia española. Universidad Politécnica de Madrid

Morgan K, y Nauwealers C (1999) Regional innovation strategies. The stationery office, London

Ruiz F (2002) Las actividades de investigación científica y desarrollo tecnológico en el subsistema empresarial de innovación andaluz: el espacio relacional de las empresas de I+D. Universidad de Sevilla

Chapter 12
Managing Systems and Innovation: An Empirical Study of Basque Firms

Juan Ignacio Igartua, Nekane Errasti and Noemi Zabaleta

12.1 Introduction

As a logical evolution in the competitiveness pathway, Basque companies are challenged nowadays with the need to innovate and improve their technology capacity. This new challenge will require as key actions the fostering of the innovative culture, the modernization and improvement of management and business organizations, and the development of management skills and leadership capabilities to drive and make possible the management of innovation.

In this direction, the aim of the present paper focuses on studying innovation from and a path dependence perspective. Thus, the main purpose is to understand how companies′ previous development and implementation of management systems (MSs), affect to innovation in a holistic perspective (innovation performance, innovation management and innovation management tools—IMTs). The purpose of this paper is to understand whether the approach towards innovation is based on an evolutionary approach from previously existing management systems implementations rather than a standalone approach.

After a brief introduction to innovation management and as well as management systems (MSs), we will develop the methodology used in this study. Subsequently we will show some empirical results of the investigation, including a conclusions section.

J. I. Igartua (✉) · N. Errasti · N. Zabaleta
Departamento de Mecánica y Producción Industrial. Escuela Politécnica Superior, Mondragon Unibertsitatea, C/Loramendi 4 20500 Mondragon, Spain
e-mail: jigartua@mondragon.edu

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_12, © Springer-Verlag London 2014

12.2 Business Innovation: A Holistic Approach

The need for understanding innovation appears to be widespread, at business level. The research done into business innovation up till now, has failed to provide clear and consistent findings or coherent advice to managers, mainly because the concept is frequently disaggregated into component parts (Tidd 2001).

Thus, scholars have adopted their own partial views and different researchers and institutions have tried to develop various models, typologies of elements of the innovation management process (Tidd 2001) or synthesized frameworks of the innovation management process (Adams et al. 2006), that intend to guide innovation management research in a more holistic way.

Some researchers have developed studies regarding the measurement of innovative performance in enterprises (Mancebo Fernández and Valls Pasola 2005), using instruments as the Community Innovation Survey instrument (CIS) trying to discover the factors that influence that result (Arundel and Hollanders 2006). These studies consider as an innovative company, any company that performs product, process, marketing or organization innovations.

On the other hand, other scholars have investigate onto the role of innovation management and the analysis of its impact on innovation and innovation performance of firms (Rigby and Bilodeau 2007; Adams et al., 2006; Prajogo and Ahmed 2006), including the emphasis on the role of systems and tools (Chiesa et al. 1996).

Finally another incipient research approach has been orientated to analyse the role of techniques and tools for managing innovation (Igartua et al. 2010; Hidalgo and Albors 2008). Some authors have even worked towards the development of a catalogue of tools, while a series of research programs led to the publication of practical guides to support the implementation of IMTs (Phaal et al. 2001).

Based on the literature review, we propose and holistic approach towards business innovation taking into account the approaches of several authors, in order to test the relationship between business innovation and management systems.

12.3 Innovation and Management Systems

Management systems (MSs) have developed in an unprecedented manner in the last few years. The impact generated by quality (To et al. 2012; Heras-Saizarbitoria 2011), environmental (Heras-Saizarbitoria et al. 2011; Nishitani 2009) and other MSs is demonstrated by different authors.

On the other hand, the assumption that the innovation process is subject to historical conditions plays a central role in the evolutionary approach, and represents the fact that evolution depends crucially on the path followed in the past (path dependency) (Mahoney 2000, 3743).

This assumption is reflected in various ways commonly used in studies of innovation. It is usual to reflect the cumulative nature of the innovation process representing the evolution of technologies through certain paths "technological trajectory" and avenues "Innovation Avenue". Also in the field of decision making in business, researchers have introduced the concept of "path dependency" and propose that the perspectives and decisions in the future are dependent and conditioned by those taken in the past.

Thus, although business innovation has been seen by different authors and researchers as an evolving process, which consists of several stages (Van de Ven et al. 2000, 7545); there are few studies that have conducted empirical studies on the influence of the historical conditions of the company on innovation, beyond the consideration of the firm age variable Control. Therefore, the approach "path dependency" could help us to understand the behavior of firms and in particular of their leaders, when making the decision to innovate and manage.

In this context and closely related to the life cycle of enterprises, various authors have sought to identify the contribution of the different philosophies and principles of management in business innovation (Prajogo and Ahmed 2007), taking as a guiding principle the cumulative nature of the innovation process (Nieto Antolín 2003, 1245), for which the innovation process is subject to historical conditions that determine their future evolution (path dependency). Some authors (Kelly and Amburgey 1991, 3715) highlight the importance of "momentum of the organization" to consider the practices, trends and strategies of the past make the organizations have a unique history, which makes it look differently opportunities (Cormican and O'Sullivan 2004, 3677).

12.4 Research Methodology

The research was conducted through a survey targeted to business managers, as others research studies conducted in the field of innovation (O'Regan et al. 2006).

The research is based on survey focused on innovation management where top managers of 566 Basque companies over a defined universe of 6282 Basque companies, were asked to answer a structured questionnaire from December 2008 till April 2009.

The gathered data has been analysed using SPSS16 and statistical methods as T Student Test. Due to the fact that the sample meets the sampling criteria needed to ensure its representativeness, the implications of the study are directly extrapolated to the entire study population.

The variables used were based on literature review, and previous researches.

12.5 Results

In order to examine whether there are significant differences between the background in management systems of companies and their innovation results on products, a Student's t-test comparison of two means was developed. The results of this test are summarized in Tables 12.1 and 12.2.

Table 12.1 Management systems means related to product innovation

		N	Mean	Std.D.	Std. err. mean
QA	Yes	363	3.37	1.162	0.061
	No	185	2.96	1.080	0.079
EN	Yes	363	2.95	3.011	0.158
	No	185	2.53	1.048	0.077
CR	Yes	358	2.46	1.151	0.061
	No	182	1.76	1.000	0.074
RD	Yes	359	2.91	1.175	0.062
	No	182	1.86	1.007	0.075

Thus, in all cases (except for environmental management systems—EN) the *t*-statistic takes a critical levels of bilateral significance lower than the critical value of 0.005 rejecting the null hypothesis of equality of means, and therefore concluding that the historical background in management systems in Quality, CSR, R&D in companies that innovate in product is higher compared to those companies that do not innovate in product. However, regarding the innovation in services and using the same statistical method, only the historical background in management systems related to CSR and R&D is higher compared to those companies that do not innovate in services.

On the other hand, background in all four management systems areas (Quality, Environmental, CSR, and R&D) is statistically higher (*t*-statistic lower than 0.005) for companies that innovate in processes.

Finally, for other kind of innovations (strategy, organizational structure, etc.), the historical background in management systems in Quality, CSR, R&D is statistically higher compared to those companies that do not innovate.

When analysing the innovation management performance of companies regarding their management systems deployment, a simple linear regression study was developed (see Table 12.3). The model takes a very high R (0.498) and R^2 indicating that 24.8 % of the variability of performance in innovation management depends on the historical background in the implementation of management systems. In addition, the F statistic shows a value below the critical level (Sig 0.05), so it can be argued that both variables are linearly related.

Finally, we have performed a simple linear regression analysis, to research onto the use of innovation management tools in companies regarding their management systems deployment (see Table 12.4). The model takes a very high R (0.668) and R^2 indicating that 44.6 % of the variability of the use of techniques and tools of innovation depends on the historical background in management systems. In addition, the F statistic shows a value below the critical level (Sig 0.05), so it can be argued that both variables are linearly related.

Table 12.2 Student's *t*-test for management systems means related to product innovation

		Levene′s test				*t*-test for equality of means				
		F	Sig.	t	df	Sig.(2- talled)	Mean std. diff.	Std. err. diff.	95 % Conf. interval of the diff.	
									Lower	Upper
QA	Equalvar.ass.	15.457	0.000	3.970	546	0.000	0.407	0.103	0.206	0.608
	Equalvar.Notass.			4.065	395.044	0.000	0.407	0.100	0.210	0.604
EN	Equalvar.ass.	1.892	0.170	1.831	546	0.068	0.418	0.228	−0.030	0.866
	Equalvar.Notass.			2.377	499.070	0.018	0.418	0.176	0.072	0.763
CR	Equalvar.ass.	10.759	0.001	6.919	538	0.000	0.694	0.100	0.497	0.891
	Equalvar.Notass.			7.243	412.255	0.000	0.694	0.096	0.506	0.883
RD	Equalvar.ass.	3.563	0.060	10.247	539	0.000	1.045	0.102	0.845	1.246
	Equalvar.Notass.			10.774	416.590	0.000	1.045	0.097	0.855	1.236

Table 12.3 Linear regression for innovation management performance and management systems

Inn. mgt. performance model				
Model	R	R^2	Adj. R^2	Std.err. of estimate
1	0.498[a]	0.248	0.246	0.81347

ANOVA[b]

	Model	Sum of squares	df	Mean square	F	Sig.
1	Regr.	122.129	1	122.129	184.561	0.000[a]
	Resid.	371.229	561	0.662		
	Total	122.129	1	122.129	184.561	0.000[a]

Model		Unstd. coeff B	Std.error	Std.coeff Beta	t	Sig.
1	(Constant)	1.737	0.091		19.040	0.000
	MngtSystBack	0.423	0.031	0.498	13.585	0.000

[a] Predictors: (Constant), MngtSystBack
[b] Dependent variable: InnMngtPerform

Table 12.4 Linear regression for innovation management tools (*IMTs*) and management systems

Use of inn. mgt. tools model				
Model	R	R^2	Adj. R^2	Std.err. of estimate
1	0.668[a]	0.446	0.445	0.56649

ANOVA[b]

	Model	Sum of squares	df	Mean square	F	Sig.
1	Regr.	144.589	1	144.589	450.561	0.000[a]
	Resid.	179.709	560	0.321		
	Total	324.297	561			

Model		Unstd. Coeff		Std.coeff	t	Sig.
		B	Std.error	Beta		
1	(Constant)	0.839	0.069		12.136	0.000
	MngtSystBack	0.173	0.008	0.668	21.226	0.000

[a] Predictors: (Constant), MngtSystBack
[b] Dependent variable: UseInnMngtTools

12.6 Discussion and Conclusions

The main purpose of the article was to identify the link between business innovation and management systems implemented by companies. The business innovation approach was based on a holistic approach, gathering three complementary approaches (innovation results, innovation management performance and the use by organizations of innovation management tools-IMTs). On the other hand, four management systems were taken into account (quality, environmental, corporate social responsibility, and research and development), and discussion about their role within business innovation was discussed.

Based on the extended set of data (566 Basque companies in Northern Spain) and using statistical methods (Student's *t*-test and linear regression), the research has underlined the importance of companies′ previous development and implementation of management systems (MSs) on their innovation.

The three complementary approaches related to business innovation, seemed to be linked with companies′ management systems background. Thus, the companies that innovate in product have a higher background in the implementation of Quality, CSR, and R&D management systems than those companies that do not innovate in product. However, innovation in services seems to be more related to historical background in CSR and R&D management systems deployment. On the other hand, background in all four management systems areas (Quality, Environmental, CSR, and R&D) is statistically higher for companies that innovate in processes, or introduce other kind of innovations (strategy, organizational structure, etc.). When analyzing these results, findings suggest that management systems play an important role in companies that develop innovations, although this role depends on the type of innovation being implemented. Furthermore, the role of environmental management systems in relation to product and services innovations seems to be questionable coinciding with previous researchers (Ramanathan et al. 2010; Shi et al. 2010; Wagner 2008). Meanwhile, R&D management system′s importance for all type of innovations seems to remain important.

When analyzing the innovation management performance, results indicate that the variability of performance in innovation management depends on the historical background in the implementation of management, what underlines the importance of management systems as a forerunner of the management of innovation in companies. Special attention has been paid to the use of innovation management tools (IMTs). The results show that the variability on the use of IMTs depends on the historical background in the implementation of management. Therefore, companies that use more intensively IMTs seem to have a previous contrasted experience in the implementation of management systems.

Based on the discussed results, we consider that the systematic achievement of innovation results in companies requires a systematic management of innovation which is very much related to the contribution of management systems philosophies and principles of management, as forerunners.

The limitations of this paper result from the research model and the variables used. Further research and analysis would provide more detailed relationships. On the other hand, the contributions of this study must be interpreted with a degree of caution since it has focused on the Basque context, which may have certain characteristics that can affect in the final performance.

References

Adams R, Bessant J, Phelps R (2006) Innovation management measurement: a review. Int J Manage Rev 8:21–47

Arundel A, Hollanders H (2006) Searching the forest for the trees: “Missing” indicators of innovation. 2006 Trend Chart Methodology Report. MERIT—Maastricht Economic Research Institute on Innovation and Technology

Cormican K, O’sullivan D (2004) Auditing best practice for effective product innovation management. Technovation 24:819–829

Chiesa V, Coughlan P, Voss CA (1996) Development of a technical innovation audit. J Prod Innov Manage 13:105–136

Prajogo DI, Ahmed PK (2007) The relationships between quality, innovation and business performance: an empirical study. Int J Bus Perform Manage (IJBPM) 9

Heras-Saizarbitoria I (2011) Mapping out ISO 9001, ISO 14001 and other management system standards. Int J Prod Qual Manage 8:33–44

Heras-Saizarbitoria I, Molina-Azorín JF, Dick GPM (2011) ISO 14001 certification and financial performance: selection-effect versus treatment-effect. J Cleaner Prod 19:1–12

Hidalgo A, Albors J (2008) Innovation management techniques and tools: a review from theory and practice. R&D Management 38:113–127

Igartua JI, Garrigós JA, Hervas-Oliver JL (2010) How innovation management techniques support an open innovation strategy. Res Technol Manage 53:41–52

Kelly D, Amburgey TL (1991) Organizational inertia and momentum: a dynamic model of strategic change. Acad Manag J 34:591–612

Mahoney J (2000) Path dependence in historical sociology. Theory Soc 29:507–548

Mancebo Fernández NR, Valls Pasola J (2005) El comportamiento innovador de la empresa industrial. Un modelo de análisis a partir de la encuesta del INE

Nieto Antolín M (2003) Características dinámicas del proceso de innovación tecnológica en la empresa. Investigaciones europeas de dirección y economía de la empresa 9:111–128

Nishitani K (2009) An empirical study of the initial adoption of ISO 14001 in Japanese manufacturing firms. Ecol Econ 68:669–679

O’regan N, Ghobadian A, Sims M (2006) Fast tracking innovation in manufacturing SMEs. Technovation 26:251–261

Phaal R, Farrukh CJP, Probert DR (2001) T-plan: the fast start to technology roadmapping: planning your route to success. Centre for Technology Management, Cambridge

Prajogo DI, Ahmed PK (2006) Relationships between innovation stimulus, innovation capacity, and innovation performance. R and D Management 36:499–515

Ramanathan R, Black A, Nath P, Muyldermans L (2010) Impact of environmental regulations on innovation and performance in the UK industrial sector. Manage Decis 48:1493–1513

Rigby D, Bilodeau B (2007) Bain’s global 2007 management tools and trends survey. Strategy Leadersh 35:4–16

Shi Y, Yang D, Lv G (2010) The influence of environmental management on technical innovation: evidence from abundant mineral resources areas. Kunming 562–566

Tidd J (2001) Innovation management in context: environment, organization and performance. Int J Manage Rev 3:169–183

To WM, Lee PKC, Yu BTW (2012) Benefits of implementing management system standards: a case study of certified companies in the Pearl River Delta, China. TQM J 24:17–28

Van De Ven A, Angle HL, Poole MS (2000) Research on the management of innovation: the Minnesota studies. Oxford University Press, Oxford

Wagner M (2008) Empirical influence of environmental management on innovation: evidence from Europe. Ecol Econ 66:392–402

Chapter 13
Knowledge Management Practices in SME: Case Study in Basque Country SME

Izaskun Alvarez, Ernesto Cilleruelo, Ibon Zamanillo and Enara Zarrabeitia

13.1 Introduction

New Economy, Globalization, Knowledge Society, Innovation and Knowledge Management, among others, are concepts that are in use nowadays in business management and society in general. In fact, what it lays behind these terms is the search for alternatives to make progress on management of organizations, mainly oriented to improve business competitiveness in a constantly changing environment and more and more demanding.

In this new organizational context and the need for searching solutions that allow organizations adapt to environment to survive, knowledge management was born in 1990s, strengthen existing knowledge and create new knowledge. Moreover, its success in organizations is linked to development and implementation of knowledge infrastructures: persons, organizational and technological systems (Sáiz et al. 2011).

The adoption of Knowledge Management practices can be considered as an essential step for the integration of organizations in the knowledge based economy.

According to a study made by OCDE (2003), knowledge management practices used by organizations are different in number and type depending on the enterprise size. That's why it can be suggested that fostering these practices has to be done in considering the size of organization that implements them. Further more, the use of these practices is directly related to innovation. This suggests that knowledge management is part of a successful, creative, innovate and productive enterprise, regardless of its size.

In today's economy, SME have a very important weight and have become an essential source of entrepreneurship, employment and innovation. In the Basque

I. Alvarez (✉) · E. Cilleruelo · I. Zamanillo · E. Zarrabeitia
Departamento de Organización de Empresas, Escuela Superior de Ingeniería de Bilbao, C/Alameda Urquijo s/n 48013 Bilbao, Spain
e-mail: izaskun.alvarez@ehu.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_13,

Country, SME are the main source of wealth and employment of its industry, specifically, 99.82 % of companies are SMEs. The SME are increasingly threatened by the emergence of competitors from emerging economy countries. Therefore, SME need to improve their products and services, that is, increase their added value, which implies the development of an unique selling point resource that allows to overcome in global market. In this way, SME emphasize the competitive advantage of their products and services with regarding to competitors. Knowledge or “know how” becomes the intangible resource that marks a competitive advantage and that makes necessary a consistent way of managing it.

This paper will describe the current situation of the Knowledge Management practices in the Basque SME. To do so, the use of Knowledge Management Practices in SME has been thoroughly analyzed.

13.2 Knowledge and its Management in Organizations

We are in a knowledge-based economy, characterized by turning knowledge into one of the main assets involved in economic exchanges and one of the key variables in the organizational structure and culture of organizations (Pérez-Montero 2008). The reasons why knowledge becomes “THE” resource rather than “A” resource (Drucker 1991) in post-industrial age are mainly technological and economic. On one hand, the development of information technologies has allowed access and management of larger amounts of information. On the other hand, globalization of markets and its current critical situation has provoked that the organizations adopt structural changes and create strategic alliances between different organizations to better adapt to ongoing changes that take place in its economic and social environment (Sánchez and Cilleruelo 2000).

The needed adaption to new scenarios results in a search for new organizational structures and approaches. As result of that change, appears the knowledge-based organizations that change the organizational vision as producer of intangible assets. The management model changes into an organization context which promotes the exchange of knowledge by creating the appropriate environment, abandoning the traditional hierarchical structures and giving flexibility to the organizations. The intangible assets provide organization with added value that allows gaining differentiating from competitors.

The knowledge grows when it is shared, that is, transmission of knowledge makes that its asset value increases. The flow of knowledge resulting from relationships with clients can be more important to success of organization than the flow of goods and money. Clients not only provide economic benefits, but also help with ideas about products, among others; a return between organizations that is a competitive advantage for both sides (Sánchez et al. 2005).

Therefore, knowledge management becomes an essential task in organizations that want to be competitive in a globalized market like the current one. But, what is knowledge management?, Knowledge Management is a dynamic process that is intended to create, identify, capture, store and transmit knowledge of an organization, so that it can be converted into value.

13.3 Empirical Study: Using Knowledge Management Practices in Basque SMEs: Results

We will now introduce the developed to analyze the use of knowledge management practices in Basque SMEs.

The studied targeted group is composed of 526 SMEs with headquarters in Basque Country that are associated with any of the following industrial clusters: Machine Tools, Electrical Appliances, Automotive, Environment, Electronics, Computing and Telecommunications, Energy, Aeronautics and Space, Paper, Audiovisual, Transport and Logistics. The reason why these activities have been selected for this work is that the sectors in which they operate have a high index of industrial production, spend about 60 % of expenditure on technological innovation activities and have diversity in terms of their level technology. Moreover, clusters are a key element in competitiveness and have become the backbone of Basque economic structure, that have allowed to encourage the flow of knowledge and innovation and learning, thanks to the geographical concentration of its enterprises activities. Consequently, the company associated with these clusters takes place in an environment where the flow of knowledge is abundant and gives more importance to knowledge management (Table 13.1).

To collect data, the survey was designed with questions about the use of knowledge management practices in order to know what practices are in use or planned to use in the next 24 months. In the questionnaire, on the one hand, there are practices related to communications in the organization in order to share knowledge through them, training and mentoring, policies and strategies in organization, capture and acquisition of knowledge in organization and, on the other hand, there are possible strategies for capturing explicit and tacit knowledge.

Table 13.1 Data sheet for research

Object of study	526 SME associated with clusters
Associated clusters	Machine-tools, electrical appliances, automotive, environment, electronics, computing and telecommunications, energy, aeronautics and space, paper, audiovisual, transport and logistics
Scope	Basque Country
Data of implementation	June–July 2011
Source for elaboration of questionnaire	1. “Measuring knowledge management in the business sector: first steps” (OCDE 2003) 2. “Estudio sobre la Gestión del Conocimiento en España 2004” (Tena and Ongallo 2004). FUNDECYT y AENOR

The analysis of the results, both quantitative and qualitative, about the use of different knowledge management practices and the use of different strategies to capture explicit and tacit knowledge, can contribute to understand better the use of Knowledge Management practices in different types of companies classified by activity sector and number of employees. This study will guide them through the most used practices and strategies and put necessary corrective resources to knowledge management practice in the company will be carried out with the greatest success.

13.3.1 Using Knowledge Management Practices in Basque Country SMEs

In Table 13.2, obtained results related to use or planned use of Knowledge Management practices in Basque Country SMEs proposed in this study are represented.

13.3.2 Strategies to Capture Explicit and Tacit Knowledge in Basque Country

In Tables 13.3 and 13.4, frequency of use of different strategies to capture knowledge, both explicit and tacit, proposed in Basque SME study is presented.

13.4 Conclusions

Knowledge Management practices in the Basque Country SMEs are linked to the availability of transfer channels that allow the capture, acquisition and communication of required knowledge and people capable to understand what it knowledge management systems mean.

Aerospace sector is one that makes use of knowledge management practices, leading to the conclusion that pointer-technology industries are more likely to improve their organizational systems implementing systems to manage intangible re- sources. It is also concluded, that those SME smaller in terms of number of employees (between 1 and 9), develop a more intense use of the Knowledge Management Practices. Therefore, it becomes clear that implementing a knowledge management system does not require a large organizational infrastructure.

The usual strategies to capture explicit knowledge in Basque SMEs are related to document management technology platforms that allow explicit knowledge to be documented and placed in an accessible repository in order to be transmitted.

Table 13.2 Percentage of Basque SME that use or has planned the use of knowledge management practices

Knowledge management practices	In use (%)	Plan to use in the next 24 months (%)
Uses knowledge gained from other industrial sources such as industrial associations, competitors, customers and suppliers	95	0
Uses internet to obtain external knowledge	95	5
Encourages experienced employees to transfer their knowledge to new or less experienced employees	77	18
Encourages participation among employees in project teams with external experts and/or multidisciplinary	77	14
Provides external training to employees to main- tain their current skills, update their skills or improve their competences	68	14
Using the knowledge gained from public research institutions, including universities and research centers	68	9
Uses partnerships or strategic alliances to acquire/share knowledge	64	18
Dedicates resources to identify and obtain external knowledge (technological vigilance)	64	14
Having a culture or value system that promotes sharing of knowledge	59	18
Encourages workers to continue their education by reimbursing tuition fees for successfully completed work-related courses	55	9
Regularly updates databases of best practices, lessons learned or listings of experts	50	14
Provides informal training related to knowledge management practices	50	5
Preparing written documentation such as lessons learned, training manuals, good work practices, articles for publication, etc. (organizational memory…)	45	32
Facilitating collaborative work by projects teams that are physically separated ("virtual teams")	32	18
Provides formal training related to knowledge management practices	27	14
Uses formal mentoring practices	23	18
Has a written knowledge management policy or strategy	18	9

The Aeronautic industry constitutes an example of intensive use of Knowledge Management Practices. But, regarding the analysis based on the size of SME, we can state that bigger companies (between 50 and 249) develop a more intense use of such strategies that require a large technical infrastructure.

Regarding to strategies for capturing tacit knowledge, it can be concluded that the strategies related to activities that enable interaction between people in appropriate contexts and to analytical activities that are performed a posteriori to activity. Analyzing these strategies based on activity sector of the SME, it is

Table 13.3 Percentage of Basque SME that use strategies to capture explicit knowledge

Strategies to capture explicit knowledge	In use (%)	Plan to use in the next 24 months (%)
Technological files creation (or files network by subject area)	59	14
Best practices management	50	9
Creation of a repository of frequently asked questions	27	14
Best practices benchmarking	27	23
Lab books: notes take in a systematic way and manage properly that are obtained from research in the organization	23	14
Mind maps: knowledge representation systems	14	18

Table 13.4 Percentage of Basque SME that use strategies to capture tacit knowledge

Strategies to capture tacit knowledge	In use (%)	Plan to use in the next 24 monthsc (%)
Socialization: communities of practice or other trust scenarios	50	5
Review after review: analysis following conclusion of the activity	50	14
Weblogs technology	41	9
Duplication strategy: create groups to develop a single product or rotation of personnel in different positions	27	5
Strategy of metaphor: combination of ideas from the person that has tacit knowledge	23	9
Storytelling	18	9

highlighted the fact that Aeronautic sector makes the least use of them, different from the case of the studies of the usage of practices and strategies to capture explicit knowledge. It is observed the fact that SMEs with fewer employees (between 1 and 9) are those that make use of knowledge capture techniques related to the interaction of people that do not require large infrastructure.

References

Cilleruelo E, Sanchez F, Zamanillo I, Echevarria B (2003) La aportación de los equipos de trabajo a la Gestión del Conocimiento mediante la socialización del “saber hacer” organizacional, V Congreso de Ingeniería de Organización. Valladolid—Burgos, 4–5 Septiembre 2003

Drucker PF (1991) The new productivity Challenge. Harvard Bus Rev 69–79

Nonaka I, Ichijo K, Krogh Gv (2000) Enabling knowledge creation: how to unlock the mystery of tacit knowledge and release the power of innovation. Oxford University Press, Oxford

Nonaka I, Takeuchi H (1995) The knowledge-creating company how Japanese companies create the dynamics of innovation. Oxford University Press, New York

OCDE (2003) Measuring knowledge management in the business sector: first steps, OCDE edn, OCDE, Paris

Pérez-Montero M (2008) Gestión del Conocimiento en las organizaciones: fundamentos, metodología y praxis, Ediciones Trea edn, España
Sáiz L, Manzanedo MA, Del Olmo R, Alcalde R (2009) La contribución de la Gestión del Conocimiento a la Competitividad de la Empresa. Su estudio en las PYMEs de Castilla y León. 3rd International Conference on Industrial Engineering and Industrial Management. XIII Congreso de Ingeniería de Organización. Barcelona-Terrasa, 2–4 Septiembre, pp 1730
Sáiz L, Pérez A, Herrero A, Corchado E (2011) Analyzing key factors of human resources management. In: Yin H, Wang W, Rayward-Smith VJ (eds) Intelligent data engineering and automated learning—IDEAL 2011. Lecture notes in computer science. Springer, Norwich, pp 463–473
Sánchez F, Cilleruelo E (2000) La gestión del conocimiento: Una necesidad del nuevo mile-nio, Bizkaia, Bilbao
Sánchez F, Echevarria B, Cilleruelo E (2005) Aplicación del concepto de Gestión del Conocimiento a organizaciones extendidas: enfoques preactivos como fuente de ventaja compe- titiva, XI Jornadas Internacionales de Proyéctica. Bidart—Francia, 20–21 Octubre
Tena R, Ongallo C (2004) Estudio sobre la gestión del conocimiento en España, SETSI; FUNDECYT; AENOR edn, FUNDECYT y AENOR, Madrid

Part III
Logistics and Supply Chain Management

Chapter 14
Internal and External Supply Chain Integration: Construct Definition and Validatiion

Juan A. Marin-Garcia, Rafaela Alfalla-Luque and Carmen Medina-López

14.1 Introduction

The concept of supply chain integration is of great interest for academics working in operational management (Flynn et al. 2010a). One of the main reasons is that it greatly influences the competitive advantage of companies (Alfalla-Luque et al. 2012a; Flynn et al. 2010a). But it is also a concept whose definition and whose operationalization are still up for debate. There is no consensus as to which components to include, nor how to measure them (Alfalla-Luque et al. 2012b; Flynn et al. 2010a; Roth et al. 2008; Zhu et al. 2008). In fact, in research carried out so far, it is common to be confronted with a variety of proposals and this means that demonstrating the effects of supply chain integration on the performance of companies is inconclusive giving contradictory results (Flynn et al. 2010a).

According to recent research, supply chain integration is comprised of two primary dimensions: internal integration and external integration. External integration can then be further subdivided: integration with clients and integration with suppliers (Alfalla-Luque and Medina-López 2009; Chang et al. 2007; Flynn et al. 2010a, b). Nevertheless, there is a slight bias in research, both empirical and conceptual, that has leant towards external rather than internal integration (Zhao et al. 2011). This is why there have been calls so that any future research takes into account the relationships between the different components of the supply chain

J. A. Marin-Garcia (✉)
ROGLE-Departamento de Organización de Empresas (DOE), Universidad Politécnica de Valencia, Camino de Vera s/n, Valencia, Spain
e-mail: jamarin@omp.upv.es

R. Alfalla-Luque · C. Medina-López
Departamento Economía Financiera y Dirección de Operaciones. GIDEAO research group, Universidad de Sevilla, Ramón y Cajal, 1, 41018 Sevilla, Spain
e-mail: alfalla@us.es

C. Medina-López
e-mail: cmedina@us.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_14,

integration and the effect that each one has on the performance indicators of the company (Alfalla-Luque et al. 2012b; Chang et al. 2007; Flynn et al. 2010a). To help with the development of the proposed future research, in this paper our objectives are the clarification of the constructs, the creation of a measurement scale for the components of the supply chain integration, the validation of these scales and a preliminary study on the effects of a variety of control variables (size of the plant, country, sector and degree of vertical integration) in the values of these scales.

14.2 Definitions of Integration

According to Flynn et al. (2010a) supply chain integration can be defined as:

> the degree to which a manufacturer strategically collaborates with its supply chain partners and collaboratively manages intra- and inter-organization processes. The goal is to achieve effective and efficient flows of products and services, information, money and decisions, to provide maximum value to the customer at low cost and high speed.

This is why it is so important to instil confidence amongst all the agents, building long-term relationships, frequent communication, share both profit and risk, and look for effective ways of sharing information, make joint decisions and re-solve conflicts (Flynn et al. 2010a). There are two main types of integration: external integration and internal integration (Chang et al. 2007; Flynn et al. 2010a; Zhao et al. 2011).

Internal integration refers to the degree to which a company can organise its practices, procedures, information, decisions and conduct in a collaborative and synchronised way between its different areas, to be able to comply with client requirements and effectively interact with its suppliers (Flynn et al. 2010a, b; Topolsek 2011; Zhao et al. 2011). External integration refers to the degree to which a company understands the need of its clients and collaborates with clients and/or suppliers to develop inter-organisational strategies and shared practices and processes, so that it manages to satisfy its clients' needs (Flynn et al. 2010a). External integration consists of integration with clients and integration with suppliers (Escrig Tena and Bou-Llusar 2005; Flynn et al. 2010a; Zhao et al. 2011). According to earlier work, there are close ties between the three basic components of integration (internal, clients and suppliers) (Chang et al. 2007; Escrig Tena and Bou-Llusar 2005). So it could be construed that internal integration is the precursor to achieving external integration (Bessant et al. 2003; Flynn et al. 2010a; Pagell and LePine 2002). The use of operational management practices in general, and supply chain integration in particular, are normally affected by national culture, industry, size of the company, the type of company (traditional or World Class) or the degree of vertical integration can affect the type and degree of supply chain integration (Marin-Gracia et al. 2013; Roth et al. 2008).

14.3 Method

The aim of this paper is to test the psychometric properties of a survey to identify four constructs of supply chain integration in industrial companies. The test bank of items used to build the survey originate from earlier works (Roth et al. 2008; Ahmad and Schroeder 2001; Anderson et al. 1995; Escrig Tena and Bou-Llusar 2005; Li et al. 2005; Sakakibara et al. 1993; Zhu et al. 2008; Marin-Gracia and Carneiro 2010; Marin-Gracia et al. 2012). Of these, 4 items have been selected for each construct, aiming to ensure that they are representative of the theoretical definition and that they are not redundant, to avoid the survey being excessively long (Watts et al. 2012). The score of the scales is the total of the sum of the items (Table 14.1).

Our empirical analysis is based on an international sample made up of 266 plants across ten countries (2005–2007 timeframe): Austria, Canada, Finland, Germany, Italy, Japan, Korea, Spain, Sweden and the USA. In each country, the plants were randomly selected from three industries: automotive components, electronics and machinery. The items were targeted at plant accounting managers, direct labour, human resource managers, inventory managers, process engineers, plant managers, quality managers, supervisors and plant superintendents. Items are responded to by at least two different managers/workers in the plant. After that, all the responses for each item in each plant were averaged to obtain plant items scores.

Table 14.1 Items selected

Scale	Item	Description
Customer integration	It01	We frequently are in close contact with our customers
	It02	Our customers give us feedback on our quality and delivery performance
	It03	We strive to be highly responsive to our customers' needs
	It04	Our customers are actively involved in our product design process
External integration	It05	We work as a partner with our customers
	It06	We work as a partner with our suppliers, rather than having an adversarial relationship
	It07	We believe that cooperative relationships will lead to better performance than adversarial relationships
	It08	We believe than an organization should work as a partner with its surrounding community
Supplier integration	It09	We maintain close communication with suppliers about quality considerations and design changes
	It10	We maintain cooperative relationships with our suppliers
	It11	Our customers are actively involved in our product design process
	It12	We strive to establish long-term relationships with suppliers
Internal integration	It13	We encourage employees to work together to achieve common goals, rather than encourage competition among individuals
	It14	Departments in the plant communicate frequently with each other
	It15	Management works together well on all important decisions
	It16	Generally, speaking, everyone in the plant works well together

14.4 Results

Our sample comprises 266 plants. Of those, 66 companies in Sweden and Germany (24.8 %) did not respond to the question on the type of company, 26 (9.8 %) did not answer the question on the size of the company (the majority of these in South Korea and the US) and 29 (10.9 %) did not respond to the question on the level of vertical integration (once again South Korea and the US are the subsample with the highest number of missing values). The sampling distribution across countries is uniform and there are only major differences to a lesser degree amongst World-class companies in Australia and Finland; a greater proportion of transport companies in Germany; larger companies in Japan and South Korea and a greater degree of vertical integration in Germany, and a lesser degree in Sweden.

Practically all the sample plants answered the 16 items concerning the degree of integration. There were only missing values in 6 items (It05, It07, It13, It14, It15, It16). And these missing values stem, for the most part, from two plants so there is no point carrying out a detailed analysis of the missing values. For the majority of the items, the distribution of responses has a high average, a typically not very high deviation, negative asymmetry and is leptokurtic. In other words, the majority of responses are in the upper part of the scale (of around 5 and 6 on a seven-level scale). More than half of the items have a "grounding" effect and the minimum values do not tend to cover the whole scale, with a range of responses covering between 3 and 5 different levels of response.

Following internal consistency testing, Item13 was removed from the internal integration scale given that its correlation with other items on the scale was too low. So is its correlation with the scale as a whole as well as its multiple squared correlation. Similarly, there would be a slight improvement to Chronbach's alpha were it to be eliminated. Average inter item correlations were 0.394–0.480, and Chronbach's alpha range from 0.716 to 0.785.

Following this, a multi-trait/multi-item analysis was carried out. To pass the test, the difference between the corrected item-total correlation and the item correlation with other scales should be greater than 0.123. Item05, has more correlation to an factor other than that of the one theoretically assigned to it and its correlation is not sufficiently different in the other two factors. It is therefore an item that could create issues during discriminant validation and will therefore be eliminated from the model. Currently, items It04 and It11 have passed the test.

The results of the exploratory factor analysis with factor extraction techniques using the maximum likelihood method and Varimax criterion under orthogonal rotation, indicate that the sampling adaptation index (0.821) and Bartlett's test of sphericity ($p < 0.000$) are adequate. There are 4 factors with values greater than 1, and which make up for 63.8 % of the variance. The items are grouped around the factors proposed by the theory. Factor loadings are all greater than 0.5 in the envisaged factor and have a different of more than 0.3 with regard to the loads in other factors. For this reason, no modifications are made to the scales following analysis.

The final step in the process was the carrying out confirmatory factor analysis to complete checking the convergent and discriminant validation of each scale. We start with the joint measurement model, which is the best representation of the theoretical model where the scales are interlinked (Flynn et al. 2010a). In the first version, two scales had 4 items, and the others 3 items. All the factorial loads were greater than 0.6 with the exception of two items (It04 and It11), which have been eliminated from the definitive version. In the definitive version, all scales have three items, which is why we choose to present the goodness of fit statistics of the model as a whole in stead of doing so scale by scale, as they can not be independently measured when the number of items in the scale is less than 4. The model adjustment statistics are exceptionally good (normed Chi2 robust = 1.32; *p* value chi2 Satorra = 0.064; CFI = 0.98; IFI = 0.98; MFI = 0.97; RMSA = 0.04; GFI = 0.96; AGFI = 0.93). All estimations are significant and the standardised factorial loads are all greater than 0.6 (Fig. 14.1). The extracted variance of the scales are between 0.45 and 0.56 and the compound reliability Cronbach's alpha are in all cases greater than the cut-off value of 0.70. These analyses confirm the convergent validity of the proposed scales. At the same time, the scales also pass the test of variance extracted compared to squared correlations and the confidence interval for correlations.

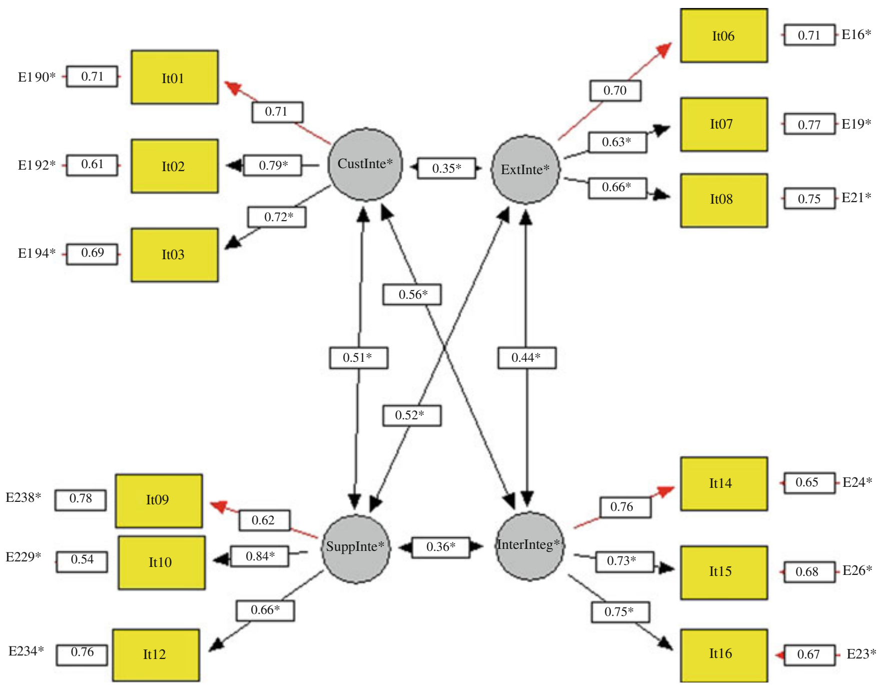


Fig. 14.1 Standardized estimate joint measurement model

Table 14.2 Scoring benchmark for the supply chain integration scales

N	Valid missing	CustIntegr total	CustIntegr machinery	CustIntegr electronics or transportation	ExtIntegr total	SuppIntegr total	InterIntegr total
		266	88	178	265	266	265
		0	0	0	1	0	1
Percentiles	10	15,125	14,469	15,378	15,400	14,654	13,500
	25	16,025	15,476	16,333	16,445	15,660	14,858
	50	17,109	16,667	17,333	17,556	16,667	16,083
	75	18,333	17,788	18,421	18,472	17,667	17,500
	90	19,092	18,744	19,340	19,333	18,333	18,167

Now that the convergent and discriminant validity of the scales has been shown, we are going to present the scale benchmarks by breaking down the percentiles into 10, 25, 50, 75 and 90 % for each scale. Firstly, we will see if the distribution of the sub-samples for each control variable of the supply chain integration scale are significant and if this is the case, we will present an independent benchmark for each of the sub-samples. There are no significant differences in the sub-samples based on the type of company, its size or the level of vertical integration. The general benchmark can therefore be applied to these business subgroups. There are only significant differences by industry for the degree of customer integration between machinery and the other three sectors. Although the differences are significant for the sub-samples of each country, the number of companies available in each sample is too small to be considered representative and therefore does not require the benchmark to be broken down (Table 14.2).

14.5 Conclusions

This research paper provides an overview of the latest chain supply integration scales and expresses the need to formulate measurement instruments that allow one to identify the degree of use of each of the four constructs in companies (internal integration, external integration, integration with clients and integration with suppliers).

Starting out with a set of items, created especially for this research, 4 scales are proposed, and are subsequently validated using a broad sample. The definitive scales show excellent psychometric properties, although they do point to certain limitations such as, for example, the generalization of other industrial sectors (given that the sample consists of companies from only three sectors); or that the range of responses are concentrated in the upper part of the scale. This behaviour could stem from the characteristics of the sectors chosen for the sample, in which case it would be desirable to test out these scales in the future using a broader sampling and with plants from different sectors. In this way, the benchmark could be extended to be able to analyse differences by country or by sector (if these were available). Developing similar scales focusing on service companies that have their own set of characteristics when it comes to understanding and applying supply chain integration would be required.

The outcomes of this paper have obvious academic implications as it responds to requests expressed in recently published articles in this field, which asked for a clearer and more concise designation of the supply chain integration measurement scales. In this way, more reliable and accurate data could be taken to analyse the relations between these constructs with other variables of interest to the academic and professional fields, such as for example the outcomes or production efficiency. From a professional perspective, this paper contributes to providing scales that are valid as a diagnostic tool for best practices, as well as providing a benchmark with which to compare the score for each individual plant against a collection of industrial companies from the machinery, electronics and transportation sectors.

Acknowledgements This paper has been made possible thanks to grant DPI2010-18243 awarded by the Spanish Ministry of Science and Innovation "coordination of operations in supply/demand networks, resilient to the uncertainty: models and algorithms for managing uncertainty and complexity" and the "HPM Project-Spain: Project for high performance manufacturing" (DPI2006-05531) by the Spanish Ministry of Education and Science.

References

Ahmad S, Schroeder RG (2001) The impact of electronic data interchange on delivery performance. Prod Oper Manag 10(1):16–30

Alfalla-Luque R, Medina-López C (2009) Supply chain management: unheard of in the 1970s, core to today's company. Bus Hist 51(2):202–221

Alfalla-Luque R, Medina-Lopez C, Schrage H (2012a) A study of supply chain integration in the aeronautics sector. Production Planning and Control http://dx.doi.org/10.1080/09537287.2012.666868

Alfalla-Luque R, Medina-Lopez C, Dey PK (2012b) Supply chain integration framework using literature review. Production Planning and Control http://dx.doi.org/10.1080/09537287.2012.666870

Anderson JC, Rungtusanatham M, Schroeder RG, Devaraj S (1995) A path analytic model of a theory of quality management underlying the deming management method: preliminary empirical findings. Decis Sci 26(5):637–658

Bessant J, Kaplinsky R, Morris M (2003) Developing capability through learning networks. Int J Technol Manag Sustain Dev 2(1):19–38

Chang WL, Ik-Whan GK, Dennis S (2007) Relationship between supply chain performance and degree of linkage among supplier, internal integration, and customer. Supply Chain Manag: Int J 12(6):444–452

Escrig Tena AB, Bou-Llusar JC (2005) A model for evaluating organizational competencies: an application in the context of a quality management initiative. Decis Sci 36(2):221–257

Flynn BB, Huo B, Zhao X (2010a) The impact of supply chain integration on performance: a contingency and configuration approach. J Oper Manag 28:58–71

Flynn BB, Wu SJ, Melnyk SA (2010b) Operational capabilities: hidden in plain view. Bus Horiz 53:247–256

Li SH, Rao SS, Ragu-Nathan TS, Ragu-Nathan B (2005) Development and validation of a measurement instrument for studying supply chain management practices. J Oper Manag 23(6):618–641

Marin-Garcia JA, Carneiro P (2010) Desarrollo Y validación de un modelo multidimensional de la producción ajustada. Intangible Cap 6(1):78–127

Marin-Garcia JA, Carneiro P, Miralles C (2012) Effect of lean manufacturing practices on non-financial performance result: empirical study in spanish sheltered work centers. In: Mejia G, Velasco N (eds). Prod Syst Supply Chain Manag Emerg Countries: Best Pract 3–24. Springer

Marin-Garcia JA, Alfalla-Luque R, Medina-López C (2013) Supply chain integration scales validation and benchmark values. J. Ind Eng and Manag 6(2):423–440

Pagell M, LePine JA (2002) Multiple case studies of team effectiveness in manufacturing organizations. J Oper Manag 20(5):619–639

Roth AV, Schroeder RG, Huang X, Kristal MM (2008) Handbook of metrics for research in operations management multi-item measurement scales and objective items. SAGE publications, New York

Sakakibara S, Flynn BB, Schroeder RG (1993) A framework and measurement instrument for just in-time manufacturing. Prod Oper Manag 2(3):177–194

Topolsek D (2011) The impact of collaboration or collaborative behaviour on the level of internal integration: case study of Slovenian retailers and motor vehicle repair companies. Afr J Bus Manag 5(26):10345–10354

Watts F, Marin-Garcia JA, Garcia-Carbonell A, Aznar-Mas LE (2012) Validation of a rubric to assess innovation competence. Working Pap Oper Manag 3(1):61–70

Zhao X, Huo B, Selen W, Yeung JHY (2011) The impact of internal integration and relationship commitment on external integration. J Oper Manag 29(1–2):17–32

Zhu Q, Sarkis J, Lai KH (2008) Confirmation of a measurement model for green supply chain management practices implementation. Int J Prod Econ 111(2):261–273

Chapter 15
Characterizing Productive Processes with Lack of Homogeneity in the Product and Its Impact on the Master Planning and Order Promising

M. M. E. Alemany, F. Alarcón, Ll. Cuenca and A. Ortiz

15.1 Introduction

The Lack of Homogeneity in the Product (LHP) is defined as "the lack of uniformity required by the customer in the products" (Alarcón et al. 2011). LHP appears in those productive processes which include raw materials that directly originate from nature and/or production processes with operations which confer heterogeneity to the characteristics of the outputs obtained, even when the inputs used are homogeneous. LHP is present in certain industries like ceramics, textile, wood, marble, tanned hides, leather goods, horticulture and oil. All these industries have in common that are obliged to include one or several classification stages along the productive process whose localization along the process and classification criteria depend on the specific industry. For instance, in the horticulture sector, important criteria for sorting and grading fresh fruit are size, weight, ripeness, damages, color, shape and firmness (Verdouw et al. 2010). In the ceramics sector, the classification criteria are based on (Poyatos et al. 2010): aspect (qualities), tone and gage.

LHP impacts the management system in various ways: the existence of several subtypes of the same item increases the number of references and the information volume to be processed. Furthermore, LHP manufacturing systems have to deal with a new kind of uncertainty: the future homogeneous quantities available of one same product. This uncertainty proves to be a problem when customers' orders

This research has been carried out in the framework of the project funded by the Spanish Ministry of Economy and Competitiveness (Ref. DPI2011-23597) and the Polytechnic University of Valencia (Ref. PAID-06-11/1840) entitled "Methods and models for operations planning and order management in supply chains characterized by uncertainty in production due to the lack of product uniformity" (PLANGES-FHP).

M. M. E. Alemany (✉) · F. Alarcón · Ll. Cuenca · A. Ortiz
Centre d'Investigació de Gestió i Enginyeria de Producció (CIGIP), Universitat Politècnica de València, Camí de Vera s/n 46022 València, Espanya
e-mail: mareva@omp.upv.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_15,

should be promised, reserved and served from planned production quantities for which the real homogeneity distribution will not be known until their production were finished. This uncertainty will lead to differences between planned and real homogeneous quantities that can make impossible to serve previously committed orders in the terms of homogeneity, quantities and dates promised. Improperly, LHP management can impact very negative in revenues, costs and customer satisfaction. In view of the scarce research in the LHP management field (Alarcón et al. 2011; Roma and Castán 2009) and being conscientious that LHP affects several sectors, the main objective of this paper is to provide a framework for characterizing LHP productive processes (Sect. 15.2). The application of the framework to a specific productive process will provide decision-makers with the LHP key aspects to properly manage their specific LHP situation. After identifying those LHP characteristics, Sects. 15.3 and 15.4 offer an analysis of their implications in the master planning and the order promising processes. Assessing the impact that each LHP aspect has on both processes, will allow the choice of the LHP characteristics that merit consideration in the decision making for each case.

15.2 Framework for Characterizing LHP Productive Processes

The research methodology for deriving the present framework has been the productive process analysis of different sectors presenting LHP (wood, ceramic, marble, horticulture, pearl, skin and textile) as regards three blocks: transformation activities, products and order proposal characteristics. Based on this analysis, the abstraction of common aspects related to the three blocks of the conceptual framework that are relevant for the properly LHP management have been derived. Figure 15.1 shows an overview of the whole paper: the three blocks composing the framework and their relationship with the master planning and the order promising processes that are described in the next sections.

15.2.1 Transformation Activities: Classification Activities as the Key

To describe any manufacturing process is necessary to identify transformation activities that take place from the input material to finished goods. Transformations are business processes that contribute directly to the creation and movement of products by a company (Verdouw et al. 2010). Traditionally they have been classified in engineering, production, assembly and distribution (transport, handling and storage) activities. However, for LHP contexts the identification of classification activities or sorting stages becomes crucial. In fact, the key LHP

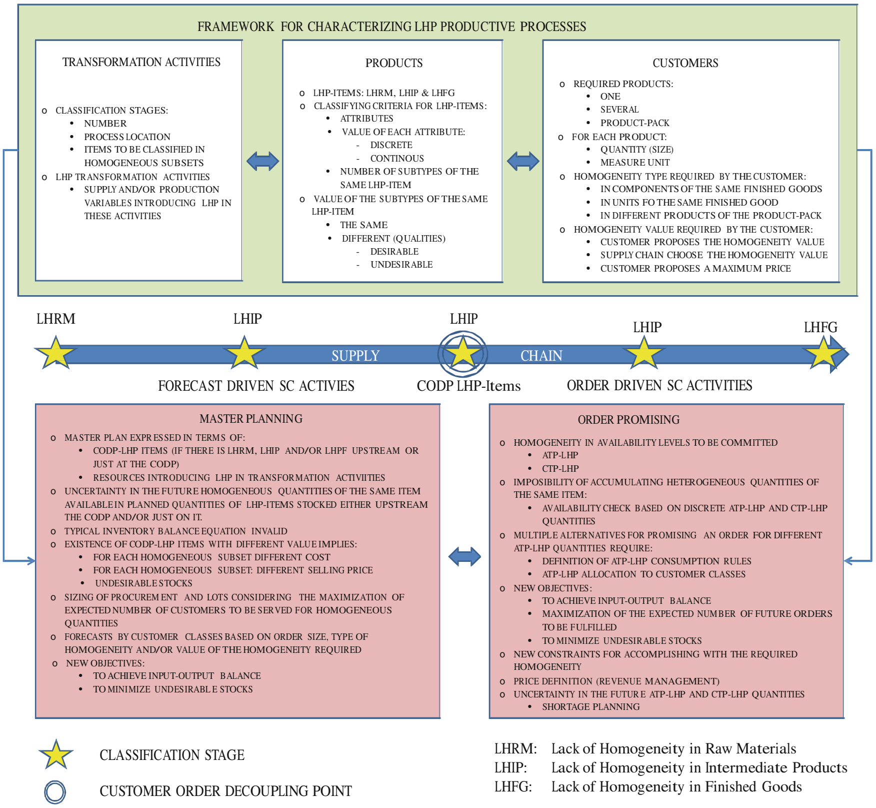


Fig. 15.1 Framework for characterizing LHP productive processes and their relationship with master planning and order promising

element will be the number and situation of classification stages along the productive process as well as items classified in each one of them. Furthermore, with the aim of anticipating the homogeneous quantities available in production plans, it will be necessary to identify the transformation activities that introduce heterogeneity in the process and the variables that cause it. It will be important to define the relationship between the heterogeneity origin and the productive resources (on the same machine, between machines, in time). This helps us to know the degree of detail for modeling resources in the master planning.

15.2.2 Products

With the aim of being more exhaustive in the determination of the LHP origin, we extend the LHP definition provided by Alarcón et al. (2011) introducing the terms

Lack of Homogeneity in Raw Materials (LHRM), Lack of Homogeneity in Intermediate Products (LHIP) and Lack of Homogeneity in Finished Goods (LHFG) to differentiate if the classified items are either raw materials or intermediate products and components or finished goods, respectively. Furthermore, this classification will allow the identification in the heterogeneity origin: raw materials (LHRM) or productive process (LHI and/or LHFG without LHRM) or both them (LHRM and/or LHI and/or LHFG), allowing the location of the uncertainty in the supply and/or the production process, respectively. For each sorted item, the classification criteria and the values they can take (discrete or continuous) should be identified. This provides us the number of subtypes of the same LHP item that can have the same and/or different value. Usually, different values imply the existence of several qualities. For instance, in the ceramic sector, the same production batch results in various qualities (first, second and third one) with a decreasing value. In addition, within each quality different shades and sizes are found with the same value.

15.2.3 Customers

Because LHP management problem arises from the homogeneity requirement imposed by customers, it is crucial to identify the customizable parameters of order proposals affecting LHP. As in most companies, it will be essential to know from the customer order, the requested products (one, several or a product-pack), the unit measure for each product (that can be dependent on the customer class: units, pallets or trucks), the quantity and the due date. But LHP introduces a new customized aspect in order proposals: the homogeneity type required by the customer among the ordered products. The customer may require uniformity between components of a product (pearls on a necklace) or between units of the same product (ceramic tiles) or between different products of a product-pack (chairs and a dining table). In addition, the customer can specify the value of the homogeneity attributes required or, in case there are subtypes of the same item with different value, the maximum price willing to pay. Note that the order size be- comes a very relevant factor for LHP because the larger the orders size, the more difficult will be to meet the uniformity requirement among all their units.

15.3 LHP Impact on Master Planning and Order Promising

Two of the key processes that attempt to provide the customer with the degree of uniformity required in his/her orders are the order promising process and the master planning. These two processes are strongly connected in the border established by the customer order decoupling point (CODP). The CODP location along the productive process is a strategic decision (Olhager 2010) that defines the manufacturing strategy adopted (make-to-stock (MTS), assemble/configure-to-order (ATO/CTO), and make-to-order (MTO)). The CODP separates the forecast-driven parts of a supply chain from the order-driven parts in such a way that only the items upstream the CODP and just at the CODP are stocked (i.e. planned against forecasts). Besides, the master plan should be expressed in terms of CODP items (Ball et al. 2004): raw materials and components in MTO; intermediate product and subassemblies in ATO, and finished goods in MTS. Based on the CODP items quantities in the master plan, the on hand inventory and the committed orders, the order promising process calculates the uncommitted available quantities to be promised to customers (ATP). Therefore, it can be understood the close relationship between the master planning and the order promising on the boundary defined by the CODP (Christou and Ponis 2009).

As it is described below, for LHP manufacturing environments it is crucial not only the CODP location but also its relative position as regards the classification stages. This aspect represent the starting point to analyze LHP implications in the master plan and order promising that, in turn, will constitute the basis for choosing the LHP characteristics relevant to be modeled.

15.3.1 CODP and Classification Stages: CODP LHP-Items

Because the master plan and the ATP quantities are expressed in terms of CODP items, the start point to properly manage LHP is to determine if CODP items are classified based on some criteria: i.e. the existence or not of CODP LHP-items. From the application of the previous described framework (Sect. 15.2), the location of classification stages along the productive processes and the classified items are known. Based on this information, the relative position of classification stages regarding the CODP can be derived. CODP LHP-Items will appear when there are some classification stages before or just at the CODP. That is, CODP-LHP items will appear when there are FHRM, FHIP o FHFG before or just at the CODP. The existence of CODP LHP-items implies to deal with different sub types stocked of the same item, not being possible to accumulate their stocks for serving customer orders at the CODP because of their heterogeneity. Additionally, if there are subtypes of the same item with different value, the existence of undesirable stocks will appear for references with low or null value.

15.3.2 LHP Master Planning

The objective is to derive a master plan that should feed up the order promising process with precise information about the expected homogeneous quantities of each subtype (LHP Master Plan). For properly LHP modeling, the master plan should be expressed in terms of CODP items that in LHP context can imply dealing with CODP LHP-items. If it is known the impact on LHP of productive resources upstream the CODP (supply and/or production variables introducing LHP in transformation activities carried out by these resources), the master plan should be defined with a detail degree regarding resources that allows anticipating as much as possible the future homogeneous quantities available of an LHP-item. For instance, in ceramic sector, batches of one same product processed in different production lines and time periods are most likely to not be homogeneous then, the master plan should specifies the quantities to be produced by each production line of each plant in each time period (Alemany et al. 2010)

LHP modeling in the master plan supposes the appearance of a new kind of uncertainty: uncertainty in the future homogeneous quantities of the same item available in planned quantities of LHP-items stocked either upstream the CODP and/or just on it. Because heterogeneous quantities of the same LHP-item cannot be mixed, the typical inventory balance equation becomes invalid.

The existence of CODP LHP-items with different value supposes a not uniform sharing of cost among the expected homogeneous quantities. This fact can lead to different selling prices for each subtype based on their value in such a way that selling prices should be greater for subtypes of the same item with scarce availability and high demand. Furthermore, undesirable stocks for LHP-items with low or null value and low or null demand can appear along the supply chain.

For maximizing the expected customer orders fulfilled, it should be recommendable to size the planned items quantities trying to serve an integer number of customer orders. This means, that the typical constraint of accomplishing the aggregate forecasted demand for an item does not ensure the fulfillment of all its orders, due to the impossibility of mixing heterogeneous quantities to serve the same customer order. In this sense, it will be useful to obtain forecasts for each item per customer classes which will be defined based on the order size, type of homogeneity and/or value of the homogeneity required. Uncertainty inherent to LHP environments and undesirable stocks can lead to define additional master plan objectives related to the balance achievement between homogeneous availabilities and uniformity requirements generated by sales (input–output balance) as well as minimizing undesirable stocks.

15.3.3 LHP Order Promising

Because ATP is derived from the Master Plan, dealing with CODP LHP-items in master plan implies the existence of multiple ATP-LHP homogeneous quanti- ties for those items than cannot be accumulated to serve an order. In case, there is not enough ATP for promising orders it will be possible to compute the uncommitted quantities of materials and productive resources (Capable-To-Promise: CTP) upstream the CODP to produce additionally quantities of CODP items modifying the master plan. Furthermore, if CODP items are not finished goods, the order promising process should compute CTP quantities for each resource downstream the CODP to ensure there is enough capacity to finally produce finished goods from the CODP items by the Final Assembly Schedule. In this case, the CTP-LHP management will be necessary if either there is LHMP and/or LHIP downstream and/or upstream the CODP or it is known the impact of the part of the productive process on the heterogeneity characteristic of finished goods upstream or downstream the CODP. If the impact of productive resources on LHP is known, to ensure as much as possible that orders are reserved from homogeneous quantities of one same product, it should be not allowed to serve an order by accumulating heterogeneous ATPs-LHP subtypes not only from the same item but also from different time periods or from different resources. When there are different ATP-LHP homogeneous quantities from which to serve an order, the final choice will affect subsequent promises. In this case, formulating consumption rules for guiding the choice of specific ATP-LHP from which to serve the order complemented with ATP-LHP allocation to customer classes can constitute different approaches to increase order promising efficiency. Implementation of such LHP consumption rules can imply the definition of additional objectives and/or constraints different from the typical ones, with the aim of guiding the best choice of reserving ATP-LHP from multiple alternatives. These new objectives should be related with the reduction of undesirable stocks when promising orders, the maximization of the expected number of future orders to be fulfilled and the input–output balance. A key element for achieving this input–output equilibrium is the selling price definition that is typical of revenue management.

Finally, uncertainty in the future homogeneous quantities will originate differences between the previous planned homogeneous quantities and the real ones. In order to minimize the committed orders that cannot be served due to this uncertainty, effective methods for shortage planning in LHP environments should be developed.

15.4 Conclusions

Improperly LHP management may have very negative effects on SCs' competitiveness: (1) appearance of undesirable stock; (2) uncertainty in the homogeneous quantities can lead to produce more than necessary increasing stocks; and (3) the customer service level may prove deficient (even when high stock volume) if the heterogeneity is not managed in a suitable manner. The master planning and the order promising processes play a crucial role in the proper LHP management. However, the special LHP characteristics to be considered in both processes are strongly dependent on the specific manufacturing process. Therefore, to help in the properly LHP management, in this paper the characterization of LHP productive processes and their impact on the master planning and the order promising have been described. The result is special LHP characteristics suitable to be considered for its right management. Because incorporating LHP characteristics implies an increase of the decision-making complexity, future research lines are focused on modeling LHP aspects and assess under which circumstances to model the complexity inherent to LHP implies substantial improvements.

References

Alarcón F, Alemany MME, Lario FC, Oltra RF (2011) La falta de homogeneidad del producto (FHP) en las empresas cerámicas y su impacto en la reasignación de inventario. Boletín de la Sociedad Española de Cerámica y Vidrio 50(1):49–58

Alemany MME, Boj JJ, Mula J, Lario FC (2010) Mathematical programming model for centralised master planning in ceramic tile supply chains. Int J Prod Res 48(17):5053–5074

Ball MO, Chen CY, Zhao ZY (2004) Available to promise. Modeling in the E-business era. In: Simchi-Levi D, David S, Shen ZM (eds) Handbook of quantitative supply chain analysis, vol 11. Kluwer Academic Publishers, Berlin, pp 447–483

Christou IT, Ponis S (2009) A hierarchical system for effective coordination of available-to-promise logic mechanisms. Int J Prod Res 47(11):3063–3078

Olhager J (2010) The role of the customer order decoupling point in production and supply chain management. Comput Ind 61:863–868

Poyatos A, Bonaque R, Mallol G, Boix J (2010) Nuevo sistema y metodología para la eliminación de los calibres en el proceso de fabricación de baldosas cerámicas. Boletín de la Sociedad Española de Cerámica y Vidrio 49(2):147–151

Roma A, Castán J (2009) La cadena de suministros para empresas que en su proceso de producción incorporan materias primas procedentes directamente de la naturaleza. 3erd In: Proceedings of international conference on industrial engineering and industrial management

Verdouw CN, Beulens AJM, Trienekens JH, Wolferta J. (2010) Process modelling in demand-driven supply chains: a reference model for the fruit industry. Comput Electron Agric 73:174–187

Chapter 16
The Reduction of CO_2 Emission into the Supply Network Design: A Review of Current Trends in Mathematical Models

Carola Pinto and Anna M. Coves Moreno

16.1 Introduction

Greenhouse gas emissions (GHGs) as key contributors to global warming have become a major concern for governmental bodies and the industrial sector in recent years. Upon the signing in 1997 of the Kyoto Protocol (Protocol 2007), whose aim was to reduce six types of greenhouse gases, 187 states (both developed and developing) have developed strict goals to their CO_2 emissions in the near future.

Virtually the entire scientific, political, business, and social community is aware of the significance of this environmental challenge. Many companies also view a "green supply network" (GSN) as a means of maintaining a positive public image, as consumers increasingly value environmentally responsible production.

One of the ways the business sector has found to reduce CO2 emissions is by establishing international standards for measuring environmental impact through emissions inventories. Various tools and guides have been developed to help companies design effective strategies to reduce emissions. One of these tools is the Greenhouse Protocol (GHG Protocol) (WBCSD/WRI 2001), which allows for the measurement of direct and indirect GHG emissions from a corporate standpoint. Another regulatory tool is ISO 14064 (ISO 14064 2006), which is coherent and compatible with the GHG Protocol. In general terms, ISO 14064 identifies the "What" and the GHG Protocol, the "How" and "Why". ISO 14064 is oriented toward audits, while the GHS protocol is oriented toward providing a set of options for reducing GHGs.

C. Pinto · A. M. Coves Moreno (✉)
Department of Management, Institute of Industrial and Control Engineering, Universitat Politècnica de Catalunya, Av. Diagonal 647 08028 Barcelona, Spain
e-mail: anna.maria.coves@upc.edu

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_16,

There is another specification with a focus on the product rather than the company known as PAS 2050 (BSI 2008, 2011), which provides a method for assessing gas emission of products and services based on Life Cycle Assessment (LCA).

Companies interested in making environmental improvements to their supply network often use LCA to analyse environmental impacts within their processes (De Benedetto and Klemes 2009). LCA assesses the environmental impact throughout a product's life cycle and includes all stages within the supply network, from raw material extraction and processing, to manufacturing, transport, distribution, consumption, reuse, recycling, and waste treatment. LCA is also used to assess possible investment alternatives related to environmental impact (Freeman et al. 1992) (raw material selection, suppliers and manufacturing processes).

Many publications use LCA for assessing and quantifying environmental impact within a supply network. One case looks for a minimization of environmental impacts in supply network design and traditional economic costs (Mir Saman and Razmi 2011). In their article, the authors propose a fuzzy, multi-objective mathematical model under conditions of uncertainty, which uses LCA to find a balance between positive economic balance and environmental impact.

This present article reviews current trends in reducing GHG emissions in supply networks and mathematical models used. This article organizes publications according to the authors' specific area of focus for reducing CO_2 emissions in the tactical-operational field (production and distribution planning) or the strategic field (technology selection and facilities locations).

This article is structured in the following manner: The article begins with an introduction explaining the importance of integrating decisions related to GHG reduction. The article then reviews the most important contributions in this field, with particular focus on the mathematical models used in network supply design that include environmental characteristics. The final section of the article includes the main conclusions and proposals for future research.

16.2 Importance of Integrating GHG Reduction into Supply Network Design

Environmental factors in supply network design have become a focus of research in recent years. Studies have analysed the implications of different transportation types with regard to CO_2 emissions, as well as of energy-saving technology in both transportation and production. The concept GSN has recently appeared to include the environmental factor in supply network design.

GSN design needs to consider initial investment in environmental protection equipment and techniques; financial needs; and consequences for system functioning. Decisions regarding facility location and capacity must be integrated with decisions regarding environmental investment, given this investment can affect environmental indicators in the operational phase.

16.3 Mathematical Models in GSN Design

Over the last two decades, environmental management has been increasingly integrated into network supply design, due, in part, to pressure on the business sector to protect the environment (Wu and Dunn 1995). This development has been accompanied by an increase in literature on GSN. We analysed the most recent contributions in the field of CO2 emission reduction in supply network design.

In Table 16.1 publications are classified according to the type of network supply design decision. Each publication is classified according to how variables reducing CO_2 emissions are integrated into the mathematical model.

This section of the article will centre on mathematical models that simultaneously optimize economic and environmental impacts in the same network design. A synthesis of the most significant contributions will be presented in order to identify the concepts considered in each article and their associated decision variables. The type of objective function and model used will also be indicated.

The following sections will discuss each of the concepts included in Table 16.1. Each section highlights the most important aspects and techniques used by the authors to reduce GHGs when designing supply networks.

16.3.1 Facility Location and Capacity

Determining number and location of facilities is one of the strategic decisions included in GSN design. One can determine the location of productive plants (Hugo and Pistikopoulos 2005; Letmathe and Letmathe 2005); the size of

Table 16.1 Publications on mathematical models for designing green supply networks

	Mathematical models					
	Location of facilities	Selection of technologies	Carbon market	Production	Transport	Recycling
2004						[10]
2005	[11]	[11]		[11]; [13]	[11]	
2006	[15]			[21]		
2007						
2008						
2009	[2]	[2]			[2]	
2010	[23]; [5]	[23]	[19]	[5]; [19]	[17]; [22]; [5]; [19]	[5]
2011	[1]		[1]	[14]; [1]	[14]; [1]	[14]

Numbers correspond to cited references

productive plants and distribution centres (Chaabane et al. 2010; Abdallah et al. 2011); as well as the location of pick-up and recycling centres (Min et al. 2006). Others studies include facility locations as variables within a multi-objective mathematical model to find a balance between possible environmental damage and economic impact (Wang et al. 2011; Bajarski et al. 2009).

16.3.2 Technology Selection

Despite the consensus on the importance and benefits of adopting sustainable practices along the entire value chain, one of the major challenges continues to be searching for innovative technologies. Thus the importance of generating long-term planning models to determine investment decisions relating to optimal selection, installation, and expansion of processes technologies (Hugo and Pistikopoulos 2005).

Economic impact is often related to environmental impact. When dealing with investment in technology, the balance between total costs and environmental effects is especially important. Choosing the level of environmental protection is one of the variables to decide in designing a GSN, and is related to the investment in processes technology (Wang et al. 2011). A greater investment in technology leads to reduced CO_2 emissions. Investment in environmental protection can imply buying equipment or technology or adopting cleaner processes. The multi-objective model developed by latest cited authors introduces a new decision variable, "environmental protection level". Technology selection depends on the environmental protection level set in the planning phase. Generally, the greater the investment gets the greater the protection. Another multi-objective model is proposed in which potential plants may be selected using different types of technology (Hugo and Pistikopoulos 2005). Their model is based on LCA principles, and presented as a support tool in sustainable investment planning.

16.3.3 Carbon Market

Article 17 of the Kyoto Protocol sets forth a new concept allowing both countries and companies to optimize CO_2 emissions by establishing an "emissions trading" scheme. Under this scheme, companies can buy or sell CO_2 credits, and in so doing, meet their environmental goals. Regardless of whether the company has set voluntary reduction goals or is subject to GHG emission caps, this scheme is based on assigning a quota of emission credits [1 credit = the right to emit one metric ton of carbon dioxide equivalent to (tCO_2e)], which each company must manage in the most efficient manner possible. At the end of each period, each company's emissions are verified. If real emissions are greater than the imposed emission quota, the difference may be compensated by purchasing credits on the market. If real emissions are less than the permitted, the company may sell CO_2 credits on the market and earn profits (Chaabane et al. 2010).

The environmental impact can be measured by converting CO_2 tonnage caused by supply network activities into CO_2 credits, according to the CO_2s tCO_2e price in the CO_2 market (Ramudhin et al. 2008). These authors propose a mixed integer linear programming (MILP) model for designing a green supply network integrating decisions related to "carbon trading". The model allows companies to assess different strategies regarding supplier and subcontractor selection, product allocation, productive capacity utilization, and transport configuration in terms of their impact on GHG emissions.

Managing CO_2 emissions through CO_2 credits is an interesting means of attaining environmental goals. In one mathematical model, CO_2 emission credits may be managed by introducing an average expected cost per CO_2 credit into a company's economic objectives (Abdallah et al. 2011). They present an optimization model which seeks to minimize traditional costs and CO_2 emissions by introducing a new concept known as "green procurement", where companies are able to decide how to manage their CO_2 emissions within the CO_2 market. Their MILP model also includes assessing supplier CO_2 emissions in order to design a green supply chain beginning at the point of material procurement.

16.3.4 Production Operations

Production operations contribute to increased greenhouse gases in two main ways: (a) through the energy source used, or (b) by emissions related to the production process, itself. The energy source used for production is the main factor in GHGs (Moomaw 1996), which means that more efficient energy use, cleaner energy sources, and cleaner processes technology can significantly reduce GHGs.

At the strategic level, it is possible to pose the problem in a long-term planning horizon that includes processes technology selection and expansion capacity (Hugo et al. 2006), and develop a systematic focus to identify the synergy among different energy generation systems (Soylu et al. 2006). They propose a multi-period, discrete and continuous MILP model, which includes investment in energy generation systems within production planning.

Some papers analyse the problem of CO_2 emissions caused by company production processes. One present mathematical models that may be used in industry to determine optimal production levels and product mix in the presence of various environmental restrictions and typical production planning limitations (Letmathe and Letmathe 2005; Bojarski et al. 2009).

16.3.5 Transport Operations

The impact of transportation on the environment may be analysed in each supply network phase from transport of raw materials from providers to production plants (Hugo and Pistikopoulos 2005) to transport of finished products to distribution centres, retailers, consumers, and recycling centres.

Others authors propose an optimization model for freight consolidation in which CO_2 emissions are computed for two transport types (highway and railroad). The relation between emissions and type of transport and freight are non-linear functions, which are later linearized with "piecewise" function (Pan et al. 2010).

One of the main causes of increasing CO_2 emissions is the low utilization of freight trucks (Van de Klundert and Otten 2010). They propose improving freight vehicle capacity use by accepting additional freight through linear programming and heuristics techniques.

Calculation factors for type of transport (Abdallah et al. 2011), travel distance, and mass transported are frequently used in calculate CO_2 emissions.

16.3.6 Recycling, Reuse and Disposal

For waste recycling and treatment, LCA is used to design models for identifying solid and liquid waste, as well as gas emissions due to various production processes (Chaabane et al. 2010). Models also analyse waste inside the supply network by analysing waste flow through the standpoint of accumulated costs (Hicks et al. 2004). Depending on the industrial sector, contributions in the area of industrial waste are found in the automotive (Duval and MacLean 2007), electronic (Ravi 2012), and paper (Counsell and Allwood 2007) industries, among others.

16.4 Conclusions

This article has analysed and classified the most important contributions relating to integration of environmental variables in supply network design. Articles published in the area of GSNs focus on specific issues such as transport; finding cleaner energy; or reducing energy consumption through technological or strategic innovation.

With respect to proposed mathematical models, in five analysed papers their authors use MILP models. Some authors adapt their models to a LCA approach (in four articles), while others authors present multi-objective models (in two analysed papers) or multi-period models in only one analysed paper.

Both facility location and technology selection are determined in the design stage, and allow a company to assess the environmental and economic impact of the supply network. While a greater investment in technology can lead to lower GHG emissions, it is important to find a balance between the economic and environmental impact of every supply network decision.

The CO_2 Market is an interesting alternative for managing CO_2 emissions via CO_2 credits. However, it is must be stressed that trading CO_2 credits does not directly lower GHG emissions.

The areas in which GHGs emissions can be significantly reduced are: production operations, transport, and recycling. In production, GHGs can be lowered through more efficient energy generation; selecting new sources of energy; introducing cleaner processes technology. In transport, emissions can be reduced by consolidating freight and maximizing freight truck utilization. And finally, in waste management and recycling, CO_2 emissions can be lowered by analysing waste flow along the supply network.

In conclusion, carbon emissions reduction in supply networks is a growing concern, requiring greater in-depth research on how to reduce CO_2 emissions in all phases of the supply network. The findings of such research must provide solutions that capitalize on the scientific and technological possibilities that exist to- day, and that can be adapted to corporate and governmental needs and realities.

The final objective of such research is to design a supply network, in which all logistical and industrial activities contribute to CO_2 reduction, preserving the environment, and as a result, obtaining strategic benefits.

Acknowledgments The authors gratefully acknowledge the partial support of grant DPI2010-15614 (Ministerio de Economia y Competitividad, Spain).

References

Abdallah T, Farhat A, Diabat A, Kennedy S (2011) A green supply chain with carbon trad- ing and environmental sourcing: formulation and life cycle assessment. Appl Math Model. doi:10.1016/j.apm.2011.11.056

Bojarski A, Laínez JM, Espuña A, Puigjaner L (2009) Incorporating environmental impacts and regulations in a holistic supply chains modeling: an LCA approach. Comput Chem Eng 33:1747–1759

BSI (British Standards Institution), PAS 2050:2011 (2011) Specification for the assessment of the life cycle greenhouse gas emissions of goods and services. BSI, London

Chaabane A, Ramudhin A, Paquet M (2010) Design of sustainable supply chains under the emission trading scheme. Int J Prod Econ 135:37–49

Counsell T, Allwood J (2007) Reducing climate change gas emissions by cutting out stages in the life cycle of office paper. Resour Conserv Recycl 49:340–352

De Benedetto L, Klemes J (2009) The environmental performance strategy map: an integrated LCA approach to support the strategic decision-making process. J Cleaner Prod 17:900–906

Duval D, MacLean H (2007) The role of product information in automotive plastics recycling: a financial and life cycle assessment. J Cleaner Prod 15:1158–1168

Freeman H, Harten T, Springer J, Randall P, Curran M, Stone K (1992) Industrial pollution prevention: a critical review. J Air Waste Manage Assoc 42:618–656
Hicks C, Heidrich O, McGovern T, Donnelly T (2004) A functional model of supply chains and waste. Int J Prod Econ 89:165–174
Hugo A, Pistikopoulos EN (2005) Environmentally conscious long-range planning and design of supply chain networks. J Cleaner Prod 13:1471–1491
ISO 14064 (2006) standards. Available via: www.iso.org. Cited 17 Feb 2012
Letmathe P, Letmathe N (2005) Environmental considerations on the optimal product mix. Prod Manufac Logistics 167:398–412
Min H, JeungKo H, SeongKo C (2006) Ageneticalgorithm approach to developing the multi-echelon reverse logistics network for product returns. Omega 34:56–69
Mir Saman P, Razmi J (2011) Environmental supply chain network design using multi- objective fuzzy mathematical programming. Appl Math Model. doi:10.1016/j.apm.2011.10.007
Moomaw W (1996) Industrial emissions of greenhouse. Energy Policy 24:951–968
Pan S, Ballot E, Fontane F (2010) The reduction of greenhouse gas emissions from freight transport by pooling supply chains. Int J Prod Econ. doi:10.1016/j.ijpe.2010.10.023
Protocol (2007) United Nations, framework convention on climate change. In: Proceedings of Kyoto protocol to the united nations framework convention on climate change. UNFCCC Secretariat
Ramudhin A, Chaabane A, Kharoune M, Paquet M (2008) Carbon market sensitive green supply chain network design. In: Proceedings of the IEEE international conference on industrial engineering and engineering management, IEEM 2008
Ravi V (2012) Evaluating overall quality of recycling of e-waste from end-of-life computers. J Cleaner Prod 20:145–151
Soylu A, Oruç C, Turkay M, Fujita K, Asakura T (2006) Synergy analysis of collaborative supply chain management in energy systems using multi-period MILP. Eur J Oper Res 174:387–403
Van de Klundert J, Otten B (2010) Improving LTL truck load utilization on line. Eur J Oper Res 210:336–343
Wang F, Xiaofan L, Shi N (2011) A multi-objective optimization for green supply chain network design. Decis Support Syst 51:262–269
WBCSD/WRI (2001) (The Greenhouse Gas Protocol: a corporate accounting and reporting standard) The GHG protocol has been, or in the Process of being, translated into Chinese, French, and Japanese. In order to reach more companies, the protocol may be translated into several other languages as well
Wu H, Dunn S (1995) Environmentally responsible logistics systems. Int J Phys Distribution Logistics Manage 25:20

Chapter 17
Design of a Continuous Review Stock Policy

Sofía Estellés-Miguel, Manuel Cardós, José Miguel Albarracín and Marta Elena Palmer

17.1 Introduction

For design a continuous review policy first it is necessary to know nature of the demand, will be explained in Sect. 17.2. The listed items will not be detail explained as it has been published in others papers. To explain two types of scenarios that can occur when there is demand but no product to serve, these are either made backorder or lost the sale, this is explained in Sect. 17.3. In Sect. 17.4, we explain the inventory management policy that focuses on this paper, this is the policy of continuous review (s, Q). Once we have selected management policy, the next step is to define the design criteria to determine policy parameters. The metric used in this article is the cycle service level (CSL). The different definitions for CSL are detailed in Sect. 17.5.

On Sect. 17.6 based on previous section definitions, we have made a summary table which lists various published methods and their characteristics. Finally, we draw conclusions in Sect. 17.7.

17.2 Nature of Demand

The first step for design an inventory management system is to study the item characteristics that the design is intended for. This analysis has two main purposes:

1. Identify the relative importance of item (Silver et al. 1998) and
2. To facilitate the selection on the best procedure for forecasting and inventory policy (Fogarty et al. 1991).

S. Estellés-Miguel (✉) · M. Cardós · J. M. Albarracín · M. E. Palmer
Departamento de Organización de Empresas (DOE), Universitat Politècnica de València, 7D, Camino de Vera s/n 46022 Valencia, Spain
e-mail: soesmi@omp.upv.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_17,

For the first purpose the ABC Classification is used, it will be explained in Sect. 17.2.1. For second purpose is used items categorize according to their demand pattern, that must be compared to probability distribution function to represent it.

17.2.1 ABC Classification

ABC classification applied to inventory management is (Fogarty et al. 1991):

1. Classify each item based on their relative importance.
2. Establish a management approach consistent with importance degree according to items classification based on their relative importance.

ABC analysis identifies the most important items and classified as A type. The minor, are classified as C. Rest places in B type (Zipkin 2000). ABC classification does not limit use to these three categories. I.e., Campbell (1975) use five different classes. And others authors limit classification to a maximum of six (Silver et al. 1998) and (Graham 1988). Traditional approach of ABC classification usually is made based on a single criterion, often this is demand value or demand volume (Teunter et al. 2010). However, a number of authors (Buzacott 1999; Ramanathan 2006; Zhou and Fan 2007; Ng 2007; Ding and Sun 2011) have considered use several criteria (such as supply security, obsolescence rate, delivery time, etc…). Based on above have been developed different multicriteria classifications. Any of the criteria annotated above serve to make an ABC classification.

17.3 Backorders Versus Lost Sales

Two situations may occur in an inventory system when there is demand:

1. That there is enough stock in warehouse to satisfy completely, and
2. That stock is not sufficient and therefore the inventory system is in stockout.

> An important system feature is what happens when this situation occurs. Basically, there are two extreme cases (Silver et al. 1998): (1) Backordering case: Demand that can not be served is deferred to following cycle and will be served as soon as system receives an order to supply large enough (Hadley and Whitin 1963); (2) Lost sales case: Demand that can not be satisfied with available stock is lost and becomes lost sales. Generally not known and therefore, these lost sales are not recorded in the company (Thomopoulos 2007).

In classical inventory models, it is common to assume that excess demand is backorder. However, studies that analyze customer behavior in practice (Gruen et al. 2002) and (Verhoef and Sloot 2006) argue that unmet demand is more common than be lost. Inventory systems, including lost sales appear to be more difficult to analyze and resolve. Also, lost sales inventory systems require different replenishment policy to minimize the replacement cost compared to backorders systems (Bijvank and Vis 2011). Most of the available inventory theory do not talk about adjustments to be made for lost sales model see Guide and Srivastava (1997), Kennedy et al. (2002), Silver (2008) and Williams and Tokar (2008). The optimal policy for continuous review model with lost sales is not well known. Few authors explain it (Johansen and Thorstenson 1996). In real life, there are often situation that combine both scenarios. However, most inventory management models are developed for one of the two (Silver et al. 1998). From a mathematical point of view, it is usually easier obtain the model if the demand can be differ (Silver 1981; Zipkin 2008), is why most literature focuses on this case.

17.4 Inventory Management policy (s, Q)

Selection of inventory policy depends on how often to check the inventory level (Cardós et al. 2009). Inventory management policies with random demand are divided into two main categories: periodical and continuous review. If the status of the inventory is permanently reviewed, we talk about continuous review policy. In the other case is periodical review policy. Most inventory management models are based on assumptions rather restrictive view (Silver et al. 1998; Axsäter 2000). For example, consider the demand for unit size and a normal distribution for the demand during the replenishment lead time. In most inventory management systems, these simplifications circumstances are allowed. Sometimes, these simplifications fundamentally differ from the actual conditions.

The inventory management policy (s, Q) is known by the name order point order quantity. Also known as reorder point system (Krajewski and Ritzman 2000). Where s is reorder point and Q quantity ordered. The model (s, Q) is an important model in literature production and management in operations research and in practice (Hadley and Whitin 1963; Johnson and Montgomety 1974; Silver and Peterson 1985; Nahmias 2008). In inventory management policy (s, Q) a fixed quantity Q is ordered whenever the inventory position reaches reorder point or falls bellow this (Silver et al. 1998). Order is received L periods later, L can be constant or variable. Are defined:

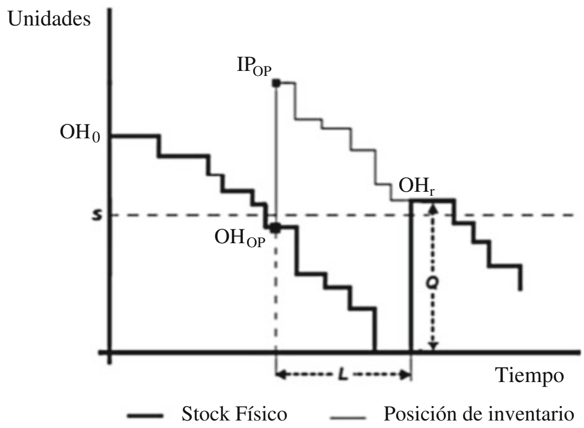
Inventory Position (IP), measure the item's ability to satisfy future demand (Krajewski and Ritzman 2000). This includes scheduled receptions and available stock and would be subtracted backorders. This doesn't take into account the committed (Yeh et al. 1997; Krajewski and Ritzman 2000; Rao 2003).

$$IP = OH + SR - BO \tag{17.1}$$

Where OH is on-hand, SR is scheduled receptions and BO are backorders. On (Silver et al. 1998) in addition to subtract the commitment (C):

$$IP = OH + SR - BO - C \tag{17.2}$$

Fig. 17.1 Evolution of physical stock and the inventory position in a system (s, Q). *Source* Own



Face with authors who say that periodic policies allow coordinate replenishment of various items, and cost savings that this implies (Sani and Kigsman 1997; Eynan and Kropp 1998; Chiang 2006, 2007) other authors such as (Yeh et al. 1997) assume that continuous review is needed to ensure an adequate level of service and (Rao 2003) says that if lead time is small, (s, Q) police is more efficient and can be manage with very little inventory, also says that in sporadic demand scenarios is better than periodic review (Fig. 17.1).

17.5 Cycle Service Level as a Design Requirement

Once management policy is defined, we must establish design the criteria to determine the policy parameters. Basically there are two methods:

1. Which minimize cost, and
2. Which minimize inventory average to a certain service level.

In the first case, inventory policies should be considered different types of costs (holding inventory, order and stockout costs) (Schneider 1981). Some authors assume that shortages stock costs can be expressed analytically simple, focusing on cost minimization. In practice, these costs are difficult to establish and estimated, are discarded in favour of a focus on a predetermined service level view satisfaction (Cohen et al. 1988; Larsen and Thorstenson 2008), for this reason most commonly used design requirements relate to customer service. Service level is closely related to stock-outs or product lack when there is a request for it. A stock-out not only causes immediate profit loss by not serving an order, but also causes a loss of long-term benefit because it reduces the possibility of receiving new orders from that customer (Lejeune 2008). See (Anderson et al. 2006) for a study on the effects of stock-outs.

Most commonly used design requirements are those relate to customer service as cycle service level (CSL) o P1 (Vereecke and Verstraeten 1994; Cardós et al. 2006, 2009); Cardós and Babiloni 2011), and percentage of demand satisfied with physical stock, called fill rate (FR) o P2 (Dunsmuir and Snyder 1989; Janssen et al. 1998; Segerstedt 1994; Snyder 1984; Strijbosch et al. 2000; Yeh et al. 1997). Present paper focuses on CSL.

In literature, there are two definitions of CSL. First, hereinafter referred to classical, defines CSL as the probability of not incurring stock-outs during the replenishment cycle. This probability, also known as P1, is equivalent to the safety factor used to calculate k safety factor when demand is normally distributed (Silver et al. 1998). Therefore, CSL is the fraction of cycles in which a stockout doesn't occur. (Silver et al. 1998) defines stockout as the moment in which the available physical stock is zero. Therefore:

$$CSL = 1 - P\,(\text{stockout in a replenishment cycle}) \tag{17.3}$$

Axsäter (2000) defines CSL as "probability of no stockout per order cycle". According to (Cardós and Babiloni 2011), this definition and the corresponding expression should be improved as follow:

1. Demand fulfilment is not taken into account and
2. There are a number of situations where this definition is scarcely useful. I.e., under intermittent or slow-movements demand context the probability of no demand when physical stock is equal to zero is not negligible, so a stockout situation and demand fulfilment can be compatible.

Chopra and Meindl (2001) proposes a convenient definition of CSL: fraction of replenishment cycles that end with all customer demand met for (Cardós et al. 2006) propose another CSL definition: "fraction of cycles in which having demand nonzero is been fully satisfied with physical stock". When applied to continuous review policy, cycle demand is always positive so this definition can be simplified becoming expression proposed by (Chopra and Meindl 2001), see Eq. 17.4. Moreover, this definition is useful not only from technical standpoint but also from management perspective.

$$CSL = P(\text{cycle demand}\,\delta\,\text{available stock} \mid \text{cycle demand}\,\epsilon\,0). \tag{17.4}$$

Chopra and Meindl (2001) say "…that stockout occurs in a cycle if demand during lead time is greater than reorder point" and also propose an estimation method:

$$CSL = P(\text{Demand during lead time of L weeks}\,\delta\,s) \tag{17.5}$$

Table 17.1 Review of methods for calculating CSL in (s, Q) inventory management policy

Author (year)	Method type s versus Q	Ignores U[1]	Applicable with backorders and/or lost sales
Chopra and Meindl (2001)	Approximate For any s	Yes	Both
Silver et al. (1998)	Approximate For any s	Yes	Only lost sales
Cardós et al. (2009)	Approximate For any s	Yes	Only backorders
Cardós and Babiloni (2008)	Exact $s < Q$	No	Only lost sales
Cardós et al. (2009)	Exact $s \geq Q$	No	Only lost sales
Cardós et al. (2009)	Exact For any s	No	Only backorders

[1] U is undershoot or deviation at the reorder point

17.6 Methods for Calculating CSL for Inventory Management Policy (s, Q)

In this section, we review the existing calculation methods for CSL and collected in a summary table to find gaps in the research: (Table 17.1).

17.7 Conclusions

This paper has revealed some relevant research gaps that will be addressed in future research projects: (1) the need of better approximations for CSL estimation; (2) all approximate methods despised undershoot; and (3) although we have not exposed in the tail any exact calculation methods we should said that the exact methods requires a high computational effort.

In future research, we will try to find a CSL approximate formula in the lost sales context with reduced deviation from the exact value.

This paper is part of a wider research project devoted to identify the most simple and effective stock policy to properly manage any particular demand pattern based on the characteristics of the demand itself.

References

Anderson ET, Fitzimons GJ, Simester D (2006) Measuring and mitigating the costs of stocks outs. Manage Sci 52:1751–1763

Axsäter S (2000) Inventory control. Kluwer Academic Publishers, Massachusetts

Bijvank M, Vis I (2011) Lost-sales inventory theory: a review. Eur J Oper Res 215:1–13

Buzacott JA (1999) Dynamic inventory targets revisited. J Oper Res Soc 50:697–703

Campbell K (1975) Inventory turns and ABC-analysis-outmoded textbook concepts? Am Prod Inv Cont Conf 420–438
Cardós M, Babiloni E (2008) On the exact and approximated calculation of the cycle service level in continuous review system. In: Proceedings of 15th Int Sym Inv
Cardós M, Babiloni E (2011) Exact and approximated calculation of the cycle service level in a continuous review policy. Int J Prod Econ 251–255
Cardós M, Miralles C, Ros L (2006) An exact calculation of the cycle service level in a generalized periodic review system. J Oper Res Soc 57:1252–1255
Cardós M, Babiloni E, Palmer M, Albarracín JM (2009) Effects on undershoots and lost sales on the cycle service level for periodic and continuous review policies. In: Proceedings of CIE 2009, Troyes, pp 819–824
Chiang C (2006) Optimal ordering policies for periodic-review systems with replenishment cycles. Eur J Oper Res 170:44–56
Chiang C (2007) Optimal ordering policies for periodic-review systems with a refined intra-cycle time scale. Eur J Oper Res 177:872–881
Chopra S, Meindl P (2001) Supply chain management. Prentice-Hall, New Jersey
Cohen MA, Kleindorfer PR, Lee HL (1988) Service constrained (S, S) inventory systems with priority demand classes and lost sales. Manage Sci 34:482–499
Ding B, Sun L (2011) An inventory classification model for multiple criteria ABC analysis. In: Proceedings of 8th Int Ser Sys Ser Manage, pp 1–6
Dunsmuir W, Snyder R (1989) Control of inventories with intermittent demand. Eur J Oper Res 40:16–21
Eynan A, Kropp DH (1998) Periodic review and joint replenishment in stochastic demand environments. IIE Tran 30:1025–1033
Fogarty DW, Blackstone JH, Hoffman TR (1991) Production and inventory management. South-Western Publishing Co., Ohio
Graham G (1988) Distribution inventory management for the 1990s. Natl Assn of Wholesale Distributor, Texas
Gruen T, Corsten D, Bharadwaj S (2002) Retail out of stocks: A worldwide examination of extent causes and consumer responses. 19 may 2002 Personal Communication
Guide V, Srivastava R (1997) Reparaible inventory theory: models and applications. Eur J Oper Res 102:1–20
Hadley HG, Whitin TM (1963) Analysis of the inventory systems. Prentice Hall, New Jersey
Janssen F, Heuts R, de Kok T (1998) On the (R, s, Q) inventory model when demand is modelled as a compound Bernoulli process. Eur J Oper Res 104:423–436
Johansen SG, Thorstenson A (1996) Optimal (r, Q) inventory policies with poisson demand and lost-sales: discounted and undiscounted cases. Int J Prod Econ 46–47:359–371
Johnson LA, Montgomety D (1974) Operations research in production planning, scheduling, and inventory control. Wiley, New York
Kennedy WJ, Patterson JW, Fredendall LD (2002) An overview of recent literature on spare-parts inventories. Int J Prod Econ 76:201–215
Krajewski LJ, Ritzman LP (2000) Administración de operaciones. Estrategia y análisis. Pearson Educación Company, México
Larsen C, Thorstenson A (2008) A comparison between the order and the volume fill rate for a base-stock inventory control system under a compound renewal demand process. J Oper Res Soc 59:798–804
Lejeune M (2008) A unified approach for cycle service level http://business.gwu.edu/decisionsciences/i2sds/pdf/TR-2008-19.pdf
Nahmias S (2008) Production and Operations Analysis. Mc-Graw-Hill, New York
Ng W (2007) A simple classifier for multiple criteria ABC analysis. Eur J Oper Res 177:344–353
Ramanathan R (2006) ABC inventory classification with multiple-criteria using weighted linear optimization. Comput Oper Res 33:695–700
Rao US (2003) Properties of the periodic review (R, T) inventory control policy for stationary stochastic demand. Manuf Serv Oper Manage 5:37–53

Sani B, Kigsman BG (1997) Selecting the best periodic inventory control and demand forecasting methods for low demand items. J Oper Res Soc 48:700–713

Schneider H (1981) Effect of service-levels on order-points or order-levels in inventory models. Int J Prod Res 19:615–631

Segerstedt A (1994) Inventory control with variation in lead times, especially when demand is intermittent. Int J Prod Econ 35:365–372

Silver EA (1981) Operations research in inventory management: a review and critique. Oper Res 29:628–646

Silver EA (2008) Inventory management: a tutorial, canadian publications, practical applications, and suggestions for future research. Inform Syst Oper Res 46:15–28

Silver EA, Peterson R (1985) Decisions system for inventory management and production planning. Wiley, New York

Silver EA, Pyke DF, Peterson R (1998) Inventory management and production planning and scheduling. Wiley, New York

Snyder RD (1984) Inventory control with the gamma probability-distribution. Eur J Oper Res 17:373–381

Strijbosch LWG, Heuts R, Van der Schoot EH (2000) A combined forecast-inventory control procedure for spare parts. J Oper Res Soc 51:1184–1192

Teunter RH, Babai MZ, Synteros AA (2010) ABC classification: service levels and inventory costs. Prod Oper Manage 19:343–352

Thomopoulos NT (2007) Lost Sales, Conference Proceding Baltimore

Vereecke A, Verstraeten P (1994) An inventory management model for an inventory consisting of lumpy items, slow movers and fast movers. Int J Prod Econ 35:379–389

Verhoef P, Sloot L (2006) Out-of-stock: reactions, antecedents, management solutions, and a future perspective. Springer, Heidelberg

Williams BD, Tokar T (2008) A review of inventory management research in major logistics journals—themes and future directions. Int J Log Manage 19:212–232

Yeh QJ, Chang TP, Chang HC (1997) An inventory control model with gamma distribution. Microelectron Reliab 37:1197–1201

Zhou P, Fan L (2007) A note on multi-criteria ABC inventory classification using weighted linear optimization. Eur J Oper Res 182:1488–1491

Zipkin P (2000) Foundations of inventory management. Jeffey J.Shelstad. McGraw-Hill, New York

Zipkin P (2008) Old and new methods for lost-sales inventory systems. Oper Res 56:1256–1263

Chapter 18
MILP Model for Designing the Intermodal Inland Terminals and Seaports Network: A Case Study

Julien Maheut, S. Furió and C. Andrés

18.1 Introduction

Globalization, increase in maritime container traffic and environmental concerns are some of the trends that make designing the logistics chains of containers transport a complex task. Nowadays, logistics platforms play an important role as key instruments for territorial balance and for the development of a more sustainable transport model by bundling volumes, rationalizing traffics and fostering intermodal transport.

For years, the container shipping business has focused on reducing maritime transport costs through economies of scale. This has led to a high level of concentration in the industry, the use of increasingly large container ships and the development of new hub-and-spoke systems where a few hub ports concentrate the cargo. The ever-increasing difference between high volumes concentration on the seaside and landside atomization has led to different kinds of problems such as terminals congestion and road congestion at seaport accesses.

In this context, shipping companies, terminal operators and port authorities now also focus on inland transport, port-hinterland connections and integral door-to-door services. Competition no longer lies between ports, but between complex logistics networks which integrate ports, inland intermodal terminals, as well as logistics and distribution centers.

J. Maheut (✉) · C. Andrés
Reengineering Operations GroupWork Logistics Excellence (ROGLE), Universitat Politècnica de València, Camino de Vera S/N, 46022 Valencia, Spain
e-mail: juma2@upv.es

C. Andrés
e-mail: candres@omp.upv.es

S. Furió
Fundación Valenciaport, Calle Del Turró 0 S/N, 46024 Valencia, Spain
e-mail: SFurio@fundacion.valenciaport.com

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_18,

In Spain, many logistic nodal infrastructures have been road-oriented and planned from a regional or local point of view, which is not always aligned with the European and Spanish general transport policy where substantial efforts are being made to foster alternative and more efficient transport modes like rail.

The literature about hub location is extensive. An interesting review is proposed by Alumur and Kara (2008), Campbell (1994) and Gelareh and Nickel (2011). Nevertheless, to the best of our knowledge, an MILP model for designing intermodal terminals and seaports network which considers the non linear discount factor has not yet been proposed.

Section 18.2 introduces a brief problem description. Section 18.3 proposes the MILP model by considering non linear scale-reduced factors. Section 18.4 presents the results, and Sect. 18.5 proposes a conclusion.

18.2 Problem Definition

The network hub location problem has been vastly analyzed by presenting different formulations as well as heuristics proposals to solve it. Alumur and Kara (2008) provide a detailed review of the different approaches available in the literature. Single and multiple allocation problems, fixed costs of opening hub facilities, cost functions, discount factors and optimization methods have been studied. Hubs are facilities which bundle volumes and concentrate flows in order to reduce transport costs through economies of scale. In the literature, a discount factor is considered, but it is a fixed parameter. Given the origin/destination matrix of traffic flows in a many-to-many distribution system, the hub location problem deals with the hub facilities location and the demand nodes allocation to hubs in order to route the traffic flows between origin and destination pairs so that total costs are minimized. In the single allocation problem, each demand node is assigned to a unique hub so that all the incoming and outgoing traffic of this node is routed through this hub, while each demand node can be assigned to more than one hub in multiple allocation problems (Fig. 18.1).

This case study analyzes the specific problem, which presents the following particularities:

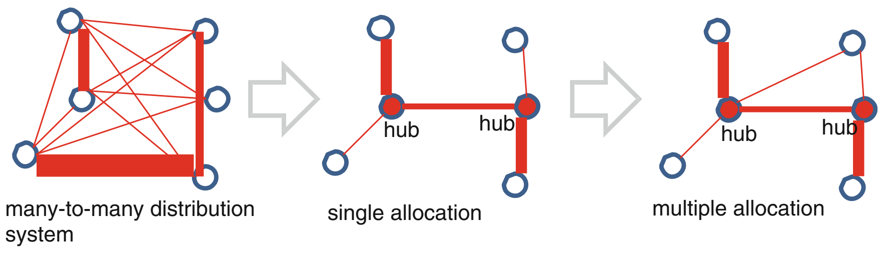


Fig. 18.1 The hub location problem

- The flow origin/destination matrix has been developed at the province (NUTS-3) level. A total of 47 Spanish provinces has been considered as freight flows origin/destination (Islands have not been considered in the study).
- Only container seaport-hinterland traffic flows from and to the four main Spanish container seaports (Valencia, Algeciras, Barcelona and Bilbao) have been considered.
- The provinces of the four main Spanish container seaports are already considered to be hub nodes.
- Any transport between hub nodes is done by rail (all hubs are connected to each other by rail), while truck transport is used to connect the rest of the nodes with their respective hubs.
- Transport costs are estimated.
- Fixed costs for opening hub facilities are not considered.
- Each province (demand node) can be assigned to a maximum number of hubs (multiple allocations).
- The objective of the model is to determine an additional hubs location, a hubs allocation, in order to minimize total costs.

18.3 MILP Model Formulation

The model described below is a mixed integer mathematical programming model. Because of the length constraint, all the constraints are not introduced. The omitted constraints are present in Ernst and Krishnamoorthy (1998).

Table 18.1 contains the notations for the sets and indices used for the formulation.

Table 18.2 contains the parameter notations.

Table 18.3 contains the variable notations.

The model can be formulated as shown below:

Minimise$[z]$

$$z = \sum_{i \in N} \sum_{j \in N} C_{ij} \cdot \sum_{p \in P} \left(Y_{pij} + Y_{jip}\right) + \sum_{p \in P} \sum_{i \in N} \alpha_{pi} \cdot C_{pi} \cdot \left(V_{pi} + V_{ip}\right) \tag{18.1}$$

Table 18.1 Sets and indices

N	Province set
P	Seaport set ($\subseteq N$)
$\prod$	Discount factor set
$p \in P$	Seaport index
$i, j, k \in N$	Province index
$r \in \prod$	Discount factor index

Table 18.2 Parameter notations

C_{ij}	Cost of transporting one container unit by truck from province i to province j
I_{pj}	Importation of total flow, whose origin is seaport p and destination is province j
E_{jp}	Exportation of total flow, whose origin is province j and destination is seaport p
$H^{\max}$	Maximum number of hubs desired
K_j	Maximum allocation number for province j
$O_p^P = \sum_{j \in N} I_{pj}$	Amount of containers whose origin is seaport p
$O_j^J = \sum_{p \in P} E_{jp}$	Amount of containers whose origin is province j
$D_p^P = \sum_{j \in N} E_{jp}$	Amount of containers whose destination is seaport p
$D_j^J = \sum_{p \in P} I_{pj}$	Amount of containers whose destination is province j
$A_r \in [0,1]$	Discount factor for reduction r
$\overline{M} \geq 1 + \sum_{p \in P} \sum_{j \in N} \left(I_{pj} + E_{jp}\right)$	A sufficiently positive large number
$\Delta_r^{I+}/\Delta_r^{I-}$	Maximum/Minimum flow of importation containers that consider reduction r
$\Delta_r^{E+}/\Delta_r^{E-}$	Maximum/Minimum flow of exportation containers that consider reduction r

Table 18.3 Variable notation

Z_{ij}	1 if province j is allocated to province i (0 otherwise)
Y_{kij}	Fraction of the container flow from province k to province j which is routed via the hubs in province i
V_{ij}	Fraction of the container flow from province i to province j
ϕ_{rpi}	1 if reduction r is applied between seaport p and province i (0 otherwise)
$\alpha_{pi} = f\left(V_{pi} + V_{ip}\right)$	Discount factor applied between seaport p and province i. It is volume-dependent

$$z = \sum_{i \in N} \sum_{j \in N} C_{ij} \sum_{p \in P} \left(Y_{pij} + Y_{jip}\right) + \sum_{p \in P} \sum_{i \in N} C_{pi} \sum_{r \in \Pi} A_{rpi} \cdot \phi_{rpi} \cdot \left(\Delta_r^{E+} + \Delta_r^{I+}\right)/2 \tag{18.2}$$

Subject to:

$$\sum_{r \in \prod} \phi_{rpi} \leq 1 \quad \forall p \in P, i \in N \tag{18.3}$$

$$\sum_{r \in \prod} \phi_{rpi} \leq Z_{ii} \quad \forall p \in P, i \in N \tag{18.4}$$

$$V_{pi} - \overline{M} \cdot \phi_{rpi} \leq -\overline{M} + \Delta_r^{I+} \quad \forall r \in \Pi, p \in P, i \in N \tag{18.5}$$

$$V_{pi} - \overline{M} \cdot \phi_{rpi} \geq -\overline{M} + \Delta_r^{I-} \quad \forall r \in \Pi, p \in P, i \in N \tag{18.6}$$

$$V_{pi} - \overline{M} \cdot \phi_{rpi} \leq -\overline{M} + \Delta_r^{E+} \quad \forall r \in \Pi, p \in P, i \in N \tag{18.7}$$

$$V_{pi} - \overline{M} \cdot \phi_{rpi} \geq -\overline{M} + \Delta_r^{E-} \quad \forall r \in \Pi, p \in P, i \in N \tag{18.8}$$

$$\phi_{rpi} \in \{0, 1\} \quad \forall r \in \Pi, p \in P, i \in N \tag{18.9}$$

Objective (18.1) consists in minimizing total transport cost, which include the sum of transport costs by road and transport costs by railway between each province and seaport. The discount factor is flow volume-dependent (it depends on the traffic between provinces), so it is variable and Objective (18.1) is non linear.

As Objective (18.1) is non linear, an alternative linear form is proposed in (18.2). This objective function has been linearized using the Special Set Orders 1 variables. In this case, transport costs are penalized in accordance with the superior limit of the flow range values.

Equation (18.3) forced the model to consider just one discount factor, which is active between seaport p and province i.

Equation (18.4) implies considering one discount factor between seaport p and province i. if i is a hub.

Constraints (18.5)–(18.8) force the container flow value between seaport p and province i to be inferior and superior to the limits for flow value when a discount factor r is active.

Equation (18.9) defines the domains of the considered variables.

18.4 Results

18.4.1 Considered Scenarios

Different scenarios have been developed for the analysis when considering different:

- Discount factors for railway transport
- Intra-province road transport cost estimation at hubs
- Maximum number of hubs
- Maximum number of allocations.

18.4.2 Experimental Results

The following figure presents some results obtained when solving the problem for the different scenarios. As observed, the total transport cost of the optimal solution, the selected inland hub nodes for this solution, a visual illustration of the transport flows between nodes, nodes allocation to hubs, are used to evaluate the solution (Fig. 18.2).

The results analysis allows us to identify key inland hub nodes, such as Alicante, Madrid and Zaragoza, in almost all the scenarios for the optimal solution. It can be observed than when intra-province road transport costs increase, hub nodes like Madrid or Zaragoza shift to alternative locations in the surrounding provinces or nodes, such as Guadalajara or Huesca, respectively (for example, see Scenarios 13, 14 and 15). This is due to the fact that an increase in intra-province road transport costs can make this even bigger than an alternative road transport from/to a neighboring province. This effect can be compared to the effect of including additional costs relating to the establishment of hubs in places like Madrid due to high land and real-estate prices.

Other additional hubs which appear as part of the solution in some of the scenarios are Seville and Castellón, and León but to a lesser extent. The Castellón hub appears in the optimal solution in the scenarios where savings through railway transport are significant. This is because of its intense traffic with the Port of Valencia hub, but Castellón does not really act as a hub and no other nodes are allocated to the Castellón hub.

	scenario nº 13	scenario nº 14	scenario nº 15
total transport cost	436.897.683,00	38228817260	432.951.562,60
selected inland hubs	N3 (Alicante)	N19 (Guadalajara)	N3 (Alicante)
	N19 (Guadalajara)	N22 (Huesca)	N14 (Córdoba)
	N22 (Huesca)	N24 (León)	N19 (Guadalajara)
	N24 (León)	N30 (Murcia)	N22 (Huesca)

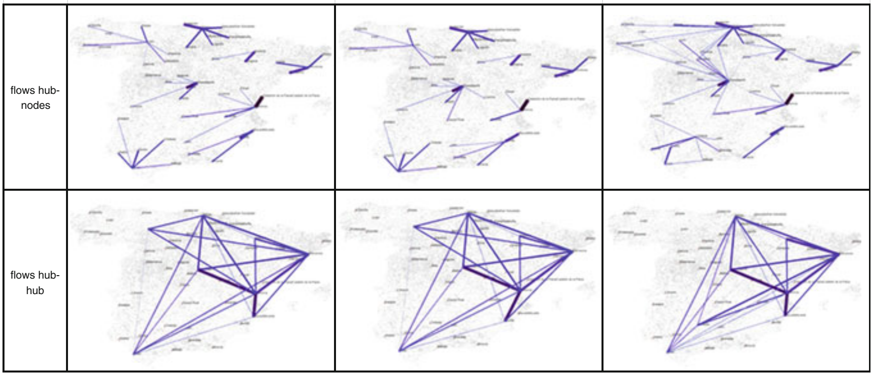


Fig. 18.2 Optimal solution for the different scenarios

Finally, and as expected, we observe that better results are obtained with the multiple allocation problem (that is, total transport costs are reduced). Nonetheless, there are no significant changes in the identification or selection of the inland hubs between the single allocation and the multiple allocation (double allocation in this case) scenarios.

18.5 Conclusion

As a general conclusion of this research work, a new MILP model formulation is proposed in this paper that considers different discount factors which are volume-dependent. Moreover, it can be stated that the application of this MILP model to different scenarios and the analysis of the results can prove most useful for policy makers and for logistic and transport operators to design and plan an efficient intermodal network that connects ports with its hinterland. As observed, this kind of analysis with a scientific approach provides interesting inputs to make strategic decisions at the infrastructure planning level, which are also very sensible from the territorial, social and political points of view.

Further research has been identified throughout this work, as follows: (1) designing specific heuristics for the problem considered herein; (2) solving the problem in a distributed manner; and (3) incorporating variants such as uncertainty (it may be stochastic or uses fuzzy methods) is another future research line.

Acknowledgments The work described in this paper has been partially supported by the Spanish Ministry of Science and Innovation within the Program “Proyectos de Investigación Fundamental No Orientada through the project “CORSARI MAGIC DPI2010-18243” and through the project” Programacion de produccion en cadenas de suministro sincronizada multietapa con ensamblajes/desemsamblajes con renovacion constante de productos en un contexto de inovacion “DPI2011-27633”. Julien Maheut holds a VALi+d grant funded by the Generalitat Valenciana (Regional Valencian Government, Spain) (Ref. ACIF/2010/222).

References

Alumur S, Kara BY (2008) Network hub location problems: the state of the art. Eur J Oper Res 190:1–21

Campbell JF (1994) Integer programming formulations of discrete hub location problems. Eur J Oper Res 72:387–405

Ernst AT, Krishnamoorthy M (1998) Exact and heuristic algorithms for the uncapacitated multiple allocation p-hub median problem. Eur J Oper Res 104:100–112

Gelareh S, Nickel S (2011) Hub location problems in transportation networks. Transp Res Part E: Logistics Transp Rev

Chapter 19
Modeling of Integrated Management System of Sugar Cane: Taking Advantage of Sugarcane Agriculture Residues

Maritza Correa Valencia, Gloria Mercedes López Orozco and Adriana Carolina Lozano Riascos

19.1 Introduction

Several countries have vast extensions of land used to grow sugar cane. In Colombia, the Cauca Valley region is known for being the first sugar cane producer, generating between 50 and 150 t/ha of residual biomass (leaves, hearts, sprouts and strains) for institutions engaged in research of bio-fuels is considered a raw mate- rial for bio-ethanol production. This is one reason why it's a priority designing a logistics system for collecting sugarcane agriculture residues (SAR) adjusted to local conditions and contribute to lower the high costs associated with their use.

This paper presents the stages that make up the supply chain of sugar cane using IDEF0, in its current state and future, in order to visualize the provision of SAR as an opportunity for product diversification through its collection in enterprise system, in this case the sugar mill.

The paper is organized in five sections. First section provides an introduction to the problem, second part shows the IDEF0 methodology, and characterize the processes involved in the generation and production of sugar cane, the third section develops the model of sugar cane management from the perspective of IDEF0, fourth is the proposed SAR recovery by leveraging existing resources in the system. Finally, the conclusions are presented.

M. Correa Valencia (✉) · G. M. López Orozco · A. C. Lozano Riascos
Grupo de Investigación en Competitividad y Productividad Empresarial (GICPE).
Facultad de Ingenieria, Universidad Autonoma de Occidente,
C/25 No. 115-85, Cali, Colombia
e-mail: mcorrea@uao.edu.co

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_19,

19.2 IDEF0 Methodology

For the representation of the activities involved in managing of sugar cane methodology was used Integration Definition for Function Modeling, commonly known as IDEF0, whose purpose is to provide simple and formal modeling techniques. Create, analyze and evaluate various systems, through the representation of hierarchically ordered diagrams, represented by boxes and arrows linking model elements in a clear and precise way (Kim and Jang 2002).

The elements used to establish the interactions between processes, are called ICOM. Figure 19.1 shows the proposed systemic approach of IDEF0 based on the inputs which are defined as those elements that activate the system, and are transformed by the process, in order to produce the outputs, controls, principles that regulate the way in which processes are active to produce the outputs, the mechanisms, defined as the resources the process needs and uses, generally consumed during the same transformation, and outputs, which are the result of the transformation and the articulation of the other three elements.

19.2.1 Characterization of Processes

For the model development we began with the characterization of the processes that are involved in the sugar production, based on information obtained during field visits to sugar mill test and the relevant literature of the topics (i.e., Viveros and Calderón 1995; Torres 2006; Nova, 2010; Amu 2010, 2011). This research provided the basis for mapping the integral production system of sugar through the IDEF0 methodology.

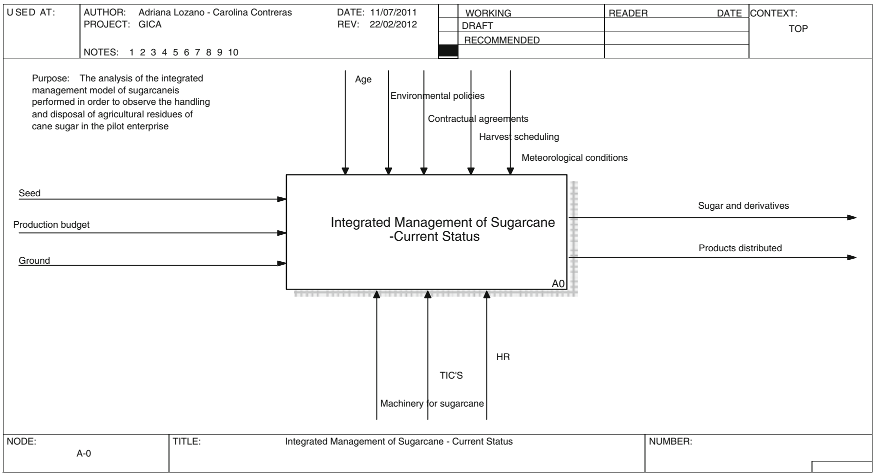


Fig. 19.1 Integrated management of sugarcane

Through a holistic view, we identified the starting point of the generation and disposal of SAR as a raw material usable in the context of product diversification and environmental responsibility of the sugar mills. To build the model we identified four stages:

1. *Processes classification*: In this phase the activities of sugar cane were characterized, are grouped in three essential sub-processes (field, harvest and production) according to the affinity of its objectives.
2. *Description and classification ICOM items*: During the development of the characterization of the processes involved in sugar production, 106 elements were identified between variables, initial conditions, restrictions, data and parameters, which through brainstorming and a dynamic configuration in association with reference sugar mill managers were grouped in only 47 considered the most important: 19 inputs, 16 outputs, 9 control and 3 mechanisms, used in modeling.
3. *Modeling*: When you have classified the processes and ICOM elements, the sequence structure and relevance of each of these, software BPW in ®-Beta was used. The IDEF0 model of the macro-process Integrated Management Sugar Cane—A_0 in its current state is represented in Fig. 19.1.
4. *Validation*: Finally, model was evaluated and approved by experts of reference sugar mill.

19.3 Integrated Management Model of Sugarcane

The processes involved in the supply chain of sugar cane are grouped into three stages of management, because in each of these, operations are where you should plan, organize, manage and control all types of resources, looking for the efficiency of operations. Classification stages were performed according to the affinity of its objectives:

Field Management: sub-processes are controlled growing conditions and generation of high quality sugar cane. *Harvest Management*: activities take place to comply with supply of sugar cane to the sugar mills, and, *Production Management*: carried out activities and operations for generating of sugar and derivatives.

This proposal has been called “Integrated Management of Sugar Cane—GICA” (for its acronym in Spanish) which integrates the stages of field management, harvest and production, providing a new way to identify and recognize the processes composes.

19.3.1 GICA Processes

In Fig. 19.2, the sequence of sub-processes is structured what makes the GICA macro process, where it’s shown the disaggregation of A0 model in its first

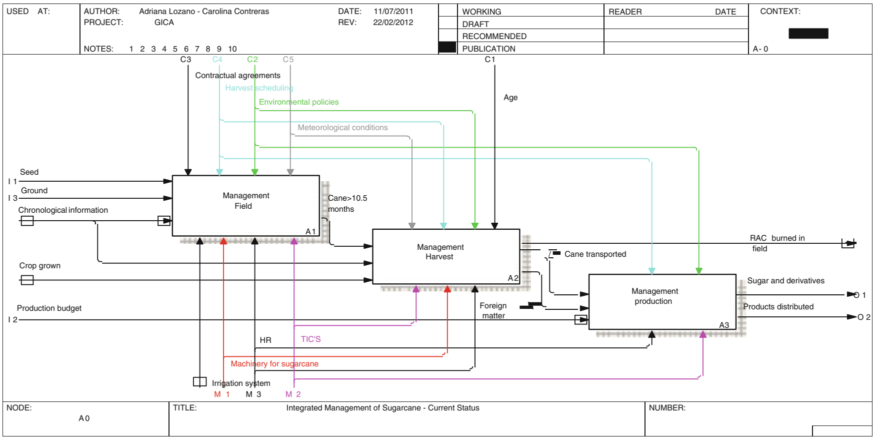


Fig. 19.2 GICA disaggregation (A_1)

hierarchical level A_1. From close observation focused on the interaction between harvest management and production management appears SAR as product that combines these two stages. 80 % of his material is burned in field and 20 % are admitted to production management as strange material.

To go further in functionality of harvest management process, which pro- duces among others SAR, was a second hierarchical level analysis of depth A_2, see Fig. 19.3, here are four sequential steps: (1) *pre-harvest and maturation*, where is planned and defined harvest type to be developed (mechanical or manual) as well as harvest scheduling sub-area for harvest sugar cane; (2) *Cut*, performance operation of previous programming. The products coming out of this stage are

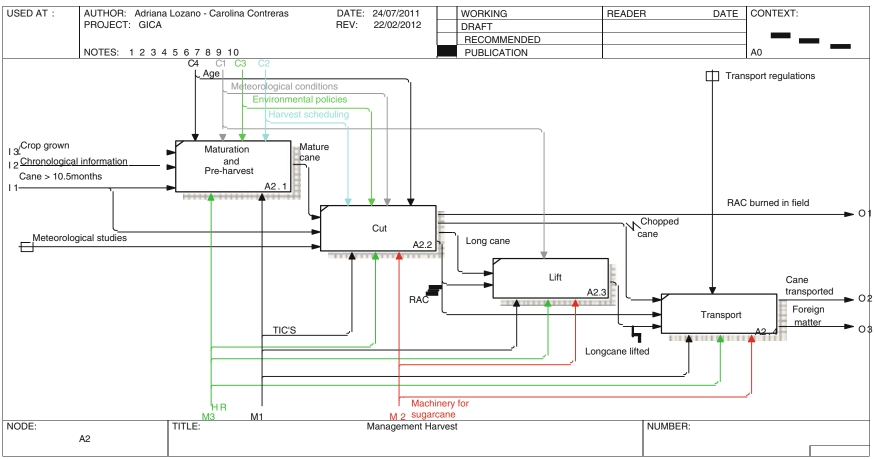


Fig. 19.3 Disaggregation harvest management. Current status (A_2)

chopped cane (mechanical) or long (manual) and SAR, that are buried or burned to ensure good germination of the strain and weed control, wasting the potential to generate new products; (3) *Lift*, operation where cane cutters organized in packages to increase the efficiency collection of lifters machine at cane wagons; and (4) *Cane transportation*, laden wagons move to chaining operation, which are clustered and hooked 3 or 4 wagons to a sugarcane train to move to the cane patios in the reference sugar mill.

19.4 Proposal for SAR Recovery

In order to facilitate the process of collecting SAR proposes to modify the stage of harvest management based on a technological alternative collection SAR, that makes it economically feasible and meets two elements of assessment.

On the one hand, to options of collection selected by importance level according to the literature reviewed (Marchi et al. 2005; Azevedo and Da Silva 1996; Ripoli 2010; Michelazzo and Braunbeck 2008) these are: baling, integral harvest, waste chopper and harvest machine adapted; and on the other hand, at four critical variables of GICA system identified as: land conditions, SAR density, foreign material and SAR disposed, obtained through a matrix of causality versus dependence (see Fig. 19.4, quadrant III) from the valuation of causality between elements (Table 19.1).

For the selection of critical variables, it performs the division of the quadrants based on the data in Table 19.1 and the calculation of mathematical expectation. The elements are located in the corresponding area. The quadrants are divided in I: In- put variables (high mobility and low dependency), II: Link variables (high mobility and high dependency), III: Outcomes measure (Low mobility and high depend- ency) and IV: minor problems (low mobility and low dependency). The variables used to define the collection system are contained in quadrant III, because to solve these elements reduces the impact of the other quadrants.

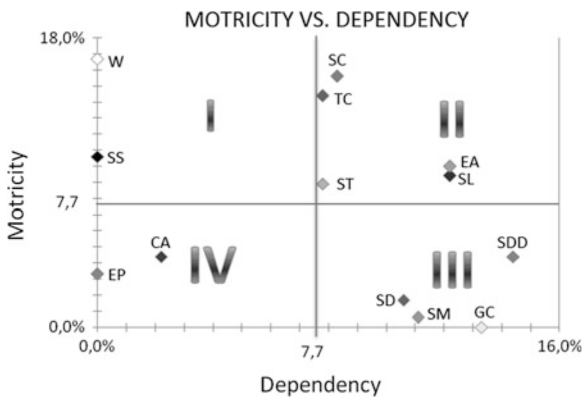


Fig. 19.4 Motricity versus dependency matrix

Table 19.1 Valuation of causality between elements

CAUSALITY \ DEPENDENCY	SS	TC	SC	SL	SDD	W	SD	EA	SM	EP	ST	GC	CA	T. Sum	% P
◆Size sub-area harvest cane (SS)		4	2	5	3	0	0	4	1	0	0	0	0	19	10.6
◆Type of cut (TC)	0		0	5	5	0	4	3	2	0	3	4	0	26	14.4
◆State of cane(SC)	0	0		5	5	0	3	5	3	0	4	3	0	28	15.6
◆SAR in land (SL)	0	0	0		5	0	0	4	0	0	3	5	0	17	9.4
◆SAR disposed (SDD)	0	0	0	4		0	0	0	0	0	0	4	0	8	4.4
◇Weather (W)	0	5	4	0	0		3	3	4	0	4	3	4	30	16.7
◆SAR density (SD)	0	0	0	0	3	0		0	0	0	0	0	0	3	1.7
◆Efficiency of alternative (EA)	0	0	0	3	5	0	5		5	0	0	0	0	18	10.0
◆Strange material (SM)	0	0	0	0	0	0	0	1		0	0	0	0	1	0.6
◆Environmental policies (EP)	0	1	5	0	0	0	0	0	0		0	0	0	6	3.3
◆SAR tenure in land (ST)	0	0	0	0	0	0	4	2	5	0		5	0	16	8.9
◆Growing conditions (GC)	0	0	0	0	0	0	0	0	0	0	0		0	0	0.0
◆Contractual agreements (CA)	0	4	4	0	0	0	0	0	0	0	0	0		8	4.4
Total sum	0	14	15	22	26	0	19	22	20	0	14	24	4	180	
Participation Rate (%)	0.0	7.8	8.3	12.2	14.4	0.0	10.6	12.2	11.1	0.0	7.8	13.3	2.2		

The positive impact on land conditions with integral harvest machine because it allows a controlled leave in the field for 50 % of waste to contribute to the contribution of organic matter, as suggested by Scala 2007. In the case of the baler and chopper this percentage is very low, whereas with harvest machine adapted its percentage tends to zero. Ripoli and Ripoli (2010), indicates that the system of integrated harvest yields a low percentage of foreign matter from the SAR compared with other systems, in addition to the effective performance of harvest machine and its effect on the charge density, which varies from 466 to 333 kg/m^3.

Michelazzo and Braunbeck (2008), claim that SAR transportation costs to factory with integral harvest machine have less variation in costs at different distances, which does not happen with other systems, evaluated, because it is influenced by the distances that increase its handling costs, caused by the low density or by increasing number of wagons required.

For these reasons, model of logistics system of SAR collection will be based on the integral harvest system, using a dry cleaning center for residue separation. Model of proposal of operational process of SAR collection in parallel to harvest cane, when it's carried out mechanically, is shown in Fig. 19.5.

From analysis proposed model of harvest management can be set to reduce operations in the crop and labor by removing activities like cut the leaves of sugar cane and separate roadside or residue burning, at harvest reduces the number of machines by leveraging the current harvesting system that collects parallel cane

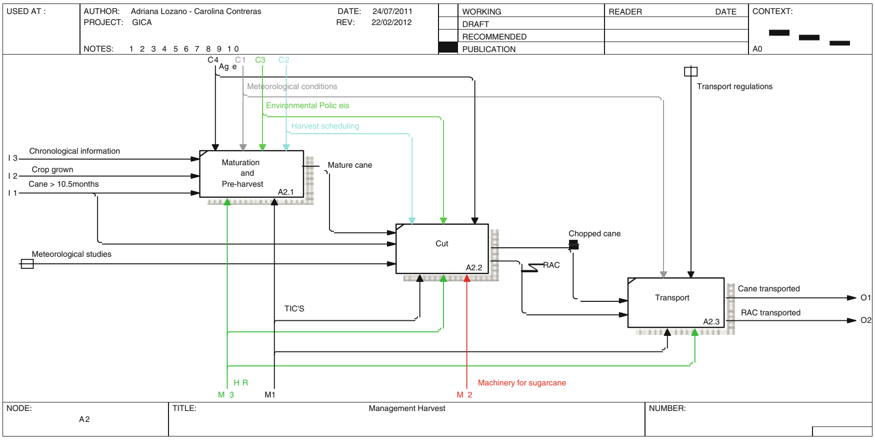


Fig. 19.5 Disaggregation harvest management. Future status (A_2)

and SAR products, also reduces land compaction, which results in better conditions for growing sugar cane.

19.5 Conclusions

Proposed methodology for current system analysis identified critical elements, selecting the technological alternatives appropriate to geographical and environmental conditions in the interest area, in this case for location of reference sugar mill. Also, modeling techniques use IDEF0 related, make visible hierarchically the set of processes and activities, consumed resources and relationship between elements that integrated management of sugar cane of a Colombian reference sugar mill.

The reference sugar mill currently considers two stages: agricultural, where the sugar cane is seen as the only usable product; and industrial, the one where products originate as sugars and derivatives. This perception is revalued to determine the SAR collection as a simultaneous operation to harvest cane, without adding complexity to the current system, or afford the current economic structure. Taking advantage of the SAR is not a fundamental feature of the business system (reference sugar mill), so it is proposed that it becomes a second product of the agricultural stage.

The emptiness expressed by the flow of materials in the supply chain reference sugar mill corresponds to the conventional structure of enterprises and their supply chains in the decades 60 and 70, where wasn't recognized the importance of the use of residues, and processes recovery were focused exclusively on the recovery of finished products and packaging. The approach presented in this paper offers a different view and current of the logistics chain for the companies of sugar industry in Colombia, including the waste recovery operations and business potential for the expansion of product portfolio, principle worked in chains supply of great food industry in the world.

Acknowledgments Grateful to GRUBIOC research group headed by Luz Marina Flores Pardo Ph.D, and to the engineer Carolina Contreras who was part of this work (Contreras, 2011).

References

Aguilar A, Hernández B, Oliva D (2007) Solución medioambiental sustentable en la cosecha de caña. Informe científico de ICINAZ, MINAZ, CUJAE, Cuba

Amú LG (2011) Tipos de cosecha en el ingenio piloto [grabación]. Cali 2011. 3 notas de voz, (2 minutos 18 segundos), Cali, Colombia

Amú LG (2010) Logística de Cosecha: Evaluación de Tiempos y Movimientos. Indicadores y Control Tecnicaña 26:25–30

Azevedo R, Da Silva JE (1996) Colheita de Cana e Recolhimento de Palha. Brazil

Contreras C, Lozano A (2011) Diseño de un sistema piloto logístico de recolección de RAC en un ingenio del Valle del Cauca. Cali, Universidad Autónoma de Occidente, Colombia

Kim SH, Jang KJ (2002) Designing performance analysis and IDEF0 for enterprise modelling in BPR. Int J Prod Econ 76:121–133

Marchi AS et al (2005) Unburned cane harvesting with trash recovery routes. Available in: Centro de Tecnología Canavieira-Piracaiba: PNUD-CTC

Michelazzo MB, Braunbeck OA (2008) Análise de seis sistemas de recolhimiento do palhiço na colheita mecânica da cana-de-açúcar. Revista Brasileira de Engenharia Agrícola e Ambiental 12:546–552

Nova J (2010) Siembra mecanizada de la caña de azúcar en Brasil. Tecnicaña 13(22):32–36

Ripoli TCC, Ripoli MLC (2010) Aspectos económicos, logísticos y energéticos en el aprovechamiento del RAC en calderas. Universidade de São Paulo, Brazil

Scala cited by Pacheco S (2011) Available via CORREIO BRAZILIENSE. http://www.correiobraziliense.com.br. Cited 8 Jun 2011

Viveros CA, Calderón H (1995) El cultivo de la caña en la zona azucarera de Colombia. Cenicaña 131–139

Torres JS, Villegas F (2006) Sistemas de manejo de residuos y efectos en la producción. Cenicaña 35:14

Chapter 20
An Overnight Parcel Logistics Company's Capillary Distribution Network Design by Regression Analysis

Oscar Rioja San Martín and Joaquim Lloveras Maciá

20.1 Introduction

One of the main factors that affect an OPLC is the randomness of the goods it has to distribute. This randomness has a large effect on all sections of an OPLC, but the greatest is on the capillary distribution network. The OPLC's managers need to design a capillary distribution network that is capable of collecting all the merchandise that their clients wish to deliver, and, at the same time, this capillary distribution network must have the capacity to distribute all the shipments to their respective destination.

To design this network, the most powerful tool the managers have is reliable and accurate information about the nature of the goods needed to be collected and delivered, and consequently, about the randomness of the merchandise. This information can be obtained through a model. For an external observer, a model of a system is an object that the observer can use to answer any question about the system he is interested in Minsky (1965). So, once a model is created, it can be used to represent the behaviour of the real system.

In the design of a capillary distribution network, the information that is needed to create the most profitable network is the number of deliveries and collections for each area, and the weight of the different deliveries and collections. From the number of deliveries and collections, a manager will know the number of vehicles he needs for each area, and depending on the weight of the collections and the deliveries, the type of vehicles that are needed.

These two variables are fundamental for another critical aspect of the OPLC; the delivery and collection cost. In parcel logistics companies these costs are as follows: the parcel logistics company pays a specific amount to the vehicle in charge of the collection, one part of which is due to pick up the shipment, the other which depends on the weight of the shipment. The delivery cost is analogous; each

O. Rioja San Martín (✉) · J. Lloveras Maciá
Technological University of California, Barcelona, Spain
e-mail: errioxa007@hotmail.com

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_20,

delivery costs the parcel logistics company a specific amount which is divided into two parts; a fixed amount for serving the shipment, and another one based on the weight of the shipment.

For the design of a capillary distribution network it is important to consider that the delivery and collection costs for the OPLC are the income of the drivers of the network. Due to the particularity of the delivery cost (and collection cost: they are analogous), the relationship between the cost and the number of deliveries and their weight cannot be predicted exactly. The model created to predict the behaviour of these costs has to be able to deal with their specific characteristics of uncertainty. Because of the uncertainty and random components, a stochastic model is required (Guasch et al. 2002).

In the literature related to logistics companies, regardless of the nature of the goods they distribute or the delivery time they offer to their clients, most of the models are created by deterministic methods. Mostly, all the aspects of logistics companies have been modelled by deterministic models, e.g., numbers of vehicles, route selection, numbers of hubs and their locations and truck loading times and flows (cross docking).

Stochastic methods have not been used extensively in researches related to logistics companies. In most cases, these stochastic models have been used as a complement of the deterministic models, adding certain stochastic characteristics. An example of this is the Vehicle Routing Problem (VRP), which was renamed the Stochastic Vehicle Routing Problem (SVRP) when certain stochastic parameters were included. VRP models are based on a number of locations to be visited, and certain characteristics, such as the weight of the deliveries and the collections, are known. However, it is more common that these characteristics are not previously known. Parameters such as costumer demand, the travel time between clients, and even locations to visit are stochastic in nature. For this reason, the VRP models were renamed as SVRP—the stochastic vehicle routing problem. The stochastic part of SVRP models are based on Markovian stochastic processes (Gendreau and Segini 1996).

Other investigations, however, assign vehicles to certain distribution areas instead of working with a determined route of clients and visits for every vehicle. These researches are focused on the familiarity of the distribution vehicle drivers with their distribution area. Here, the productivity of the distribution vehicles is analysed when the familiarity of a driver with its distribution area increases. With increased familiarity, driver performance improves due to ease in finding addresses and locations, and efficiency in organising daily routes. In this way, their ability to make deliveries and collections increases, and therefore, their productivity (Zhong et al. 2004).

This line of investigation will be followed in this paper. The distribution network will be divided into distribution areas based on the drivers' income in each area, instead of assigning a determined number of clients or a determined route. These distribution areas will be based on postcodes and the drivers' income in each area will be predicted. If this income is not high enough, a driver can have more than one postcode. If the income is too high, more than one vehicle can share the same postcode.

The aim of assigning each vehicle to specific postcode areas is to guarantee a minimum income, thus to ensure the continuity, of its driver, because this continuity maximises driver familiarity within their distribution area. With increased familiarity, driver performance improves due to ease in finding addresses and locations as well as efficiency in organising daily routes. Their capacity to make deliveries and collections increases, and therefore, so does their productivity. The way the drivers' incomes model of each distribution areas is obtained is by regression analysis. The regression analysis is the most used technique nowadays and because of its multiple uses, regression applications are numerous and there are in almost any field (Montgomery et al. 2002). In the reviewed literature, cases of capillary distribution networks modelled by regression analysis have not been found. This research will demonstrate that regression analysis is a valid technique to develop a model which helps a parcel logistics company's manager in the decision making related to the distribution costs of the capillary network, and therefore, in predicting the incomes of the various vehicle drivers.

20.2 Case Study

The case study for this research is a hub of an OPLC located in Barberá del Vallés, in the metropolitan area of Barcelona, Spain. This hub has several towns within its influence zone, and in this paper, one town called Sant Cugat del Vallés, composed of seven postcodes, will be studied. Sant Cugat del Vallés is located 11.3 km from the OPLC's hub, and they are connected by the A-7 highway. The vehicle income of each one of these postcodes will be predicted to analyze if a vehicle can be assigned to each one.

The vehicles that work in this particular OPLC are in a production regime. Each OPLC has its distribution vehicles in the regime most beneficial for the company, but in most cases a production regime is selected: the more deliveries and collections they make, the more they earn. The vehicle drivers do not have fixed incomes and their incomes depend on the number of deliveries and collections they do.

The income of each delivery and collection is tabulated in different strata based on its weight. A fixed price is assigned to the drivers of the vehicles due to the delivery of each shipment or each collection done. Another variable price is added to the fixed one depending on the weight of each shipment they deliver or collect. Both, the fixed and variable part, depend on the weight of every delivered shipment or collection. The income for a delivery does not have to be the same as for a collection, and the variation among the prices of the different strata does not have to be linear. Every OPLC regulates these prices in the way it believes best suits its interests.

20.3 Methodology

As explained in the introduction, the distribution vehicles' incomes per postcode area will be modelled by regression analysis. Regression analysis is a statistical methodology that uses a relationship between two or more quantitative variables, in such a way that a response or output variable is related to one or more of these quantitative variables (Kutner et al. 2004). So, in order to perform a regression analysis, first it is necessary to know which output variable will be modelled, i.e., which is the endogenous variable. Secondly; which other variables are related with the one to be modelled, i.e., which are the exogenous variables. And finally, it is necessary to know the relationship between the endogenous variable and the exogenous variables: how the endogenous variable can be estimated by the exogenous ones.

20.3.1 Variable Identification

The income of one vehicle per postcode area can be divided into the delivery income and collection income. Therefore, one model will be developed to estimate the delivery income, and a different model will be developed to estimate the collection income; these incomes being the endogenous variable of their respective models. The delivery income will be estimated by the number of deliveries per day and the total delivered weight per day, considered as the exogenous variables. In the regression analysis these two variables will be raised to the second power; four endogenous variables in total. The collection income is analogous: the number of collections per day and the total collected weight per day, *and* these variables raised to the second power, are the exogenous variables. As the exogenous variables are expressed per day, the delivery and collection income will also be estimated per day.

Once all the variables that are related with the distribution incomes have been identified, the next step is the sampling of them. Data collection is one of the most laborious stages in a model construction, yet it is of utmost importance for achieving an efficient model. Any model is only as good as the data on which it is based (Vincent 1998). For this research, the sampling will be an observational study, where the system is not affected by the sampling, obtaining all the data from the OPLC database. For each one of the six variables, endogenous and exogenous, 84 days of data will be obtained, providing 84 observations per variable in each one of the postcode areas that are to be analysed. Afterwards, the independence of the 84 observations of each one of the variables has to be checked to ensure that there is not any correlation between them. To do this, two heuristic tests will be undertaken: correlation graphs and dispersion diagrams (Guasch et al. 2002).

Once the independence of the observations of each variable is checked, the observations of each variable will be divided into two groups. The first, called the calibration sample, will be used for the regression analysis and to create the model which will estimate the delivery and collection costs. The second group, the prediction sample, will be used to check the validity and the prediction capacity of the model (Snee 1997). This separation will be done by random assignment.

20.3.2 Regression Model Elaboration

When the endogenous and exogenous variables have been identified and their sampling has been completed and checked, the next step is to analyze the relationship between the endogenous variable and the exogenous variables: the regression model has to be elaborated or adjusted. For that, the regression parameters for each one of the endogenous variables have to be calculated. The regression model adjustment will be developed by maximum likelihood. The maximum likelihood method is an interactive procedure. With this method, assertions or statements about the unknown parameters θ of a probability distribution or a function can be made from the observed data of a sample (Hocking 2003). For a sample composed of independent observations y_i the equation that defines maximum likelihood is:

$$L(\theta) = f(y; \theta) = \prod_{j=1}^{n} f(y_i; \theta) \tag{20.1}$$

This expression is known as the maximum likelihood function. The assumption that f is known except for the uncertainty of θ, reduces the problem of making assertions about the plausible values of θ, since y_i values are given (Davison 2003). The maximum likelihood function quantifies the possibility that θ generates the observed sample values. The higher the value of the maximum likelihood, the more likely that θ generates the observed sample values. In the case of regression analysis, the θ parameters will be the unknown regression parameters of each of the exogenous variables. Using a spreadsheet, the value of the regression parameters that maximize the maximum likelihood function value will be determined.

The main advantage of the use of this iterative procedure is that without very complicated modifications it enables the adjustment of the regression models with different characteristics. For example, the least squares method assumes that the residuals are distributed according to a normal probability distribution function. Using the maximum likelihood method, you can adjust the model under this assumption, but it also allows you to adjust it assuming that residuals are distributed with any other probability distribution functions. It is possible to check if these models with residuals distributed with non-normal probability distributions increase the accuracy of the regression analysis or not, by comparing the maximum likelihood values. Using maximum likelihood, the model can also be adjusted under the principles of generalised linear models and compared with the adjusted models previously carried out, thus checking if a non-linear regression analysis better fits the data than a linear one, by comparing again the maximum likelihood values.

For this research, three types of regression models will be compared, which have been adjusted under these three different assumptions:

- Ordinary least squares.
- The regression analysis residuals' probability distribution function is double exponential or logistic.
- Under the criterion of generalized linear models.

20.3.3 Model Selection

Once the procedure with which the regression model will be developed is known, and before carrying it out, it is necessary to consider the procedure that will determine which exogenous variables really influence the behaviour of the endogenous variable in a substantial way. That is, the model has to respect the parsimony principle: the best model is the simplest one that explains the observed facts (Navidi 2006).

The maximum likelihood method offers the possibility of determining to what extent the addition of a new variable to the model provides a better fit to the data, using the likelihood ratio test. The likelihood ratio test will determine whether or not the inclusion of certain variables increases the accuracy of the regression analysis when adjusting the model. This test compares the maximum likelihood value obtained with $k + 1$ variables with that obtained for k variables, and if the difference is not higher than a freedom degree of a X^2 probability distribution function for the selected significance level, the new $k + 1$ variable will not be included in the model.

In short, the maximum likelihood method has been chosen for its flexibility in adjusting the regression models under different assumptions and the ability to compare them by observing the maximum likelihood values. The maximum likelihood method also shows whether adding new variables to the model provides a better fit to the data, to fulfil the parsimony principle.

20.3.4 Model Validation

After the adjustment of the different models and identifying which one fits better to the data, the next stage in the development of the model is its validation. For this, the data from the prediction sample will be used instead of the data from the calibration sample, which was used for the adjustment. The objective of model validation is to verify that the model meets the requirements according to objective and subjective criteria under which it was conceived (Johansson 1993).

The validation procedure consists of introducing the exogenous variable data from the prediction sample into the model, and comparing the outputs provided by it with the correspondent endogenous variable data of the prediction sample. As the observations of the prediction sample are independent, classical statistical methods can be applied. For this research, Welch test or paired-t test will be used (Law and Kelton 1991).

20.4 Conclusions

In this research the hypotheses made in the introduction of this work have been solved successfully: regression analysis is a valid technique to help a parcel logistics company in the decision making related to the distribution costs of the capillary network, and therefore, in predicting the incomes of the different vehicle drivers. The delivery and collection incomes of seven postcode areas have been correctly modelled, and it is possible to ascertain if each one of these postcode areas can be assigned to a vehicle, or on the contrary, more than one postcode should be assigned to a vehicle to guarantee a minimum income for the vehicle driver. To estimate these incomes the number of deliveries and collections per day and the total delivered and collected weight per day needs to be known.

For the cases studied in this research, the linear regression models have had better results than the non-linear ones. The models elaborated under the assumption of the ordinary least square and the residuals distributed by double exponential and logistic probability distribution functions have had better results than the ones elaborated under the assumption of the exogenous variables' transformation. The first models have provided a better fit to the data of the samples, their maximum likelihood values being higher than the ones of the models made under the generalized linear models criteria.

Of the seven delivery income models created, four models adjusted under the assumption of the ordinary least square have obtained the highest maximum likelihood values. For the other three models, the highest maximum likelihood values were obtained under the assumption that the residuals are distributed according to a logistic distribution function. In the case of the collection income models, five out of seven models adjusted under the assumption of the ordinary least square provided the highest maximum likelihood values. Of the other two, one was adjusted supposing that the residuals are distributed according to a logistic distribution function, and the other, according to a double exponential probability distribution function. In the cases where the models have been adjusted under the supposition of the ordinary least square and the maximum likelihood value has not been the highest, it has been proved that these ordinary least square models can still successfully predict the delivery or collection income. So, the ordinary least squares method has been proved as an appropriate regression technique to create the models with which the distribution costs can be estimated.

References

Davison AC (2003) Statistical models. Cambridge University Press, Cambridge
Guasch A, Piera MA, Casanovas J, Figueras J (2002) Modelado y simulación: Aplicación a procesos logísticos de fabricación y servicios. Edicions UPC, Barcelona
Gendreau M, Laporte G, Segini R (1996) Stochastic vehicle routing. Eur J Oper Res
Hocking RR (2003) Methods and applications of linear models. Willey, New Jersey
Johansson R (1993) System modelling and identification. Prentice Hall, New Jersey
Kutner MH, Nachtsheim CJ, Neter J (2004) Applied linear regression models. Mc Graw Hil, New York
Law AM, Kelton DW (1991) Simulation modelling and analysis. Mc Graw Hill, New York
Minsky M (1965) Matter, mind and models. Spartan Books, Washington DC
Montgomery D et al (2002) Introducción al análisis de regresión lineal. Compañía editorial Continental, México DF
Snee RD (1997) Validation of regression models: Methods and examples. Technometrics
NavidiI W (2006) Estadística para ingenieros y científicos. Mac Graw Hill, México DF
Vincent S (1998) Input data analysis: handbook of simulation. In: Banks J (ed) Wiley, New Jersey
Zhong J, Hall RW, Dessouky M (2004) Territory planning and vehicle dispatching. University of Southern California, Los Angeles

Chapter 21
Optimization of Recyclable Waste Collection Using Real-Time Information

R. Grosso de la Vega, J. Muñuzuri Sanz, M. Rodriguez Palero and J. Teba Fernandez

21.1 Introduction

Trying to solve the problem of waste collection in cities is not a new problem. Already in the 70 authors can be found attempting to address the problem, either from a mathematical point of view (Marks and Liebman 1970), either modeling and solving a vehicle routing problem or VRP (Beltrami and Bodin 1974; Turner and Hougland 1975). This problem is not easy to solve because it is included within the family of problems called Vehicle Routing Problem (VRP), as ever known, they all fall under the classification of NP-hard.

The increased levels of consumption and associated waste generation, environmental considerations and sustainability of cities have led to the emergence of new European and national policies regarding the management of municipal waste. An example is the National Integrated Waste Plan implemented in Spain in 2009, which is to continue the anterior National Urban Waste Plan (PNRU), and, among other things, forces municipalities with more than 5,000 inhabitants to ensure proper separation for selective collection of waste. Such measures make to consider new challenges to municipalities, even more so in the economic recession framework in which we live. Different types of containers, different types of waste,

R. Grosso de la Vega (✉) · J. Muñuzuri Sanz · M. Rodriguez Palero · J. Teba Fernandez
Departamento de Organization Industrial y Gestion de Empresas II, Escuela Tecnica Superior de Ingenieria de Sevilla, Camino de los Descubrimientos, s/n. Isla de la Cartuja 41092 Seville, Spain
e-mail: rgrosso@us.es

J. Muñuzuri Sanz
e-mail: munuzuri@esi.us.es

M. Rodriguez Palero
e-mail: mariarodriguez@us.es

J. Teba Fernandez
e-mail: jteba@us.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_21,

containers location, pollution, energy consumption, cost reduction, are any of these challenges. Thus authors that address the problem from the consumption of fuel (Sonesson 2000), until which encompass environmental and economic goals can be found in the literature.

Nowadays with the emergence of new technologies and the lowering of its price give researchers new tools to solve this problem. Examples of these new technologies are Geographic information system (GIS), volumetric sensors, radio frequency identification (RFID). Using this technology the issues can be addressed as eliminating unnecessary stops, fleet reduction and balancing according to demand, pollution impact reduction, operating costs reduction, etc. In this direction it works in recent years (Chang et al. 1997; Nuortio et al. 2006), and in which there is great potential for future work.

And it is in this direction that this work moves. In this paper we address the problem of waste disposal in urban areas with the real-time level data of the containers. In particular we focus on the collection of glass containers. We describe in this work the problem to solve; we present the proposed collect policy, and compared with other classical optimization algorithm. Finally, we show the results obtained and present the conclusions of the work.

21.2 Problem Description

We consider a capacitated vehicle routing problem on a graph: G: [N, A], where N is the set of nodes and L is the set of links communicating them. The set of nodes N contains one node d with a positive level of demand (depot), a subset C of nodes with a positive level of supply (containers), and another subset $\bar{C}$ of nodes with zero levels of supply and demand, so that $N = (C \text{ U } \bar{C}) \text{ U } d$. The supply level of containers in subset C is time variant, and is known daily.

A number V of vehicles (where V is a variable) will travel through the graph visiting the different containers, only one vehicle per container. We consider capacity restrictions on vehicles (Q) equal for all of them.

The problem is defined inside a predefined time horizon, N days, and the objective is to minimize the number of vehicles that need to be used and the cost (in time units) of transporting waste from the containers of C to the depot d, crossing along the way the necessary nodes of the subset $\bar{C}$.

We also define a set T of time costs associated to the different links in the graph. These costs depend only on the transit of vehicles through links, and not on the amount of waste carried by those vehicles. In general, we will incur in cost t_{ij} when travelling from node i to node j. We will also compute the loading time at each customer as a time cost tr, incurred every time a vehicle visits one of the nodes contained in C.

21.3 Proposed Solution

We propose a collection policy based on three stages: calculation, estimation and optimization. Previously we fixed the fill level (RL) of containers which are to collect.

In the first stage, we calculate the routes needed to minimize the travel length after knowing the containers to collect in a day *t* with the volumetric sensor data and the fixed RL. In the next stage, we estimate the containers to be collected over the next N days (t + 1,…,t + N). We use its current fill level and its daily fill rate. The necessary routes are also calculated for those *N* days. In the last stage and seeking to reduce the number of kilometers traveled in the planning horizon, we look for the possible containers, from those *N* days, which can be collected on day *t*. Obviously the fill levels that have these containers in the day *t* is lower than the value *RL* fixed by the policy, so the proposed decision rule takes into account that not exploited container capacity.

This policy is compared with another used in the literature (Nuortio et al. 2006; Johansson 2006; Faccio et al. 2011), which simply collects the containers with the fixed fill level.

Below clarifies the nomenclature used in the description of the implemented algorithm for simulating policies.

- L (r) denotes the length of route r, in time units.
- The used operators are known (Bräysy and Gendreau 2005). These are: Insertion Operator, Local Search Operator, 2-Opt, OR-Opt, 3-Opt, Exchange, Relocate, 2-opt*, CROSS-Exchange and GENI-Exchange.
- Parameter that we use as decision rule to determine which containers with fill levels lower than *RL* are collected at day *t* is defined as follows:

$$P(i) = (l - Nll(i)) \cdot tr \cdot k \tag{21.1}$$

  – Being *NLL* (*i*) the fill level of each container at the current moment, and *k* a parameter as a weight of not exploited container capacity in the decision rule. The simulation uses different values of *k* in search of its optimal value.

Below we present the pseudo-code of the algorithm used by the proposed policy. This algorithm calculates the routes needed for a particular day, but as discussed above, it will be simulated continuously for three months in order to compare the overall results.

Calculate containers to collect day *t* (real-time data)

for $d1 = 1$: N Estimate container to collect in day $t + d1$ (historic data)
end
for $d2 = 1$: $N + 1$ Build collection routes (Operators already mention)
end
for $d3 = 1$: N for each day since $t + 1$ to $t + 7$ and considering the capacity constrains

```
for each container j in each route r at day t
   for each container i in each route s at day t + d3
      if L(r with i between j and j + 1) + P(i) + L(s without i) <
      L(r) + L(s)
      Save container i in containers to collect in day t
      end
   end
 end
end

for build day t routes with the new containers
   while the length of routes improves
   end
end
```

The algorithm to simulate the policy to compare:

```
Calculate containers to collect day t (real-time data)
for build day t routes (Operators already mention)
   while the length of routes improves
   end
end
```

21.4 Case Study

We consider the problem of collecting recyclable waste containers in the city of Seville, in particular glass containers. These containers are located throughout the city so dispersed. These containers is not necessary to collect daily because of non-degradable nature of the glass, the rate of generation of this type of waste which is not very high and the capacity of the containers (in the case of Seville is 3 m^3).

Currently it used a policy that combines on the one hand the collection of containers according to estimates of historic filling rates and on the other the containers collected after receiving a call from a neighbor alerting the complete filling of any of them.

The implementation of automated sensors that emit a signal to the waste management center with the fill level data in the containers of this type of waste is a trend seen in recent times (Nuortio et al. 2006; Johansson 2006; Faccio et al. 2011).

And assuming that such sensors have been implemented in the city of study the problem to solve is:

- A model of Seville consisting of a graph: G: [N, A], with $N = 1{,}217$ nodes and $N = 4{,}510$ arcs. The cost associated with each arc is in t_{ij} kilometers.

- It assumes the existence of a sufficient fleet to service. The capacity of the truck was fixed in terms of number of full containers that can contain. Each vehicle can collect $Q = 7$ full containers. Associated with vehicles is also fixed in $tr = 2.5$ min the time required to collect each container (the mechanical collection of glass containers in Seville requires a crane). The estimated average speed of vehicles was fixed at 20 km/h.
- A single depot (d) from which the vehicles begin and end collection routes is considered.
- Distributed by the graph are located containers (subset C) to be collected. The number of containers was fixed at 300. It is considered that each container has a volumetric sensor that provides daily the fill level of each of them. In addition to its exact location, two data have associated to each container; one is the current filling level (%) and the other a daily filling rate (%), different for each. This rate is assumed to follow a normal distribution (Johansson, 2006), with an average value 0.1428, the standard deviation value is a parameter in the experiments (0.5 or 1).
- The problem is to solve for a planning horizon of $\mathrm{N} = 6$ day, although the proposed policy aims to minimize the number of kilometers within a time of three months, so there will be a rolling-horizon procedure for that time.

21.4.1 Results

After these we present and analyze the results of the implementation of two policies to the problem.

Several experiments on the model of Seville from the two policies were conducted to compare.

As parameters to study the sensitivity on the results we used the standard deviation (σ) of the containers daily rate of filling and the fixed RL in both cases. And the value of k in proposed policy. For a better comparison we added the value of k in the cost function of both policies.

As service satisfaction index we used the demand met daily. Unmet demand is considered, and therefore is not accounted for in the index, the estimated amount of glass arriving to the container once it is full. This amount of waste is not collected.

The cost function used is:

$$CT = \left(\frac{Kilometers}{Average\ speed}\right) + Number\ of\ collected\ containers \cdot tr \cdot k \tag{21.2}$$

- Table 21.1 show that the proposed policy is better suited to the different scenarios with $k = 0.5$, because gets the best percentages of met demand with lower costs.

Table 21.1 Proposed policy results

σ	RL	Km	N° R	N° RT	NlIMV (%)	DS (%)	k	CT
0.5	0.95	19611	548	3759	91.7	94.7	0.5	63532
0.5	0.95	19337	547	3657	91.6	94.9	1	67154
0.5	0.95	19222	542	3568	92.5	94.5	3	84426
1	0.95	22935	655	4478	93.2	91.6	0.5	74401
1	0.95	22647	651	4409	93.6	91.5	1	78965
1	0.95	22629	646	4310	94.1	91.4	3	100213
0.5	1	22293	586	4664	91.3	99.3	0.5	72710
0.5	1	22133	592	4503	90.1	98.6	1	77656
0.5	1	21608	581	4331	91.3	98.3	3	97308
1	1	27309	728	5880	91.6	98.5	0.5	89276
1	1	26842	725	5752	91.6	98.3	1	94907
1	1	26699	725	5640	91.4	97.9	3	122396

σ Standard deviation, *RL* fixed fill level, *Km* Total distance traveled in kilometers, *N° R* number of routes, *N° RT* number of collected containers, *NlIMV* vehicles fill level, *DS* met demand, *CT* total cost (depending on the value of k in Table 21.2)

Table 21.2 Results from experiments on the model to compare policy

σ	RL	Km	N° R	N° RT	NlIMV (%)	DS (%)	CT k = 0.5 CT k = 1	CT k = 3	
0.5	0.94	19565	552	3582	91.53	95.05	63174	67651	85561
1	0.94	22762	656	4318	93.10	91.97	73685	79082	100672
0.5	0.96	20054	583	3694	89.94	98.98	64778	69396	87866
1	0.96	22351	651	4226	92.37	90.62	72336	77619	98749
0.5	0.98	18907	541	3424	89.95	92.17	61000	65280	82400
1	0.98	21971	660	4146	89.68	89.22	71095	76277	97007
0.5	1	18702	605	3397	80.08	91.03	60352	64598	81583
1	1	21975	720	4121	81.68	87.96	71076	76227	96832

- It is also noteworthy that the proposed policy is better suited to larger values of o with the *RL* = 1, because gets percentages of met demand very high, although with higher costs.
- The proposed policy is in general more expensive, although in small percentages, than the other policy, but also gets a significantly higher percentage of met demand, so more garbage is collected.
- Even with the above, the distance traveled in proposed policy routes is not significantly greater than the other. So in environmental and economic considerations would be considered more balanced.
- Under the proposed policy gets better resource use and more optimized, because collected greater number of containers with less number of routes, so that the average fill level of the vehicle is higher. This may lead to a reduction in the fleet of vehicles needed.

21.5 Conclusions

We have built a route optimization procedure to recyclable waste collection using real-time information about the containers fill level.

In order to do it we propose a collection policy based on three stages: calculation, estimation and optimization. In the first stage, we calculated the routes needed to minimize the travel length after knowing the containers to collect in a day t with the volumetric sensor data and the fixed *RL*. In the next stage, we estimated the containers to be collected over the next 6 days $(t+1,\ldots,t+6)$. We use its current fill level and its daily fill rate. The necessary routes are also calculated for those 6 days. In the last stage and seeking to reduce the number of kilometers traveled in the 90 days, we look for the possible containers, from those 6 days, which can be collected on day t. And we recalculated the necessary routes with the new containers. Thus the proposed procedure using real data optimizes routes on two levels, daily and within a larger planning horizon.

The proposed policy has been compared to policies currently used in the literature which only takes into account the daily optimization.

According to the conclusions drawn, the policy with which we compare could be optimal from the point of view of the concessionary company, because it has lower costs, in general, with met demand that could be considered within the acceptable levels.

And the policy proposed in this paper could be adopted by the municipalities, because while having higher costs it has higher levels of met demand and uses resources more optimally, using fewer vehicles.

References

Beltrami EJ, Bodin LD (1974) Networks and vehicle routing for municipal waste collection. Networks 4(1):65–94

Bräysy O, Gendreau M (2005) Vehicle routing problem with time windows. Part I: Route construction and local search algorithms. Transp Sci 39(1):104–118

Chang N, Lu HY, Wei YL (1997) GIS technology for vehicle routing and scheduling in solid waste collection systems. J Environ Eng 123(9):901–910

Faccio M, Persona A, Zanin G (2011) Waste collection multi objective model with real time traceability data. Waste Manage 31(12):2391–2405

Johansson OM (2006) The effect of dynamic scheduling and routing in a solid waste management system. Waste Manage 26(8):875–885

Marks DH, Liebman JC (1970) Mathematical analysis of solid waste collection, US Public Health Serv Publ 2104

Nuortio T, Kytöjöki J, Niska H, Bräysy O (2006) Improved route planning and scheduling of waste collection and transport. Expert Sys Appl 30(2):223–232

Sonesson U (2000) Modelling of waste collection—A general approach to calculate fuel consumption and time. Waste Manage Res 18(2):115–123

Turner WC, Hougland ES (1975) Optimal routing of solid waste collection vehicles. A I I E Trans 7(4):427–431

Part IV
Production and Operations Management

Chapter 22
Managing Qualities, Tones and Gages of Ceramic Supply Chains Through Master Planning

M. I. Mundi, M. M. E. Alemany Díaz, A. Boza and R. Poler

22.1 Introduction

Lack of Homogeneity in the Product (LHP) appears in those productive processes which include raw materials that directly originate from nature and/or production processes with operations which confer heterogeneity to the characteristics of the outputs obtained, even when the inputs used are homogeneous (Alarcón et al. 2011). LHP in ceramic supply chains (SCs) implies the existence of units of the same finished good (FG) in the same lot that differ in the aspect (quality), tone and gage that should not be mixed to serve the same customer order. This is due to the fact that units of the same FG (e.g. ceramic tiles) should be jointly presented being necessary their homogeneous appearance. The order promising process plays a crucial role in customer requirements satisfaction and, therefore, in properly managing the special LHP characteristics. But in turn, one of the main inputs to this process is the master plan. Then, the objective of this paper is to define a master plan that anticipate LHP features and can provide the order promising process with reliable information about future homogeneous quantities available.

The paper is structured as follows. Section 22.2 describes the problem under consideration. Section 22.3 presents the mixed integer linear programming model proposed for the centralized master planning of ceramic SCs that explicitly takes into account LHP. Finally, Sect. 22.4 reports the methodology followed for the model validation and the conclusions derived from the obtained results.

This research has been carried out in the framework of the project funded by the Spanish Ministry of Economy and Competitiveness (Ref. DPI2011-23597) and the Polytechnic University of Valencia (Ref. PAID-06-11/1840) entitled "Methods and models for operations planning and order management in supply chains characterized by uncertainty in production due to the lack of product uniformity" (PLANGES-FHP).

M. I. Mundi · M. M. E. Alemany Díaz (✉) · A. Boza · R. Poler
Centre d'Investigació de Gestió i Enginyeria de Producció (CIGIP),
Universitat Politècnica de València, Camí de Vera s/n 46022 València, Espanya, Spain
e-mail: mareva@omp.upv.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_22, © Springer-Verlag London 2014

22.2 Problem Description

In this paper, we consider the master planning problem for replenishment, production, and distribution in ceramic tiles SCs with LHP. These SCs are assumed to be multi-item, multi-supplier, multi-facility, multi-type and multi-level distribution centers. The characteristics of the problem under study are the same as in Alemany et al. (2010) but with relevant differences introduced by the LHP consideration. As in Alemany et al. (2010) the master plan considers the capacitated lot-sizing and loading problem (Özdamar and Birbil 1998) to reflect the fact that production lots of the same product processed in different production lines present a high probability of not being homogeneous. Furthermore, the splitting of each lot into homogeneous sub-lots of the same FG is also incorporated to reflect the LHP characteristics. The sizing of lots is made in such a way that an integer number of customer order classes can be served from homogeneous quantities of each sub-lot. To this end, different customer order classes are defined according to their size. The next section describes the mixed integer programming model proposed to solve this problem.

22.3 Mathematical Programming Model for Ceramic Supply Chains with LHP: MP-CSC-LHP

The following mixed integer linear programming model (MP-CSC-LHP) is proposed to solve the master planning problem described above. The model MP-RDSINC proposed by Alemany et al. (2010) is considered as the starting point to formulate the present model but properly modified in order to reflect the LHP characteristics. Tables 22.1, 22.2, 22.3, 22.4, respectively, describe the indices, sets of indices, model parameters and decision variables of the MP-CSC-LHP, respectively. Those model elements that differ from the MP-RDSINC are written in *italics*.

Table 22.1 Indices

i	Finished goods ($i = 1, \ldots, I$)	q	Logistics centers ($q = 1, \ldots, Q$)
f	Product families ($f = 1, \ldots, F$)	w	Shops ($w = 1, \ldots, W$)
c	Raw materials and components ($c = 1, \ldots, C$)	r	Suppliers of raw materials and components ($r = 1, \ldots, R$)
p	Production plants ($p = 1, \ldots, P$)	k	*Customer order classes* ($k = 1, \ldots, K$)
a	Warehouses ($a = 1, \ldots, A$)	t	Periods of time ($t = 1, \ldots, T$)

Table 22.2 Sets of indices

Il(*l*)	Set of FGs that can be manufactured on manufacturing line *l*
Fl(*l*)	Set of product families that can be manufactured on manufacturing line *l*
If(*f*)	Set of FGs that belong to product family *f*
Ip(*p*)	Set of FGs that can be produced in production plant *p*
Ia(*a*)	Set of FGs that can be stored in warehouse *a*
Ic(*c*)	Set of FGs of that RM *c* form part
Iq(*q*)	Set of FGs that can be sent to logistic center *q*
Iw(*w*)	Set of FGs that can be sent to shop *w*
Lf(*f*)	Set of manufacturing lines that may produce product family *f*
Lp(*p*)	Set of manufacturing lines that belong to production plant *p*
Pa(*a*)	Set of production plants that can send FGs to warehouse *a*
Aq(*q*)	Set of warehouses that can supply logistic center *q*
Rc(*c*)	Set of suppliers that can supply RM *c*
Rp(*p*)	Set of suppliers of RMs that can supply production plant *p*
Cr(*r*)	Set of RMs that can be supplied by supplier *r*
Qa(*a*)	Set of logistics centers that can be supplied by warehouse *a*
Wq(*q*)	Set of shops that can be supplied by logistic center *q*
Qw(*w*)	Set of logistics centers capable of supplying shop *w*
Ap(*p*)	Set of warehouses that can be supplied by production plant *p*

Objective Function:

$$\begin{aligned}
&M\acute{a}x \sum_t \sum_i \sum_k \left\{ \sum_a pak_{iak} * VENAK_{iakt} + \sum_w pwk_{iwk} * VENWK_{iwkt} \right\} \\
&- \sum_t \sum_p \sum_{r \in Rp(p)} \sum_{c \in Cr(r)} costtp_{crp} * CTP_{crpt} - \sum_t \sum_p \sum_{l \in Lp(p)} \sum_{i \in Il(l)} costp_{ilp} * MP_{ilpt} \\
&- \sum_t \sum_p \sum_{l \in Lp(p)} \sum_{f \in Fl(l)} costsetup_{flp} * ZF_{flpt} - \sum_t \sum_p \sum_{l \in Lp(p)} \sum_{i \in Il(l)} costsetupi_{ilp} * ZI_{ilpt} \\
&- \sum_t \sum_a \sum_{p \in Pa(a)} \sum_{i \in Ip(p)} \sum_k costtak_{ipak} * CTAK_{ipakt} - \sum_t \sum_a \sum_{i \in Ia(a)} \sum_k costinak_{iak} * INVNAK_{iakt} \\
&- \sum_t \sum_a \sum_{i \in Ia(a)} \sum_k costdifak_{iak} * DIFAK_{iakt} - \sum_t \sum_a \sum_{q \in Qa(a)} \sum_{i \in Iq(q)} \sum_k costtclk_{iaqk} * CTCLK_{iaqkt} \\
&- \sum_t \sum_q \sum_{w \in Wq(q)} \sum_{i \in Iw(w)} costtwk_{iqwk} * CTTWK_{iqwkt} \sum_t \sum_w \sum_{i \in Iw(w)} \sum_k costdifwk_{iwk} * DIFWK_{iwkt}
\end{aligned} \tag{22.1}$$

Constraints:

$$INC_{cpt} = INC_{cpt-1} + \sum_{r \in Rc(c)} CTP_{crpt} - \sum_{i \in Ic(c)} \left(v_{ic} * \sum_{l \in Lp(p)} MP_{ilpt} \right) \quad \forall c, p, t \tag{22.2}$$

$$INC_{cpt} \geq ssc_{cp} \quad \forall c, p, t \tag{22.3}$$

Table 22.3 Parameters

ca_{crt}	Capacity (units) of supplying RM *c* of supplier *r* in period *t*
$costtp_{crp}$	Purchase and transport cost of one unit of RM *c* from supplier *r* to production plant *p*
caf_{lpt}	Production capacity available (time) of production line *l* at plant *p* during time period *t*
cm_i	Loss ratio of FG *i* (percentage of faulty m2 obtained of the production process)
cq_i	Percentage of m^2 that can be sold of product *i* as first quality
$costp_{ilp}$	Cost of producing one m^2 of FG *i* on production line *l* of production plant *p*
$costsetupf_{flp}$	Setup costs for product family *f* on production line *l* of production plant *p*
$costsetup_{ilp}$	Setup costs for FG *i* on production line *l* of production plant *p*
$tfab_{ilp}$	Time to process one m^2 of FG *i* on production line *l* of production plant *p*
$tsetup_{flp}$	Setup time for product family *f* on production line *l* of production plant *p*
$tsetupi_{ilp}$	Setup time for article *i* on production line *l* of production plant *p*
lmi_{ilp}	Minimum lot size (m^2) of FG *i* on production line *l* of production plant *p*
tmf_{flp}	Minimum run length (expressed as multiples of the time period used) of product family *f* on production line *l* of production plant *p*
v_{ic}	Units of RM *c* needed to produce one m^2 of FG *i*
ssc_{cp}	Safety stock of RM *c* in production plant *p*
ssa_{ia}	Safety stock (m^2) of FG *i* at warehouse *a*
$capal_a$	Storage capacity (m^2) in warehouse *a*
$costtak_{ipak}$	*Unitary transport cost of FG i from production plant p to warehouse for customer order class k*
$costtclk_{iaqk}$	*Unitary transport cost of FG i from warehouse a to logistic center q for customer order class k*
$costinak_{iak}$	*Unitary holding cost of FG i of customer order class k in the warehouse in a period*
$costdifak_{iak}$	*Unitary backorder cost of FG i for customer order class k in warehouse a in a period*
pak_{iak}	*Sales value of FG i in warehouse a for customer order class k*
$\alpha 1_k$	*Maximum backorder quantity permitted by customer order class k in a period in warehouses expressed as a percentage of the demand of that period*
$costtwk_{iqwk}$	*Unitary transport cost of FG i from logistics centre q to shop w for customer order class k*
$costdifwk_{iwk}$	*Unitary backorder cost of FG i of customer order class k in a time period at shop w*
pwk_{iwk}	*Sales price of FG i in shop w for customer order class k*
$\alpha 2_k$	*Maximum backorder quantity permitted in a period by customer order class k in shops expressed as a percentage of the demand of that period*
M1, M2	Very large integers
$ordq_{ik}$	*Average size of the order of FG i of customer order class k*
dw_{iwkt}	*Forecast of demand of FG i at the warehouse a of customer order class k in period t*
da_{iakt}	*Forecast of demand of FG i in shop w of customer order class k in period t*
$\beta 1_{ilp}$	*Percentage of a batch of FG i produced on the line l of the plant p at any period which can be considered as the first homogeneous sub-batch of product i*
$\beta 2_{ilp}$	*Percentage of a batch of FG i produced on the line l of the plant p at any period which can be considered as the second homogeneous sub-batch of product i*
$\beta 3_{ilp}$	*Percentage of a batch of FG i produced on the line l of the plant p at any period that can be considered as the third homogeneous sub-batch of product i*

Table 22.4 Decision variables

CTP_{crpt}	Amount of RM *c* to be purchased and transported from supplier *r* to production plant *p* in period *t*
INC_{cpt}	Inventory of the RM *c* at plant *p* at the end of period *t*
MPF_{flpt}	Amount of product family *f* manufactured on production line *l* of production plant *p* in period *t*
MP_{ilpt}	Amount of FG *i* manufactured on production line *l* of production plant *p* in period *t*
X_{ilpt}	Binary variable with a value of 1 if FG *i* is manufactured on production line *l* of production plant *p* in time period *t*, and with a value of 0 otherwise
Y_{flpt}	Binary variable with a value of 1 if product family *f* is manufactured on production line *l* of production plant *p* in time period *t*, and with a value 0 otherwise
ZI_{ilpt}	Binary variable with a value of 1 if a setup takes place of product *i* on production line *l* of production plant *p* in time period *t*, and with a value of 0 otherwise
ZF_{flpt}	Binary variable with a value of 1 if a setup takes place of product family *f* on production line *l* of production plant *p* in time period *t*, and with a value of 0 otherwise
$CTAK_{ipakt}$	*Amount of FG i to be transported from production plant p to warehouse a for customer order class k in time period t*
$INVNAK_{iakt}$	*Inventory of FG i in warehouse a for customer order class k in period t*
$VENAK_{iakt}$	*Amount of FG i sold in warehouse a to customer order class k during period t*
$DIFAK_{iakt}$	*Backorder quantity of FG i of customer order class k in warehouse a during period t*
$CTCLK_{iaqkt}$	*Amount of FG i of customer order class k transported from warehouse a to logistics centre q in period t*
$CTTWK_{iqwkt}$	*Amount of FG i of customer order class k transported from logistics centre q to shop w in period t*
$VENWK_{iwkt}$	*Amount of FG i of customer order class k sold in shop w during period t*
$DIFWK_{iwkt}$	*Backorder quantity of FG i of customer order class k in shop w during time period t*
NKL_{ilpkt}	*Number of orders of FG i from customer order class k which can be served from the lot of the FG i to be produced on line l of the plant p in period t*
$NKL1_{ilpkt}$	*Number of orders of FG i from customer order class k which can be served from the first homogeneous sub-lot of the FG i to be produced on line l of the plant p in period t*
$NKL2_{ilpkt}$	*Number of orders of FG i from customer order class k which can be served from the second homogeneous sub-lot of the FG i to be produced on line l of the plant p in period t*
$NKL3_{ilpkt}$	*Number of orders of FG i from customer order class k which can be served from the third homogeneous sub-lot of the FG i to be produced on line l of the plant p in period t*
NKP_{ipkt}	*Number of orders of FG i from customer order class k which can be served from lots of the article i to be produced on all lines of the plant p in period t*

$$\sum_{p} CTP_{crpt} \leq ca_{crt} \quad \forall c, p, t \tag{22.4}$$

$$\sum_{f \in Fl(l)} tsetupf_{flp} * ZF_{flpt} + \sum_{i \in Il(l)} \left(tsetupi_{ilp} * ZI_{ilpt} + tfab_{ilp} * MP_{ilpt} \right) \leq caf_{lpt} \quad \forall p, l \in Lp(p), t \tag{22.5}$$

$$MPF_{flpt} = \sum_{i \in If(f)} MP_{ilpt} \quad \forall p, l \in Lp(p), f \in Fl(l), t \tag{22.6}$$

$$MP_{ilpt} \geq lmi_{ilp} * X_{ilpt} \quad \forall p, l \in Lp(p), i \in Il(l), t \tag{22.7}$$

$$MP_{ilpt} \leq M1 * X_{ilpt} \quad \forall p, l \in Lp(p), i \in Il(l), t \tag{22.8}$$

$$MPF_{flpt} \leq M2 * Y_{flpt} \quad \forall p, l \in Lp(p), f \in Fl(l), t \tag{22.9}$$

$$ZI_{ilpt} \geq X_{ilpt} - X_{ilpt-1} \quad \forall p, l \in Lp(p), i \in Il(l), t \tag{22.10}$$

$$\sum_{i} ZI_{ilpt} \geq \sum_{i} X_{ilpt} - 1 \quad \forall p, l \in Lp(p), t \tag{22.11}$$

$$ZF_{flpt} \geq Y_{flpt} - Y_{flpt-1} \quad \forall p, l \in Lp(p), f \in Fl(l), t \tag{22.12}$$

$$\sum_{f} ZF_{flpt} \geq \sum_{f} Y_{flpt} - 1 \quad \forall p, l \in Lp(p), t \tag{22.13}$$

$$\sum_{t=t'}^{t'+tmf_{flp}\ 1} ZF_{flpt} \leq 1 \quad \forall p, l \in Lp(p), f \in Fl(l), t' = 1, \ldots, T\ tmf_{flp} + 1 \tag{22.14}$$

$$(1 - cm_i) * cq_i * \beta 1_{ilp} * MP_{ilpt} = \sum_{k} NKL1_{ilpkt} * ordq_{ik} \qquad \forall p, \forall l \in Lp(p), i \in Ip(p), t \tag{22.15}$$

$$(1 - cm_i) * cq_i * \beta 2_{ilp} * MP_{ilpt} = \sum_{k} NKL2_{ilpkt} * ordq_{ik} \qquad \forall p, \forall l \in Lp(p), i \in Ip(p), t \tag{22.16}$$

$$(1 - cm_i) * cq_i * \beta 3_{ilp} * MP_{ilpt} = \sum_{k} NKL3_{ilpkt} * ordq_{ik} \qquad \forall p, \forall l \in Lp(p), i \in Ip(p), t \tag{22.17}$$

$$NKL_{ilpkt} = NKL1_{ilpkt} + NKL2_{ilpkt} + NKL3_{ilpkt} \quad \forall p, i \in Ip(p), \forall l \in Lp(p), \forall k, \forall t \tag{22.18}$$

$$NKP_{ipkt} = \sum_{l \in Lp(p)} NKL_{ilpkt} \quad \forall p, i \in Ip(p), \forall k, \forall t \tag{22.19}$$

$$NKP_{ipkt} * ordq_{ik} = \sum_{a \in Ap(p)} CTAK_{ipakt} \quad \forall p, i \in Ip(p), \forall k, \forall t \tag{22.20}$$

$$INVNAK_{iakt} = INVNAK_{iakt-1} + \sum_{p \in Pa(a)} CTAK_{ipakt} - VEANK_{iakt} - \sum_{q \in Qa(a)} CTCLK_{iaqkt} \forall i \in Ia(a), a, k, t \tag{22.21}$$

$$VENAK_{iakt} + DIFAK_{iakt} - DIFAK_{iwkt-1} = da_{iakt} \; \forall i \in Ia(a), a, k, t \tag{22.22}$$

$$DIFAK_{iakt} \leq \alpha 1_k da_{iakt} \qquad \forall i \in Ia(a), a, k, t \tag{22.23}$$

$$\sum_k INVNAK_{iakt} \geq ssa_{ia} \quad \forall a, i \in Ia(a), t \tag{22.24}$$

$$\sum_{i \in Ia(a)} \sum_k INVNAK_{iakt} \leq capal_a \quad \forall a, t \tag{22.25}$$

$$\sum_{a \in Aq(q)} CTCLK_{iaqkt} = \sum_{w \in Wq(q)} CTTWK_{iqwkt} \quad \forall q, i \in Iq(q), k, t \tag{22.26}$$

$$\sum_{q \in Qw(w)} CTTWK_{iqwkt} = VENWK_{iwkt} \quad \forall w, i \in Iw(w), k, t \tag{22.27}$$

$$VENWK_{iwkt} + DIFWK_{iwkt} - DIFWK_{iwkt-1} = dw_{iwkt} \qquad \forall i \in I(w), w, k, t \tag{22.28}$$

$$DIFWK_{iwkt} \leq \alpha 2_k dw_{iwkt} \qquad \forall i \in I(w), w, k, t \tag{22.29}$$

$$\begin{aligned}
&MPF_{flpt}, MP_{ilpt}, CTP_{crpt}, INC_{cpt}, CTAK_{ipakt}, INVNAK_{iakt}, CTCLK_{iaqkt}, CTTWK_{iqwkt} \geq 0 \\
&VENAK_{iakt}, VENWK_{iwkt}, DIFAK_{iakt}, DIFWK_{iwkt} \geq 0 \\
&NKL_{ilpkt}, NKP_{ipkt}, NKL1_{ilpkt},\ NKL2_{ilpkt},\ NKL3_{ilpkt} \geq 0 \; y\ enteras \\
&and \quad X_{ilpt}, Y_{flpt}, ZF_{flpt}, ZI_{ilpt} \in \{0, 1\} \\
&\forall f \in F, \forall i \in I, \forall c \in C, \forall l \in L, \forall p \in P, \forall a \in A, \forall q \in Q, \forall w \in W, \forall r \in R, \forall k \in K, \forall t \in T
\end{aligned} \tag{22.30}$$

For being concise, in this section only the MP-CSC-LHP functions that differ from the MP-RDSINC are described. For more details, the reader is referred to Alemany et al. (2010). The objective function (22.1) expresses the gross margin maximization over the time periods that have been computed by subtracting total costs from total revenues. In this model, selling prices and other costs including the backlog costs can be defined for each customer class allowing reflect their relative priority.

Constraints (22.1) to (22.14) coincide with those of the MP-RDSINC and make reference to suppliers and productive limitations related to capacity and setup. Constraints (22.15–22.17) reflect the splitting of a specific lot into three homogeneous sub-lots of first quality ($\beta 1_{\text{ilp}} + \beta 2_{\text{ilp}} + \beta 3_{\text{ilp}} = 1$). The number of sub-lots considered in each lot can be easily adapted to other number different from three. Through these constraints the sizing of lots is decided based on the number of orders from different customer order classes that can be served from each homogeneous sub-lot. Customer order classes are defined based on the customer order size (i.e., the m^2 ordered). Constraint (22.18) calculates for each time period, customer class and finished good the total number of orders of a specific customer class that can be served from a certain lot by summing up the corresponding number of orders served by each homogeneous sub-lot of this lot. Constraint (22.19) derives the number of each customer order class that is possible to serve from the planned production of a specific plant. Through constraints (22.15–22.19), the production is adjusted not to the aggregate demand forecast as traditionally, but to different customer orders classes.

Furthermore, in contrast to the MP-RDSINC, the distributed, stocked and sold quantities downstream the production plants are expressed in terms of the customer class whose demand will be satisfied through them being possible to discriminate the importance of each order class. Constraint (22.20) calculates the quantity of each FG to be transported from each production plant to each warehouse for each customer class based on the order number of each customer class that is satisfied by each production plant and the mean order size. Constraint (22.21) represents the inventory balance equation at warehouses for each finished good, customer class and time period. As backorders are permitted in both central warehouses and shops, sales may not coincide with the demand for a given time period. Backorder quantities in warehouses for each customer class are calculated using constraint (22.22). Constraint (22.23) limits these backorder quantities per customer class in each period in terms of a percentage of the demand of each time period. Constraint (22.24) forces to maintain a total inventory quantity higher or equal to the safety stock in warehouses. Constraint (22.25) is the limitation in the warehouses' capacity that is assumed to be shared by all the FG and customer order classes.

Constraint (22.26) represents the inflows and outflows of FGs and customer order classes through each logistic centre. Because it is not possible to maintain inventory in shops, constraint (22.27) ensures that the total input quantity of a FG for a specific customer class from warehouses to shops coincides with the quantity sold in shops. As backorders are permitted in both central warehouses and shops, sales may not coincide with the demand for a given time period. Constraints (22.28) and (22.29) are similar to constraints (22.22) and (22.23), respectively, but referred to shops instead of warehouses. The model also contemplates non-negativity constraints and the definition of variables (22.30).

22.4 Model Validation and Conclusions

The MP-CSC-LHP model has been implemented in MPL (V4.11) and solved with CPLEX 6.6.0. With the aim of comparing the performance of the model with and without LHP modelling, the input data for validation has been mainly extracted for the paper of Alemany et al. (2010) that do not consider LHP: MP-RDSINC.

Table 22.5 Comparison of results from MP-RDSINC, MP-CSC-LHP and MP-RDSINC-LHP

	MP-RDSINC	MP-CSC-LHP	MP-RDSINC-LHP
Incomes	1.008.539,55	1.008.539,55	1.003.116,65
Supply costs	208.465,58	216.835,92	208.465,58
Production costs	381.918,37	397.034,01	381.918,37
Inventory costs	9.313,91	11.397,90	9.387,50
Setup costs	7.584,24	9.676,45	7.584,24
Transport costs	42.642,71	42.775,75	42.269,60
Backorder costs	0	0	94.500,00
Total costs	649.924,81	677.720,03	744.125,29
Gross margin	358.614,74	330.819,52	258.991,36

However, some additional parameters have been necessary for the LHP version (MP-CSC-LHP). These parameters have been defined maintaining the coherence of the data used by the two models. With this input data the MP-CSC-LHP and the MP-RDSINC have been solved. Results show that MP-RDSINC obtains a greater gross margin than the MP-CSC-LHP mainly due to the lower production costs of the former. This is due to the fact that the MP-RDSINC should produce a lower quantity than the MP-CSC-LHP for satisfying the aggregate demand (Table 22.5).

This result can lead to the wrong conclusion that the MP-RDSINC outperforms the MP-CSC-LHP. This is not true because, the MP-RDSINC does not take into account the homogeneity requirement for customer orders and considers the demand forecasts in an aggregate manner. To obtain results from both models that were really comparable, the lots obtained by the MP-RDSINC model solution (value of decision variable MP_{ilpt}) was transferred as an input data to the MP-CSC-LHP computing the new gross margin obtained (MP-RDSINC-LHP). As expected, the new value of the gross margin for the MP-RDSINC-LHP was lower than the MP-CSC-LHP because a lower number of customer orders were able to be served with homogeneous quantities by the lots initially defined by the MP- RDSINC (see backorder costs for MP-RDSINC-FHP-mod).

References

Alarcón F, Alemany MME, Lario FC, Oltra RF (2011) La falta de homogeneidad del producto (FHP) en las empresas cerámicas y su impacto en la reasignación de inventario. Boletín de la Sociedad Española de Cerámica y Vidrio 50(1):49–58

Alemany MME, Boj JJ, Mula J, Lario FC (2010) Mathematical programming model for centralised master planning in ceramic tile supply chains. Int J Prod Res 48(17):5053–5074

Özdamar L, Birbil SI (1998) Hybrid heuristics for the capacitated lot sizing and loading problem with setup times and overtime decisions. Eur J Oper Res 110:525–547

Chapter 23
Strategic Capacity Planning in KIOs: A Classification Scheme

C. Martínez, A. Lusa, M. Mas, R. de la Torre and M. Mateo

23.1 Introduction

This paper introduces a classification scheme for strategic capacity planning prob- lems in knowledge intensive organizations (KIOs), which is mainly related to determining the sizes, types and scheduling of capacity expansion and reduction of skilled people as the main limiting factor of their capacity.

Strategic capacity planning is extremely important for every company (Luss 1982; Olhager et al. 2001; Geng and Jiang 2009). For manufacturing industries and some types of services (such as telecommunications, transport, electricity distribution, water distribution, etc.) companies have to invest huge amounts of money in tangible assets with long payout times (Paraskevopuolos et al. 1991), and sometimes these decisions are irreversible or the assets invested have insignificant resale, scrap or salvage value (Berman et al. 1994). For this reason, most of the developed capacity planning tools are focused on organizations that have significant expansion costs. In our study we will focus in service organizations for which

Supported by the Spanish Ministry of Economy and Competitivity (project DPI2010-15614).

C. Martínez · A. Lusa (✉) · M. Mas · R. de la Torre · M. Mateo
Departamento de Organización de Empresas, Instituto de Organización y Control, ETS de Ingeniería Industrial de Barcelona, Universitat Politècnica de Catalunya, Av. Diagonal 647, planta 11 08028 Barcelona, Spain
e-mail: amaia.lusa@upc.edu

C. Martínez
e-mail: mcarme.martinez@upc.edu

M. Mas
e-mail: marta.mas-machuca@upc.edu

R. de la Torre
e-mail: maria.rocio.de.torre@upc.edu

M. Mateo
e-mail: manel.mateo@upc.edu

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_23, © Springer-Verlag London 2014

the main expansion cost is related to personal and the workforce planning constitutes a major problem.

Capacity planning has been an important research topic in Operations Management. However, most of the literature concerning this problem is focused on manufacturing companies (whose characteristics may not fit with many service industries) or very simple services systems (that are often modelled by means of queuing theory).

To the best of our knowledge, there are no formalized tools or procedures to deal with strategic capacity planning in KIOs. Defining the strategic capacity planning problem, identifying the most relevant characteristics and proposing a classification scheme is the first step towards the design of a general solving methodology and the development of specific solving procedures for each case.

The rest of the paper is organized as follows: Sect. 23.2 contains the main findings regarding KIOs and points out the relevant differences between manufacturing companies and KIOs; Sect. 23.3 defines the strategic capacity planning problem in KIOs, introduces the most important characteristics and proposes a classification scheme; finally, Sect. 23.4 contains the conclusions and future research lines.

23.2 Manufacturing Companies Versus Knowledge Intensive Organizations

As it is said in the introduction, most of papers dealing with strategic capacity planning are focused in manufacturing companies. Service organizations differ from manufacturing industries in a number of ways. One of the most important differences is that most service facilities exist in a restricted local market, so that service product cannot be shipped to other markets and it cannot be stocked to meet fluctuations in demand. Second, the economies of scale in service industries are often considerable less than for manufacturing or process industries (Berman et al. 1994).

Also, the service industry is very broad and businesses are different. Knowledge-intensive organizations represent a specific case in the service industry, for which capacity depends on the size and composition of the workforce.

The relevance of the idea of knowledge-intensive firms (KIFs) or, in a general way for any organization, knowledge-intensive organization (KIOs) as a knowledge company has increased in recent years (Alvesson 1993; Kärreman 2010), even though there is still a lack of consensus on the definition of KIOs (Makani and Marche 2010).

According to the seminal work of Starbuck (1992) a KIF assumes knowledge as the more important resource, distinct from the labour- and capital-intensive organization. Knowledge differs from other resources in being immaterial and ambiguous (Alvesson 1993). The principle of organization of knowledge-creating work may differ significantly from the traditional organization of physical work (Choo 1997).

One KIF's key characteristic is the capacity to solve problems trough creative and innovative solutions (Robertson and Swan 2003). In this sense, the competitive advantage for KIFs consists of the creation, application and preservation of superior knowledge and expertise within a firm (Starbuck 1992). Makani and Marche (2010) proposed a typology and analysis of the factors that differentiate KIOs from other organizations. One step further, in order to classify KIOs, these authors identified two dimensions of knowledge intensity: the worker dimension and the organizational/unit dimension. Our research is focused on the knowledge-intensive organizations (KIO), that is, the organizations where knowledge has been regarded as a critical and strategic resource and a key core competence, such as universities, consulting firms or high-tech and engineering firms (Robertson and Swan 2003).

According to previous ideas, the strategic capacity planning problem in a KIO can be assumed, mainly, to a workforce capacity planning problem in which developing human resource with necessary skills to meet the future demand is a key decision. The problem involves identifying the current and future skill types and numbers of employees required for the organization needs, transferring (from one department or branch to another), hiring and firing (Song and Huang 2008).

Recently, the problem of managing highly skilled employees has received an increasing research interest as the world is moving from an industrial-based to a more service- and information-based economy (Song and Huang 2008).

Service sector has an increasing importance in developed economies in recent decades, both in production as in employment. Also, service activities are being incorporated more and more into manufacturing companies. However, the relevance of the services sector in developed countries has not been reflected in the importance given to Operations Management research (a field for which capacity design and long-term capacity decisions are one of the main interest topics). As Machuca et al. (2007) pointed out despite the importance of service organizations little attention is still paid to service operations research in the Operations Management field. Regarding KIOs, there are not almost works in Service Operations Management research.

23.3 Strategic Capacity in KIOs: A Problems' Classification Scheme

In an organization where knowledge or, in particular, people with specific and difficult to get knowledge, is the main resource (as a university or a consulting company), the strategic capacity planning problem can be basically defined as a strategic workforce (staff, personnel, workers) planning problem.

The problem consists mainly on deciding the number and type of workers to hire (or promote) for each category and to fire, for every period of the planning horizon, which can be from one year up to, for example, 10 years (the "long term" can be more or less long depending on the case). Of course, decisions regarding training and transfers (from one department or branch to another) must be also considered.

Economic issues (such as cash management) should be taken into account, and there can be different evaluation criteria such as the profit, the fulfilling of the demand or achieving a staff whose composition (categories, age, etc.) equals an ideal situation.

Even though a general methodology can be developed to deal with this problem, a specific procedure has to be designed ad hoc for each particular case, depending on its characteristics.

23.3.1 Organization Structure

The organization can be structured by departments or by processes/projects. The main difference, concerning capacity planning, is that while a worker cannot belong to more than one department, he or she can belong to more than one process/project.

23.3.2 Workforce Characteristics

The workforce is supposed to be organized by categories, and all members of a category are supposed to be able to perform the same set of tasks. If there is cross-training, a type of task can be performed by more than one category, even though the yield in performing the task can depend on the category. In the opposite case (dedicated categories), a task can be done only by members of one category.

When a worker is hired or promoted to a category, there may exist a learning period during which the yield performing the task can be low and increasing up to the maximum after a certain number of periods.

Besides the category (which is directly related to the tasks that can be performed and, somehow, with the quality and or speed in performing those tasks), there are other characteristics that can be considered to classify workers: age (or time to the retirement), turnover ratio, etc.

23.3.3 Capacity Decisions

The available capacity depends basically on the size and composition of the staff (and their experience if there is a learning period for the new workers). Of course, a big expansion may lead to the necessity of getting additional space (a new site) so the corresponding costs should be considered. Also, when the KIO is organized by processes or projects, the capacity depend on how the workers are allocated to the different projects.

The capacity decisions may mainly include hiring and firing, promotions and transfers (from one department or one project to another). For the transfers, a training period may be necessary.

Usually it is desirable to consider also some tactical decisions in strategic planning (a system will be better if it is designed taking into account its operation). Regarding capacity, overtime and outsourcing decisions, as well as project or tasks assignments may be included.

23.3.4 Capacity Requirements (Demand)

The capacity requirements (or demand), or a probabilistic distribution or a set of scenarios of them are supposed to be known. These may depend on uncontrollable factors and on decisions taken also at the strategic level but that are considered to be fixed for the capacity planning, such as the introduction of new products (or services), or the opening to new markets.

The capacity requirements may be considered by category, type of task or project. Also, a minimum, a maximum and a desired or ideal capacity requirement can be defined.

23.3.5 Service Level

There are many ways of quantifying the service level of a company. For example, it can be forced that the available capacity meets, at least, a certain percentage of the required capacity. Also, it must be considered if demand can be delayed (a consulting can delay the starting of a project; instead, a university cannot delay or stop the course).

23.3.6 Workforce Costs

The variable costs to be considered in this problem may include salaries, hiring, firing and training. If from a given number of workers it is necessary to open a new site (or increase the available space) and, possibly, to hire complementary staff (for example, for administrative and IT tasks), the corresponding costs can be assigned to the workforce. In this case, the relation between the number (and type) of workers and the costs will be not linear.

23.3.7 Finance

Financial planning decisions can be considered together with capacity decisions or not. The expansions or reductions may lead to financial needs that cannot be faced by the organization (in this case, the costs due to getting a loan from a bank should be considered). Also, in high income periods, money can be invested in different ways. Finally, budget constraints can be taken into account.

23.3.8 Uncertainty

Uncertainty may affect many factors such as capacity requirements/demand, economic parameters, workforce turnover, etc. The uncertainty can be faced by solving several deterministic scenarios (in this case, uncertainty is not considering when designing a solving tool) or by means of a stochastic approach.

23.3.9 Planning Horizon

Strategic Capacity Planning is also known as Long Term Capacity Planning. However, depending on the type of organization (how changing are the conditions), the planning horizon can be more or less long; for example, from one year up to 20 years. The length of the planning horizon may affect the kind of decisions to be included in the planning (for example, to include or not tactical decisions, how to consider financial issues, etc.) and, also, the importance of the uncertainty regarding some parameters.

23.3.10 Evaluation Criteria

Several strategic capacity planning solutions may be generated or designed, and there are different criteria that can be used to evaluate them and choose the best one. The economical one (for example, the profit) is probably the most used one, but there are other regarding the service level (for example, to get a capacity as close as possible to the desired one) or the composition of the staff (for example, to have a workforce whose composition, in terms of age and category is as close as possible to an ideal one). The different criteria can be considered in a hierarchical way or can be combined into an evaluation function.

Table 23.1 Strategic capacity planning in KIOs: a classification scheme

Issue	Characteristic	Options
Organization	Organization structure	Departments
		Projects
Workforce	Categories	Dedicated categories
		Cross-training
	Age of workers	Relevant
		Not relevant
	Learning effect	Considered
		Not considered
	Workforce turnover	Considered
		Not considered
Capacity decisions	Hiring and Firing	Unlimited
		Limited
	Workers promotion	Unlimited
		Limited
	Transfers	Allowed
		Not allowed
	Training	Included
		Not included
	Tactical decisions	Included (overtime/outsourcing/assignment)
		Not included
Demand	Capacity requirements	By category
		By type of task
		By process/project
Service level	Actual capacity	Percentage of the requirements, without delays
		Percentage of the requirements, with delays
Costs and Finance	Workforce costs	Linear
		Not linear
	Financial planning	Included
		Not included
Uncertainty	Stochastic variables	Considered
		Not considered
Planning horizon	Term	Medium (1–5 years)
		Long (>5 years)
Goal	Evaluation criteria	Economic
		Service level
		Staff composition

23.3.11 Classification Scheme

Previous ideas lead to the classification shown in Table 23.1. Even though not all combinations may have sense, the scheme gives rise to a high number of variants.

23.4 Conclusions

This paper presents a classification scheme for the Strategic Capacity Planning in KIOs, a problem that, to the best of our knowledge, has not been previously dealt with (or, at least, no formalized solving procedures have been proposed). Future research includes designing a general solving methodology and develop solving tools for different variants of the problem.

References

Alvesson M (1993) Organization as a rethoric: knowledge-intensive firms and the struggle with ambiguity. J Manage Stud 30:997–1015

Berman O, Ganz Z, Wagner JM (1994) A stochastic optimization model for planning capacity expansion in a service industry under uncertain demand. Naval Res Logistics 41:545–564

Choo CW (1997) The knowing organization: how organizations use information to construct meaning, create knowledge, and make decisions. Oxford University Press, Oxford

Geng N, Jiang Z (2009) A review on strategic capacity planning for the semiconductor manufacturing industry. Int J Prod Res 47:3639–3655

Kärreman D (2010) The power of knowledge: learning from 'Learning by Knowledge-Intensive Firm'. J Manage Stud 47:1405–1416

Luss H (1982) Operations research and capacity expansion problems: a survey. Oper Res 30:907–947

Machuca JAD, González-Zamora MM, Aguilar-Escobar VG (2007) Service operations management research. J Oper Manage 25:585–603

Makani J, Marche S (2010) Towards a typology of knowledge-intensive organizations: determinant factors. Knowl Manage Res Pract 8:265–277

Olhager J, Rudberg M, Wikner J (2001) Long-term capacity management: linking the perspectives from manufacturing strategy and sales and operations planning. Int J Prod Econ 69:215–225

Paraskevopuolos D, Karakitsos E, Rustem B (1991) Robust capacity planning under uncertainty. Manage Sci 37:787–800

Robertson M, Swan J (2003) 'Control- What Control?' Culture and ambiguity within a knowledge intensive firm. J Manage Stud 40:831–858

Song H, Huang H-C (2008). A successive convex approximation method for multistage workforce capacity planning problem with turnover. Eur J Oper Res 188:29–48

Starbuck WH (1992) Learning by knowledge-intensive firms. J Manage Stud 29:713–740

Chapter 24
Leagility in Enterprise Networks Configuration of Capital Goods Sector

Raquel Sanchis, Eduardo Saiz, Eduardo Castellano and Raul Poler

24.1 Introduction

Markets have become global and it is vital that the operations management research focuses on enterprise networks and not only in a single factory. This need was detected during the late 1970s and the early 1980s when some practitioners realised the necessity to manage not only the single factory, but also enterprise networks. Rudberg and Olhager (2002) state that, although the new trend is to focus on enterprise networks, the research performed during this period covers only single organizations.

A decade after, the market in which companies developed their activity was characterised by an increasing demand, calling for a wider range of products, with good quality, a low profit margin and a high level of service (Bolwijn and Kumpe 1998; Brown and Eisenhardt 1998). For this reason, the research on operations management was addressed to enterprise network issues (Shi and Gregory 1998; Khurana and Talbot 1999).

R. Sanchis (✉) · R. Poler
Centro de Investigación en Gestión e Ingeniería de Producción (CIGIP),
Universitat Politècnica de València, Plaza Ferrándiz y Carbonell 2,
03801 Alcoy-Alicante, Spain
e-mail: rsanchis@cigip.upv.es

R. Poler
e-mail: rpoler@cigip.upv.es

E. Saiz · E. Castellano
Ikerlan-IK4. Centro de Investigaciones Tecnológicas, Paseo JM Arizmendiarrieta 2,
20500 Arrasate-Mondragón, Spain
e-mail: esaiz@ikerlan.es

E. Castellano
e-mail: ecastellano@ikerlan.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_24,

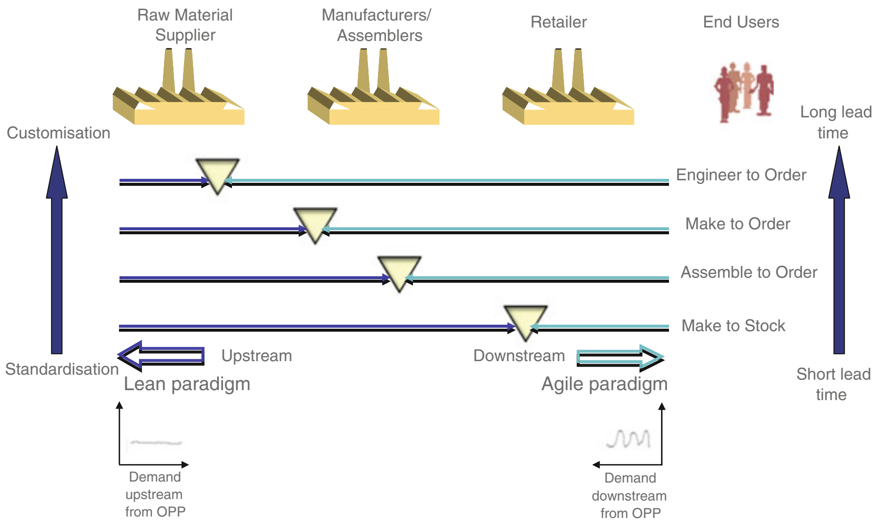


Fig. 24.1 Approach of the different networks' configurations (Adapted from Hoekstra and Romme 1992)

24.2 Lean and Agile Paradigm (Leagility) in Enterprise Networks Configuration: Literature Review

Mason-Jones et al. (2000) develop an approach to configure enterprise networks taking into account the lean and agile paradigm and the position of the Order Penetration Point (OPP), also termed decoupling point. The concept of OPP and its appropriate position have been widely studied in the literature and it has been contemplated as an effective strategy to get the right product, at the right price, at the right time to the consumer. The OPP defines the point where a particular product is linked to a specific customer order.

Agility means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile market place. Whereas, leanness means developing a value stream to eliminate all waste, including time, and to enable a level schedule. The combination of agility and lean in enterprise networks via the strategic use of an OPP has been defined as "leagility" (Naylor et al. 1997).

Mason-Jones et al. (2000) make an identification of the main distinguishing factors between the lean and the agile paradigm in order to define different networks' configurations (Table 24.1).

From the total value provided to the customer, the main difference between leanness and agility is that service is the key factor for agility whilst cost, and hence the sales price, is essential for lean.

By varying the position of the OPP, Mason-Jones et al. (2000) model highlights different common configurations' structures. These structures range from

Table 24.1 Main distinguishing factors between the lean and the agile paradigms

Distinguishing attributes	Lean network	Agile network
Typical products	Commodities	Fashion goods
Marketplace demand	Predictable	Volatile
Product variety	Low	High
Customer drivers	Cost	Availability
Product life cycle	Long	Short
Profit margin	Low	High
Dominant costs	Physical costs	Marketability costs
Stockout	Long term contractual	Immediate and volatile
Purchasing policy	Buy goods	Assign capacity
Information enrichment	Highly desirable	Obligatory
Forecasting mechanism	Algorithmic	Consultative

providing unique products to an end-user who is prepared to accept long lead times (engineer-to-order) through to providing a standard product at a fixed location (make-to-stock) (Fig. 24.1).

The lean paradigm can be applied to network upstream of the OPP as the demand is smooth and standard products flow through a number of value streams. Thereafter the agile paradigm should be applied downstream from the OPP as demand is variable and the product variety per value stream has increased.

24.3 Empirical Study in the Capital Goods Sector

A quantitative study was performed by means of the development of an online survey.[1] The main objective of the survey was to gather information from a representative sample of European capital goods manufacturing plants in order to identify the main paradigm used in the capital goods sector by means the distinguishing factors between the lean and the agile paradigms and the position of the OPP.

24.3.1 Distinguishing Factors between the Lean and the Agile Paradigms

The study performed is only focused on the first 4 distinguishing factors of Table 24.1:

- Typical products

[1] Survey URL: http://www.remplanet.eu/ResilienceSurvey

This factor is analysed with regard to the different customisation degree. Most companies offer some type of product customisation. Only 20 % point out that their product is standard and cannot be customised. Special characteristics of the target market for capital goods manufacturers lead to a high percentage of companies (28 %) to provide highly customised products (unique products) where participation of design and production engineering departments is a pre-requisite. Often, companies have catalogues in which products take in a set of standard options that can be combined with tailor-made options to cover specific customer needs (35 %). To a lesser extent, 17 % of companies offer to market products that can only be configured from a number of standard options with no custom development (Fig. 24.2).

- Marketplace demand

The empirical study analyses the demand characteristics over the past 5 years. A large majority of companies (87 %) states that current economic crisis, which is taking place worldwide, has increased dramatically the volatility and uncertainty of demand directly concerning their productive activity (Table 24.2).

- Product variety

In order to analyse the product variety, the number of different product families that are in the catalogue of the companies is studied. The results show that companies

Fig. 24.2 Degree of product customisation

Table 24.2 Demand characteristics over the past 5 years

	No (%)	Yes (%)
Stability: demand is distributed more or less regularly throughout the year	59	41
Volatility and uncertainty: demand has changed abruptly due to the economic cycle	13	87

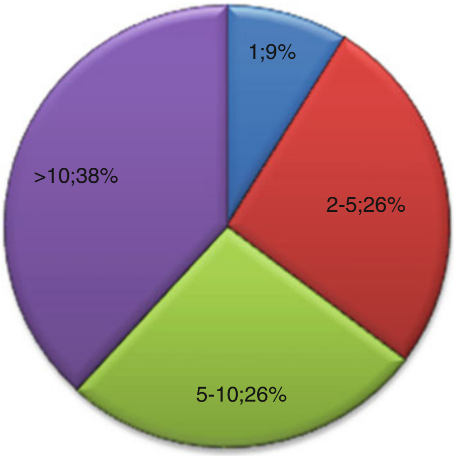


Fig. 24.3 Number of different product families in the catalogue

Table 24.3 Competitive factors valued by customers

		Not relevant (%)	Little relevant (%)	Relevant (%)	Very relevant (%)	Decisive (%)
	Product price	0	10	47	27	17
Services	Product quality	0	0	13	38	50
	Product customisation ability	9	13	6	25	47
	Consistency with commitments	0	0	22	41	38

have product catalogues with a high varied product range. Most of them (38 %) have a wide catalogue that includes more than ten product families (Fig. 24.3).

- Customer drivers

Additional services as product delivery time, quality, customisation and consistence with commitments offered by companies are very well valued by customers. Whereas, price of the product, while important, is not decisive for purchasing decisions (Table 24.3).

24.3.2 The Position of the OPP

Companies in the sector of capital goods embrace one or more order fulfilment strategies, which are defined by the position of the OPP, based on the target market and product characteristics. Main strategies referenced in the production management literature are present in the sample. Strategies such as Engineer to Order (ETO) in 55 % of the cases and Make to Order (MTO) in 18 % are the most common. Both comprise design and manufacturing activities to meet product characteristics with customer needs. These strategies are usually associated with complex and technical products and long lead times requiring a high level of customisation (e.g. machine tool). Pressure exerted by markets demanding shorter delivery times, is driving companies to adopt different strategies such as Assembly to Order (ATO) (16 %) in which final products are manufactured from standard components or modules that are assembled based on orders received. This strategy involves the assumption of high risks due to the large investment in inventories companies require and the great uncertainty on market performance concerning forecasts made. Product complexity, wide configuration options possibilities alongside a frequent small number of orders hugely complicate forecasting. Finally, only 11 % of the companies supply their products from stock (Fig. 24.4).

Sanchis et al. (2012) performed a study of the capital good sector in which they corroborated that a correlation between the degree of product customisation and the position of the OPP exists. They state (based on empirical data too) that the capital goods sector products are mainly complex and customisable products from a catalogue with standard options and unique products with complete design and production engineering and the producers chose MTO and ETO as the main strategies to manufacture these types of products.

24.4 Correlation between the Distinguishing Attributes of Lean and Agile Paradigm and the Position of the OPP

In order to analyse Mason-Jones et al. (2000) approach applied to the capital sector, the data of the four distinguishing attributes of the lean and agile paradigm,

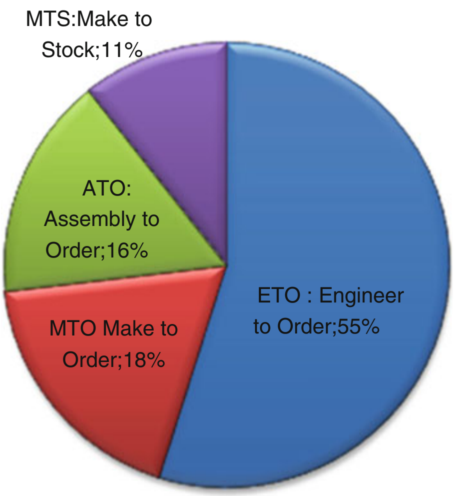


Fig. 24.4 Order fulfilment strategies used by companies

already studied in isolation in the previous section, have been crossed with the data of the different order fulfilment strategies, which are the different positions of the OPP (Table 24.4).

With regard to the typical product factor, the capital good sector offers an agile response when products have high degree of customisation in order to adapt its network to the high variety of customers' requirements, using mainly ETO strategy. However, when products are standard or present low customisation degree, the capital goods sector seems to approach to a more costs efficient structure than a flexible one and to do so, the strategies most used are ATO and MTS.

The correlation study also shows that although in some cases the demand is predictable, the specific requirements of customers make difficult the task of forecasting. Moreover, currently markets are characterised by an increasingly volatile and unpredictable demand amplified by the situation of global economic crisis. For this reason, in this type of competitive environment, it seems that the most important value for the capital goods sector is to maximise its ability to configure their processes and operations to the demand requirements, being as flexible as possible. For this reason, capital goods producers apply ETO and MTO to face up to this unpredictability.

The factor of product variety has been studied considering the different product families in the catalogue and the capital goods sector offers a high range of products families. The four order fulfilment strategies analysed in this studied present high percentages of product variety, being MTO and ATO the ones that offer the highest levels of product variety. The capital goods manufacturers that adopt MTO have their production systems ready to offer a wide range of product combinations from the initial production stages and the manufacturers that use ATO, also offer high product variety to the customer through the combination of standard options that are already in stock. In the case of ETO and MTS, the product variety decreases. In the first case, it may be due to the fact that the product is highly customisable but with fewer options to choose, and in the second case, because the finished product demand is very difficult to predict.

Finally, the customer preferences are equally balanced. Customers require to the capital goods sector to configure its network as efficiently as possible both in price and in additional services, such as quality, availability of products on time or consistency with commitments. Therefore, the capital goods sector should apply the lean and agile approaches depending on different aspects such as the customisation degree or complexity of products, the preferences of each specific customer, among other. All these aspects also support the adoption of one order fulfilment strategy or another.

Table 24.4 Correlation between the distinguishing attributes of lean and agile paradigm and the position of the OPP

	Typical products		Marketplace demand		Product variety		Customer drivers	
	Standard and configurable (%)	Customizable and unique (%)	Stability (%)	Volatile (%)	Low (%)	High (%)	Cost (%)	Availibility /Service (%)
ETO	0	100	3	97	38	61	49	51
MTO	49	51	15	85	30	72	43	57
ATO	100	0	24	76	18	83	44	56
MTS	100	0	33	67	36	65	48	52

24.5 Conclusions

The analysis of the distinguishing attributes between the lean and agile networks in the capital goods sector shows that agility is one of the most required features to configure networks in order to give the quickest response to customers. Moreover, it seems that there is a correlation between the agile paradigm and the OPP position. In the capital goods sector, the ETO strategy is aligned with the distinguishing attributes of Mason-Jones et al. (2000) approach.

Acknowledgments The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° NMP2-SL-2009- 229333.

References

Bolwijn PT, Kumpe T (1998) Marktgericht ondernemen. Management van continuïteit en vernieuwing. Van Gorcum, Assen

Brown SL, Eisenhardt KM (1998) Competing on the edge, strategy as structured Chaos. Business School Press, Boston

Hoekstra S, Romme J (1992) Integrated logistics structures: developing customer oriented goods flow. McGraw-Hill, London

Khurana A, Talbot B (1999) Plant missions in global manufacturing networks: a resource-based view with evidence from the global color picture tube industry. Working Paper 99-0005. University of Michigan Business School, Ann Arbor, Michigan, USA

Mason-Jones R, Naylor B, Towill DR (2000) Engineering the leagile supply chain. Inter J Agile Manage Syst 2(1):54–61

Naylor JB, Naim MM, Berry D (1997) Leagility: integrating the lean and agile manufacturing paradigm in the total supply chain. Int J Prod Econ 62:107–118

Rudberg M, Olhager J (2002) Manufacturing networks and supply chains: an operations strategy perspective. Omega-Int J Manage S 31:29–39

Sanchis R, Saiz E, Castellano E, Poler R (2012) Order fulfilment strategies in the capital goods sector. An empirical research. In: Industrial engineering: innovative network, vol 29. Springer, pp 257–264

Shi Y, Gregory M (1998) International manufacturing networks—to develop global competitive capabilities, J Oper Manag 16(2, 3):195–214

Chapter 25
Minimizing the Makespan on Parallel Batch Scheduling with Stochastic Times

R. Sahraeian, F. Samaei and I. Rastgar

25.1 Introduction

In this paper, we compare different heuristics for the batch processing machine (BPM) problem scheduling (each batch is a group of different jobs) on a set of identical parallel machines. The BPM have been widely used as semiconductor for printinin chemical industries. The processing time of batch is the longest processing time among the jobs in the batch, and also the longest release time of jobs in batch is equal the batch release time. Set-up time for specific batch depends on the size of the batch. The BPM problems are often bottleneck because of their long processing times; thereby in this scheduling problem makespan is an important objective.

BPM scheduling problems have been studied extensively in recent years. Chandru et al. (1993) presented heuristics and exact methods for parallel batch processing machine and single batch processing machine problems in order to minimum sum of the compellation times. Chang et al. (2004) provided simulated annealing (SA) for problem under study and presented a mathematical formulation for minimizing makespan. Kashan et al. (2008) proposed a Genetic Hybrid which used a local search, and presented a lower bound for minimizing makespan. Cheng et al. (2011) provided mixed integer programming method for minimizing makespan and sum of compellation times of jobs and presented polynomial time algorithm. All mentioned papers have deterministic times but stochastic times are much closer to the real world. So, in this paper, the jobs' processing times, setup times and release times are assumed stochastic for better depiction of the real world. The simulation has been populated over the past three decades. The reason for this is that the simulation model can afford to become quite complex (Kelton et al. 2004). The BPM problem is NP-hard so we design a special simulation

R. Sahraeian (✉) · F. Samaei · I. Rastgar
Department of Industrial Engineering, Shahed University, Tehran, Iran
e-mail: Sahraeian@shahed.ac.ir

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_25, © Springer-Verlag London 2014

approach for stochastic BPM model. The remainder of this paper is structured as follows.

In the next section, the problem definition is presented. Section 25.3 deals with simulation model. Section 25.4 details a brief overview of heuristics. The computational results are presented in Sect. 25.5. Finally, a discussion of the results is explained in the last section.

25.2 Problem Definition

The problem under study using the standard three field notation presented by Graham et al. (1979) can be denoted by $P_m|batch, r_j|C_{max}$. In a BPM, all jobs are divided to different batches. Jobs allocated in a batch are processed simultaneously in start time and then released from the machine together in finish time. The BPM is able to process a number of jobs as long as the sum of job sizes in the batch is not greater than the capacity of the machine. The BPM problem considered in this paper can be described as follows:

1. There are *n* jobs to be processed by *m* identical parallel batch processing machines.
2. All jobs have arbitrary release time and size.
3. The machines are available at zero time.
4. The jobs' processing times and release times are stochastic for better depiction of the real world.
5. The processing time of a batch is defined with the longest processing time of all the jobs allocated in the batch.
6. Once a batch is processed by a machine, it cannot be Interrupted, i.e., no preemption is allowed.
7. No jobs can be introduced or removed from a batch while the batch is being processed.
8. All the jobs are considered equal in importance.
9. The performance measure is makespan. Our objective is to minimize the makespan.

25.3 Simulation Approach

As digital computers appeared in the 1950s and 1960s, people began writing computer programs in general purpose-procedural language like FORTRAN to do simulations of complicated systems. This approach was highly customizable and flexible, but also painfully tedious and error-prone (Kelton et al. 2004). We apply

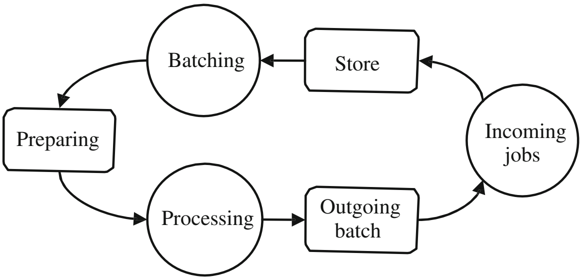


Fig. 25.1 Activity diagram

simulation by programming in MATLAB language because our model is complicated and its framework is not the kind of simulation that many people do like special purpose simulation language like GPSS and SIMAN or high-level simulators like Arena not flexible enough to simulate our model. Discrete-event simulation is used to simulate the real model which is a popular simulation technique, and applicable to a large variety of problems in the real world. In discrete- event simulation, the operation of a system is represented as a chronological sequence of events. Each event occurs at an instant in time and marks a change of state in the system (Stewart 2004).

Many mechanisms have been proposed for carrying out discrete-event simulation; among them are the event-based, activity-based, process-based and three-phase approaches (Pidd 2004). The proposed simulation model applies activity-based mechanism. In the model, jobs are entities and machines are recourses according to Kelton et al. (2004) definition. Figure 25.1 shows activity diagram of the simulation model.

Two phase structure has defined which in the first phase batch sequence based on each heuristic method which has been driven and, in the second phase, discrete-event simulation is applied. Figure 25.2 shows the basic model of the phase two.

Verification plays a very important role in the model results. We use two strategies for verification our model. The first one is applying deterministic data instead of stochastic data for the release, processing and setup times; this allowed

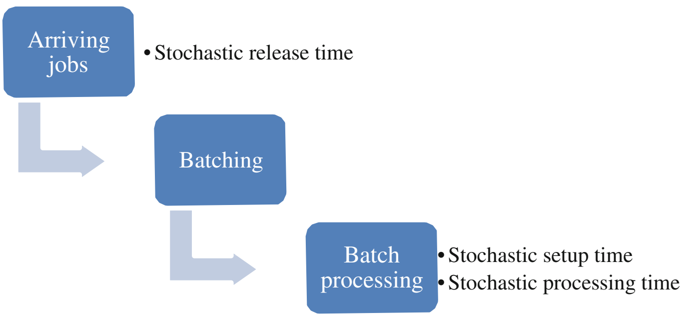


Fig. 25.2 Second phase of simulation model

us to predict the system's behavior. Second strategy is checking outputs in order to match as close as possible with the real data. The verification of simulated model shows valid simulation which has been done.

25.4 Heuristic Algorithms

The BPM belongs to the class of NP-hard problems. Because of its complexity, the instances with a large number of jobs cannot be solved to optimality within a reasonable time. Therefore, many heuristic and meta-heuristic algorithms have been developed in order to find a near optimal solution in reasonable computational time. In this section, different heuristics are presented. The Marginal Cost heuristic (Damodaran and Velez-Gallego 2010) is applied to batching arriving jobs. Then the four flowing heuristics apply to schedule batches.

25.4.1 ERT

In the ERT (Equalization of Runout Time) rule, the batches are listed in non-decreasing order of their release times (break ties using LPT-Longest Processing Time first), and following that order, each batch is assigned to the first available machine.

25.4.2 ERT-LPT

In the ERT–LPT rule, the batches are listed in non-decreasing order of their release times (break ties using LPT), and following that order, the batches are assigned to the first available machine until the minimum machine release time is greater or equal to the maximum batch release time. At this point, the batches are assigned to the first available machine by applying the LPT rule.

25.4.3 ERT-SPT

In the ERT–LPT rule, the batches are listed in a non-decreasing order of their release times (break ties using LPT), and following that order, the batches are as signed to the first available machine until the minimum machine release time is greater than or equal to the maximum batch release time. At this point, the batches are assigned to the first available machine by applying the SPT (Shortest Processing Time first) rule.

25.4.4 LECT

In LECT rule, the earliest completion time of each batch (i.e., $C_j = r_j + P_j$) is computed. The batches are then listed in non-increasing order of C_j, and following that order, each batch is assigned to the first available machine.

25.5 Computational Results

The simulation has been coded in MATLAB 7.1. The presented heuristics have been modeled and compared using the proposed simulation model. All three stochastic times take value of different uniform distributions. We used uniform distributions because of their high variances which ensuring that the presented heuristics are being tested under unfavorable conditions Weng et al. (2001).

Eight test problems according to Table 25.1 randomly generated. Random generation is based on Kashan et al. (2008) paper. For each problem, all approaches have been applied and for each case 10,000 runs have been applied.

The number of runs or replications was obtained by following the steps that Banks et al. (2004) recommended in order to obtain good confidence intervals. We decided on the tolerable half width that the appropriate values in the following equation which based on $100(1-\alpha)\%$ confidence t distribution:

$$H = t_{\frac{\alpha}{2},R-1}\frac{S}{\sqrt{R}} \tag{25.1}$$

where $S2$ is sample variance and R is the number of runs. Supposing that an error criterion ε is specified; a sample size R must be chosen such that $R \geq R_0$ and $H \leq \varepsilon$. The error criterion is $\varepsilon = 0.001$, and the confidence coefficient is $1-\alpha = 0.99$.

Table 25.2 illustrates the relative performance of four heuristics. The ERT-LPT method significantly outperformed the other methods for all test problems. The relative performance for method k was calculated as follows:

Table 25.1 Test problems

Test problem	Machine	Job
1	2	10
2	2	25
3	2	50
4	2	100
5	4	10
6	4	25
7	4	50
8	4	100

Table 25.2 Relative performance obtained from simulation

Test problem	ERT	ERT-LPT	ERT-SPT	LECT
1	0.9647	1	0.9277	0.9484
2	0.9708	1	0.9542	0.9601
3	0.9771	1	0.9329	0.9552
4	0.9669	1	0.9662	0.9648
5	0.9843	1	0.9558	0.9512
6	0.9692	1	0.9236	0.9209
7	0.9798	1	0.9614	0.9643
8	0.9654	1	0.9293	0.9265

$$RP_k = \frac{c_k}{c_{\min}} \tag{25.2}$$

where C_k is the makespan of heuristic k and C_{min} refers to the minimum makespan between all four heuristics.

25.6 Output Analysis

For better understanding the behavior of model, the sensitivity analysis has been done for test problem 3. Figure 25.3 shows the sensitivity of stochastic release time which processing time and setup time considered deterministic. As it can be seen, the performance of methods will be closed by increasing the interval of uniform distribution. Figure 25.4 shows the sensitivity of stochastic processing time and setup time, respectively. It is obvious that stochastic processing time and setup time do not have significantly influence whereas stochastic release time has. Figure 25.5 shows the sensitivity of all stochastic times together.

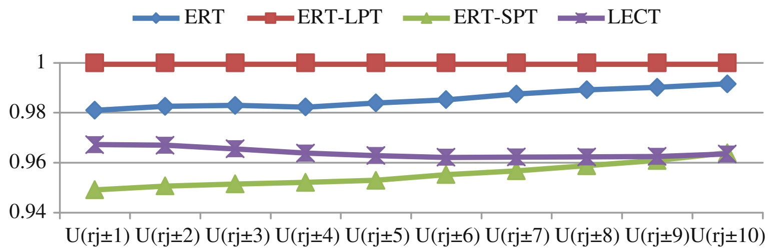


Fig. 25.3 The sensitivity of release time

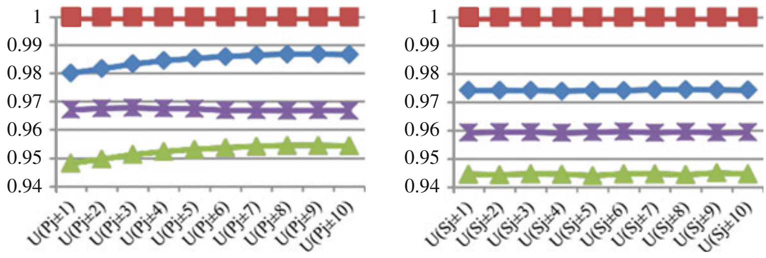


Fig. 25.4 The sensitivity of setup time (*left*) and the sensitivity of processing time (*right*)

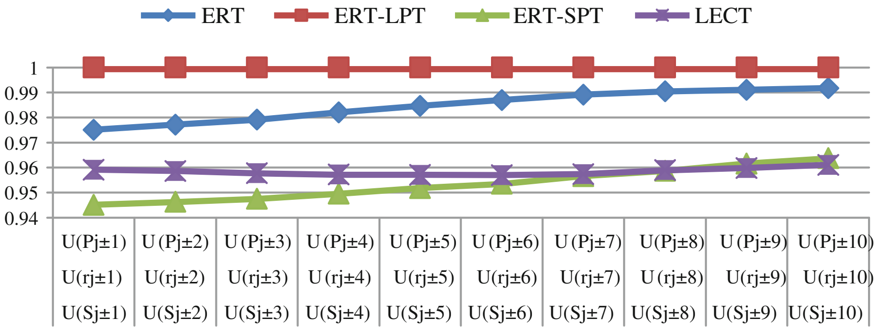


Fig. 25.5 The sensitivity of interval of uniform distribution for all stochastic times

25.7 Conclusions

In this paper, the special simulation approach was developed to simulate the batch processing machine model. It was used to analyze the performance of four heuristics. The ERT-LPT method outperformed significantly the other methods for all test problems. The four heuristics presented in this paper were also tested in a deterministic model, and the results obtained were similar to the stochastic model in the sense that ERT-LPT significantly outperformed the other methods. So we can conclude that this procedure is the first strategy of verification.

References

Banks J, Carson J, Nelson BL, Nicol D (2004) Discrete-event system simulation, 4th edn. Prentice Hall

Chandru V, Lee C, Uzsoy R (1993) Minimizing total completion time on batch processing machine. Int J Prod Res 31:2097–2121

Chang P, Damodaran P, Melouk S (2004) Minimizing makespan on parallel batch processing machines. Int J Prod Res 42:4211–4220

Cheng B, Yang S, Hu X, Chen B (2011) Minimizing makespan and total completion time for parallel batch processing machines with non-identical job sizes. Appl Math Model 1:1010–1016

Damodaran P, Velez-Gallego MC (2010) Heuristics for makespan minimization on parallel batch processing machines with unequal job ready times. Int J Adv Manuf Technol 49:1119–1128

Graham R, Lawler E, Lenstra J, Rinnooy Kan A (1979) Optimization and approximation in deterministic sequencing and scheduling: a survey. Ann Discret Mathem 5:287–326

Kashan A, Karimi B, Jenabi M (2008) A hybrid genetic heuristic for scheduling parallel batch processing machines with arbitrary job sizes. Comput Oper Res 35:1084–1098

Kelton D, Sadowski R, Sturrock D (2004) Simulation with arena, 3rd edn. McGraw-Hill, New York

Pidd M (2004) Computer simulation in management science, 5th edn. Wiley

Stewart R (2004) Simulation: the practice of model development and use. Wiley

Weng M, Lu J, Ren H (2001) Unrelated parallel machine scheduling with setup consideration and a total weighted completion time objective. Int J Prod Econ 70(3):215–226

Chapter 26
A Makespan Minimization in an m-Stage Flow Shop Lot Streaming with Sequence Dependent Setup Times: MILP Model and Experimental Approach

Pedro Gómez-Gasquet, Rubén Segura Andrés, Rubén D. Franco Pereyra and Carlos Andrés-Romano

26.1 Introduction

Lot Streaming (LS) is a concept that allows splitting jobs in smaller entities, sublots, what makes easier material transfer between stages. In the no hybrid flow shop, LS makes possible makespan or Cmax reduction such as it is showed in Fig. 26.1. Nevertheless, industrial companies should value if this reduction is enough in order to be worthy the increment of the complexity in the management that supposes the increase of materials flow in the shop. Besides of a LS use analysis in terms of Cmax reduction, it must not be subestimated the difficulty increase that involves job splitting, in a complex problem itself. In the Fig. 26.1, it is shown an example in what the use or not of LS is compared, in a two-stage flow shop with 3 jobs.

In this paper, a literature review is carried out in Sect. 26.2. Problem definition for a general case with m stages and n jobs through a MILP model is introduced in Sect. 26.3. A mathematical model for the two- and three-stages problem is instantiated in Sect. 26.4 with the objective of showing in a simple case the potential benefits of LS technics as well as the limitation in the use of optimum technics. Finally, in Sect. 26.5 conclusions are summarized.

P. Gómez-Gasquet (✉) · R. Segura Andrés · R. D. Franco Pereyra · C. Andrés-Romano
Centro de Investigación de Gestión e Ingeniería de la Producción (CIGIP), Universitat Politècnica de València, De Vera s/n 46022 Valencia, Spain
e-mail: pgomez@cigip.upv.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_26,

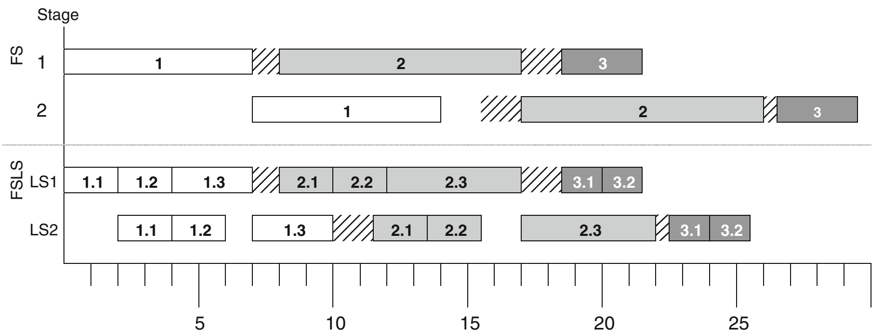


Fig. 26.1 Flow shop versus flow shop lot streaming

26.2 Literature Review

An analysis in a Flow Shop environment (FS) will be presented in this paper. We will compare the use of lot streaming versus not using it. Many years have passed since the first paper about flow shop (FS) was published (Johnson 1954). From that paper up to now have passed more than five decades in which researchers have published hundreds of papers, some of them presented in a FS review (Gupta and Stafford Jr. 2006). The concept of lot streaming was introduced a decade after Johnson's paper (Reiter 1966) with the aim of improving the objective function in a certain type of problems through splitting jobs into smaller sublots. Whereas the most difficult task in an n jobs FS problem is defining the sequence of jobs, when we combine FS and lot streaming (FSLS) we increase the difficulty of the problem; we need to decide the number of sublots besides the sequence, and even it might be necessary decide the size of each sublot also. One problem of this type, with only two machines, it could be classified as a NP-hard due to its complexity and the possibility of multiple combinations (Glass and Possani 2011). A simple two-machine example showed that, an optimal solution generally cannot be found when the sequencing approach and the splitting approach are used independently (Potts and Baker 1989). They suggested that the two approaches should be used simultaneously. There are problems that have not yet been addressed in any paper up to date such as it is showed in a wide FSLS review (Sarin and Jaiprakash 2007) or in the work of(Martin 2009) or (Feldmann and Biskup 2007).

In-between different operations in a FS configuration, it may appear setup times to reconfigure each machine to the next sublot; this sublot may be part of the same job or even though from a different one. To reduce the gap, setup concept has been widely tackled in FS environments (Allahverdi et al. 1999). In this paper, setup times will be sequence dependent (SDST); setups depend not only on the job to be processed next, but also on its immediately preceding job on the same machine. Different authors have published m machines FSLS papers with SDST for minimizing makespan as objective function using genetic algorithm (GA) (Lee et al.

1997) or discrete harmony search (Pan et al. 2010). However, none of them achieved an optimal solution.

In a wide range of industrial situations, companies usually work in FS configurations, where in one or more stages it may be available more than one resource to perform their operations. This configuration it is known as Hybrid Flow Shop (HFS) and recently was published a review of the published papers (Ruiz and Vázquez-Rodríguez 2010).

In this paper, we will analyze two different problems: FS versus FS lot streaming (FSLS). We will consider also sequence dependent setup times (SDST).

26.3 Model Definition

Lot streaming problems under study will be defined following the notation described in Sarin and Jaiprakash (2007) as reference. Our model will be *M/N/C/II/DV/{SDST,*C_{max}*}*. This model consists in a flow shop (FS) of *m* stages (M), one machine per stage, where *n* jobs (N) must be processed. Each job consists of U_i identical units. A job can be split into sublots that will be treated as separate entities in production. Each sublot requires processing on any of the machines in all stages. Sublots are consistent (C); the size of each sublot is kept constant on all stages. Intermittent idling (II) is allowed and sublots sizes have discrete values (DV). Setup times will be sequence dependent (SDST) and the objective is to minimize makespan (C_{max}).

The following assumptions are made: (1) all jobs are available at time zero; (2) the processing time of each item is known and deterministic; (3) no preemption is allowed; (4) there is a given smallest allowable size for the sublots of each job; (5) machines are available at any time; (6) each machine can process at most one sublot at a time; (7) each sublot can be processed on one machine at a time; (8) interleaving of sublots of different lots is not allowed.

The problem consists to decide number and size of sublots, for each job, as well as schedule them to minimize makespan. With the aim of constructing a general mathematical model, the information will be presented using the following indexes:

i	index set of jobs $\{0..n\}$;	t, t'	index set of jobs $\{0..n+1\}$
h	index set of jobs $\{1..n+2\}$;	b, b'	index set of jobs $\{0..n+2\}$
l, v	index set of sublots of *i* job $\{0..L_i\}$		
r	index set of stages on the shop $\{1..R\}$		
j, f	index set of machines in *r* stage $\{1..m_r\}$		

Parameters in the model are the data known beforehand:

Z_i	number of units in job *i*
z_i	minimum size of each sublot in job *i*

$P_{i,j,r}$	processing time for units of job *i* on machine *j* at stage *r*
$S^{X}_{t,t',j,r}$	setup time for a sublot of job *t'*, preceded by a sublot of job *t*, on machine *j* at the stage *r*
$S^{m}_{i,j,r}$	setup time for a sublot of job *i*, preceded by a sublot of job *i*, on machine *j* at the stage *r*
M	a very large positive number (larger than makespan)

MILP model determines the following variables:

$X_{l,i,j,r}$	(integer) number of units in sublot *l* of job *i* assigned to machine *j* at stage *r*
$C_{l,t,j,r}$	(integer) completion time of sublot *l* of job *t* on machine *j* at stage *r*
K_i	(integer) completion time of job *i* (it corresponds to the maximum $C_{l,i}$)

Note that for a given job *i* and sublot *l*, $X_{l,i,j,r} > 0$ for at most one machine *j* ($j = 1\ldots m_r$) in stage *r*, indicating that sublot *l* of job *i* is allocated to machine *j* at the *r* stage.

$$\mathbf{y}_{l,i,j,r} = \begin{cases} 1, \text{ if sublot } l \text{ of job } i \text{ is performed on machine } j \text{ at stage } r \\ 0, \text{ otherwise} \end{cases}$$

$$\mathbf{q}_{l,b,v,b',j,r} = \begin{cases} 1, \text{ if sublot } l \text{ of job } b \text{ is performed before sublot } v \text{ of job } b' \\ \quad \text{on machine } j \text{ at stage } r \\ 0, \text{ otherwise} \end{cases}$$

With these notations, the problem can be formulated as the following MILP model. The objective is to minimize makespan (26.1):

$$\boldsymbol{F.O.}\ \ \boldsymbol{min}\left\{\boldsymbol{max}_i^n\{\boldsymbol{C_i}\}\right\} = \boldsymbol{C_{max}} \tag{26.1}$$

The constraints of the model are presented below in three sets, each representing one type of system constraint. The model is subject to:

Precedence constraints: This set of constrains ensures the processing order of sublots

$$\boldsymbol{C_{l,i+1,j,r}} \geq \boldsymbol{C_{v,t,j,r}} + \boldsymbol{P_{i,j,r}} * \boldsymbol{X_{l,i,j,r}} + \left(\boldsymbol{S^X_{t,i+1,j,r}} + \boldsymbol{S^m_{i+1,j,r}}\right) + \boldsymbol{M} * \boldsymbol{q_{v,t,l,i+1,j,r}} - \boldsymbol{M} \quad \forall \boldsymbol{l}, \forall \boldsymbol{v}, \forall \boldsymbol{t}, \forall \boldsymbol{i}, \forall \boldsymbol{j}, \forall \boldsymbol{r} \tag{26.2}$$

$$\boldsymbol{C_{l,i+1,j,r}} - \boldsymbol{P_{i,j,r}} * \boldsymbol{X_{l,i,j,r}} \geq 0 \quad \forall \boldsymbol{l}, \forall \boldsymbol{i}, \forall \boldsymbol{j}, \forall \boldsymbol{r} \tag{26.3}$$

$$\boldsymbol{C_{l,i+1,j,r}} - \boldsymbol{P_{i,j,r}} * \boldsymbol{X_{l,i,j,r}} \geq \boldsymbol{C_{l,i+1,f,r-1}} + \boldsymbol{Y_{l,i,j,r}} * \boldsymbol{M} - \boldsymbol{M} \qquad \forall \boldsymbol{l}, \forall \boldsymbol{i}, \forall \boldsymbol{j}, \forall \boldsymbol{f}, \forall \boldsymbol{r} > 1 \tag{26.4}$$

$$\sum\nolimits_{t=0}^{n+1} \sum\nolimits_{v=0}^{L_t} \boldsymbol{q_{v,t,l,i+1,j,r}} - \boldsymbol{Y_{l,i,j,r}} = 0 \qquad \forall \boldsymbol{l}, \forall \boldsymbol{i}, \forall \boldsymbol{j}, \forall \boldsymbol{r} \tag{26.5}$$

$$\sum_{h=1}^{n+2}\sum_{v=0}^{L_h} q_{l,i+1,v,h,j,r} - Y_{l,i,j,r} = 0 \qquad \forall l, \forall i, \forall j, \forall r \tag{26.6}$$

$$\sum_{h=1}^{n+2}\sum_{v=0}^{L_h} q_{0,0,v,h,j,r} = 1 \qquad \forall j, \forall r \tag{26.7}$$

$$\sum_{t=0}^{n+1}\sum_{v=0}^{L_t} q_{v,t,0,n+1,j,r} = 1 \qquad \forall j, \forall r \qquad \forall l, \forall i, \forall j, \forall r \tag{26.8}$$

$$C_{0,0,j,r} = 0 \qquad \forall j, \forall r \tag{26.9}$$

$$q_{l,i+1,l+1,i+1,j,r} = \sum_{j=0}^{m_r} Y_{l+1,i,j,r} \qquad \forall l < L_i, \forall i, \forall j, \forall r \tag{26.10}$$

Constraint (26.2) ensures that a sublot cannot start on machine j at stage r before the previous sublot in the same machine j at the same stage r has been completely processed for any job at any stage. Constraint (26.3) ensures that the first sublot on machine j at stage r can be completed only after it has been on the machine for the necessary processing time. Constraint (26.4) ensures that a sublot of a job cannot start in the next stage before it has been completed in the actual stage. Constraints (26.5) and (26.6) ensures that every sublot must have a previous one (26.5) and another one which comes later (26.6). Constraints (26.7), (26.8) and (26.9) define all the fictitious jobs so each job will have an initial and a last job. Constraint (26.10) is used to avoid interleaving on the problem. It makes that every job must be performed continuosly; sublot $l + 1$ will be processed just after it is finished sublot l in the same machine.

Constraints related to sublot sizes:

$$\sum_{j=0}^{m_r} Y_{l,i,j,r} \le 1 \qquad \forall l, \forall i, \forall r \tag{26.11}$$

$$X_{l,i,j,r} \ge z_i * Y_{l,i,j,r} \qquad \forall l, \forall i, \forall j, \forall r \tag{26.12}$$

$$X_{l,i,j,r} \le Z_i * Y_{l,i,j,r} \qquad \forall l, \forall i, \forall j, \forall r \tag{26.13}$$

$$\sum_{l=0}^{L_i}\sum_{j=0}^{m_r} X_{l,i,j,r} = Z_i \qquad \forall i, \forall r \tag{26.14}$$

$$\sum_{j=0}^{m_r} Y_{l,i,j,r} \ge \sum_{j=0}^{m_r} Y_{l+1,i,j,r} \qquad \forall l < L_i, \forall i, \forall r \tag{26.15}$$

$$\sum_{j=0}^{m_r} X_{l,i,j,r} = \sum_{j=0}^{m_{r+1}} X_{l,i,j,r+1} \qquad \forall l, \forall i, \forall r < R \tag{26.16}$$

$$\sum_{l=0}^{L_i}\sum_{j=0}^{m_r} Y_{l,i,j,r} = \sum_{l=0}^{L_i}\sum_{j=0}^{m_{r+1}} Y_{l,i,j,r+1} \qquad \forall i, \forall r < R \tag{26.17}$$

$$q_{l,i+1,l,i+1,j,r} = 0 \qquad \forall l, \forall i, \forall j, \forall r \tag{26.18}$$

Constraints (26.11), (26.12) and (26.13) define Y variables. Constraint (26.14) ensures that all the units are processed for all job at all stage. Constraint (26.15) ensures that sublots with a null number of units are required to follow the ones with units for each job at each stage. Constraint (26.16) ensures that the size of each sublot will remain equal in all job at all the stages. Constraint (26.17) ensures that the number of sublots will remain equal in all jobs at all stages. Constraint (26.18) avoids redundancy to process sublots that they have been already processed.

26.4 Experimental Analysis and Results

With the experimental analysis it is possible to notice makespan minimization using lot streaming technics (LS) in the case of $m/6/C/II/DV/\{SDST, C_{max}\}$ with m = 2 and m = 3. Besides it is possible to assess the existing percentage of makespan reduction. Due to the theoretical difficulty the problem arise, it is proposed to analyze in what degree the increase in the computational effort is profitable in an industrial environment, and if substituting the optimizing technic by a sub-optimum one it would be recommendable in terms of efficiency because, obviously, it will not be in terms of invested time.

The experiment is based in the resolution of the mathematical model discussed in the Sect. 26.3, using Gurobi Optimizer 4.6 in different scenarios. In all cases, unitary process times per stage and size of jobs are generated with a uniform distribution between [1…6] and [1…30] respectively. Minimum sublot size considered is 1 unit. For its analysis, design of experiments (DoE) has been performed with two factors: setup times (SDST) and number of stages (Stg). In the case of SDST, three different values have been considered, 10, 30 and 50 % time of the process time, all of them generated with a uniform distribution. Stg factor analyses of two- and three-stage shops. In every scenario a total of 5 replications have been performed. Dependent variable of the experiment is Cmax reduction percentage (rCmax), expressed in (Ec. 19) $rCmax = (CmaxLS - Cmax)/Cmax$, being Cmax the obtained value without LS and CmaxLS, same example with LS. Due to the required computational effort for the LS case, analyzed values in the problem correspond to the 7.200 s, hence sub-optimum. In the case without LS optimal values have been always achieved.

The results shown that in all cases the Cmax was bigger than CmaxLS, in other words LS approach is suitable for the problem. But in the Table 26.1 ANOVA

Table 26.1 Analysis of variance for rCmax—type III sums of squares

Source	Sum of squares	Df	Mean square	F-ratio	P-value
Main effects					
A:SDSS	660,527	2	330,263	0.13	0.8758
B:Stg	103,103	1	103,103	41.62	0.0000
Interactions					
AB	125,672	2	628,362	0.25	0.7780
Residual	594,484	24	247,702		
Total (corrected)	164,469	29			

All F-ratios are based on the residual mean square error analysis shows as results using LS are not dependent on setup time values. However, the increment of stage from 2 to 3 influences in the makespan, the mean of rCmax passes from −7.8 to −19.5 %. In terms of an industrial application an improvement of 19.5 %, even if setup times were high, could be consider excellent.

In the same experiment results of makespan for LS at 200 s were recorded, but the ANOVA of this new rCmax(200) shown no significant factors. It indicates the problem presented is very difficult to solve especially when LS is applied.

26.5 Conclusions

After the comparison between a flow shop with and without using lot streaming, we can conclude that the problem presented is, as it is highlighted in Sect. 26.2, an interesting challenge from research point of view, where further research needs to be carried out in order to exploit this technic/concept properly. This technic might improve companies' efficiency when it is possible to apply. And we should not forget that these problems, once we introduce SDST combined with lot streaming, are NP-hard.

At the same time, the experimental analysis that deal with a representative industrial situation, although not too complex, it makes clear that in all cases, makespan is minimized with the use of lot streaming techniques although it is not better as longer setup times are as initially thought. However, its industrial application needs to be validated due to it persist the doubt if the makespan minimization compensates the complexity in the materials flow management that entails its startup over all for small shops.

Finally, it is worth pointing out the makespan difference achieved in 7,200 s is lightly better than the one in 200 s obtained for 2-stage problem but much better form 3-stage problem. This means, from our point of view, optimal approaches need so much time in order to reach a solution where the problem is complex but well-oriented suboptimal approach could be a well balanced method in terms of makespan and computational efforts.

In the future, our research will introduce and consider more realistic approaches such as Hybrid FS environments (HFS). When we combine HFS and lot streaming it increases the difficulty to find some relevant papers on the topic.

This work has been carried out as part of the project "PAID-06-10-2396 (NegoSol-MAS)"funded by Vicerrectorado de Investigación of Universitat Politècnica de València and the project "Programación de la Producción con Partición Ajustable de Lotes en entornos de Planificación mixta Pedido/Stock (PP-PAL-PPS) ref. GVA/2013/034" funded by Conselleríade Educación, Cultura y Deportes de la Generalitat Valenciana.

References

Allahverdi A, Gupta JN, Aldowaisan T (1999) A review of scheduling research involving setup considerations. Omega 27(2):219–239. doi:10.1016/S0305-0483(98)00042-5

Feldmann M, Biskup D (2007) Lot streaming in a multiple product permutation flow shop with intermingling. Int J Prod Res 46(1):197–216. doi:10.1080/00207540600930065

Glass CA, Possani E (2011) Lot streaming multiple jobs in a flow shop. Int J Prod Res 49(9):2669–2681. doi:10.1080/00207543.2010.532935

Gupta JND, Stafford EF Jr (2006) Flowshop scheduling research after five decades. Eur J Oper Res 169(3):699–711. doi:10.1016/j.ejor.2005.02.001

Johnson SM (1954) Optimal two- and three-stage production schedules with setup times included. Naval Res Logistics Q 1(1):61–68. doi:10.1002/nav.3800010110

Lee I, Sikora R, Shaw MJ (1997) A genetic algorithm-based approach to flexible flow-line scheduling with variable lot sizes. IEEE Trans Syst Man Cybern B Cybern 27(1):36–54. doi:10.1109/3477.552184

Liu J (2008) Single-job lot streaming in m − 1 two-stage hybrid flowshops. Eur J Oper Res 187(3):1171–1183. doi:10.1016/j.ejor.2006.06.066

Martin CH (2009) A hybrid genetic algorithm/mathematical programming approach to the multi-family flowshop scheduling problem with lot streaming. Omega 37(1):126–137. doi:10.1016/j.omega.2006.11.002

Pan Q-K, Duan J, Liang JJ, Gao K, Li J (2010) A novel discrete harmony search algorithm for scheduling lot-streaming flow shops. In: Proceedings of control and decision conference (CCDC), 2010, IEEE. pp 1531–1536 doi:10.1109/CCDC.2010.5498265

Potts CN, Baker KR (1989) Flow shop scheduling with lot streaming. Oper Res Lett 8(6):297–303. doi:10.1016/0167-6377(89)90013-8

Reiter S (1966) A system for managing job-shop production. J Bus 39(3):371–393

Ruiz R, Vázquez-Rodríguez JA (2010) The hybrid flow shop scheduling problem. Eur J Oper Res 205(1):1–18. doi:10.1016/j.ejor.2009.09.024

Sarin SC, Jaiprakash P (2007) Flow shop lot streaming. Springer, Berlin

Zhang W, Yin C, Liu J, Linn RJ (2005) Multi-job lot streaming to minimize the mean completion time in m-1 hybrid flowshops. Int J Prod Econ 96(2):189–200. doi:10.1016/j.ijpe.2004.04.005

Chapter 27
A Modified Approach Based on Ranking Fuzzy Numbers for Fuzzy Integer Programming with Equality Constraints

Manuel Díaz-Madroñero, Josefa Mula and Mariano Jiménez

27.1 Introduction

Integer linear programming problems have an outstanding relevance in many fields, such as those related to production planning and transport planning problems when the product units are required to be defined with integer values. Furthermore, production and transport planning decisions are used to be made under uncertainty (Mula et al. 2006b). According to Mula et al. (2006a), it can be distinguished between randomness or uncertainty corresponding to an objective variability in the model parameters, or epistemic uncertainty or lack of knowledge of the parameter values. Epistemic uncertainty, which is considered in this paper, is concerned with ill-known parameters modelled by fuzzy intervals in the setting of possibility theory (Zadeh 1978; Dubois and Prade 1988). Herrera and Verdegay (1995) present methods to solve fuzzy integer linear programming problems with either fuzzy constraints, or fuzzy numbers in the objective function or fuzzy numbers defining the set of constraints. These methods are based on the representation theorem and on fuzzy number ranking methods. However, the authors do not consider equality constraints.

This paper considers integer linear programming problems with equality constraints whose cost/profit coefficients of the objective function and right hand side terms of constraints are defined by fuzzy numbers but whose decision variables are

M. Díaz-Madroñero · J. Mula (✉)
Centro de Investigación en Gestión e Ingeniería de Producción (CIGIP), Escuela Politécnica, Superior de Alcoy, Plaza Ferrándiz y Carbonell 2, 03801 Alcoy, Alicante, Spain
e-mail: fmula@cigip.upv.es

M. Díaz-Madroñero
e-mail: fcodiama@cigip.upv.es

M. Jiménez
Dto. de Economía Aplicada I, Escuela Universitaria de Estudios Empresariales, Universidad del País Vasco-Euskal Herriko Unibersitatea, Plaza Oñati 1, 20018 San Sebastián, Spain
e-mail: mariano.jimenez@ehu.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_27,

crisp. In order to handle the relationship between the fuzzy left and the fuzzy right hand side of the constraints and to find the optimal value for the fuzzy objective function we propose a modified approach of the method of ranking fuzzy numbers by Jiménez (1996) and Jiménez et al. (2007) to solve integer linear programming problems. This method has been previously applied but for linear programming problems (Peidro et al. 2010). With the aim of validating our proposal, we apply it to a fuzzy integer transportation problem (FITP) with equality constraints. The parameters of each transportation problem are unit costs (profits) and demand and supply (production, storage capacity) values. In practice, these parameters are fuzzy in nature. Chanas and Kuchta (1998) propose an alternative algorithm to solve the transportation problem with crisp costs, fuzzy supply and demand values and the integrity condition imposed on the solution. The rest of the paper is structured as follows. Section 27.2 presents the FITP problem and the notation used. Section 27.3 develops the solution of the problem. Section 27.4 solves a FITP and compares the results of three methods: the proposal by Jiménez et al. (2007) for linear programming problems, dubbed as LFRN; the LFRN forcing the decision variables to be integer, dubbed as IFRN; and our proposal, dubbed as MFRN, which is the modification proposed in this paper to introduce the integer decision variables in LFRN to solve the unfeasibility problems that arise with IFRN. Finally, Sect. 27.5 provides the conclusions and further research.

27.2 Formulation of the Problem and Notation

The FITP considered in this paper can be described as follows. We assume a decision-maker who seeks to determine the right transportation planning of a homogeneous commodity from m sources to n destinations. Each destination is characterized by a forecasted demand which can be fulfilled with amounts of the commodity received from several sources, and each source has a total available supply capacity of the commodity to distribute to various destinations. The total available supply capacity for each source, the total forecast demand for each destination, and transport costs from each source to each destination are considered fuzzy due to incomplete or unobtainable information over the planning horizon. The purpose of the FITP is to minimize total transportation costs by using fully the available supply capacity at each source, and meeting the demand exactly at each destination. The sets of indices, parameters and decision variables for the FITP model are defined in the nomenclature (see Table 27.1).

The FITP is formulated as follows:

$$\text{Minimize } z \cong \sum_{i=1}^{I} \sum_{j=1}^{J} \tilde{c}_{ij} X_{ij} \tag{27.1}$$

Table 27.1 Nomenclature (fuzzy parameters are shown with a *tilde* ($\sim$))

Sets of indices		Decision variables	
i	Set of sources ($i = 1,\ldots,I$)	X_{ij}	Units transported from source i to destination j (units)
j	Set of destinations ($j = 1,\ldots,J$)		
Parameters			
$\widetilde{C}_{ij}$	Transportation cost per unit delivered from source i to destination j (€/unit)	$\widetilde{D}_i$	Total forecast demand of each destination j (units)
$\widetilde{S}_i$	Total available supply for each source i (units)		

Subject to

$$\sum_{j=1}^{J} X_{ij} = \tilde{S}_i \quad \forall i \tag{27.2}$$

$$\sum_{i=1}^{I} X_{ij} = \tilde{D}_j \quad \forall j \tag{27.3}$$

$$X_{ij} \geq 0, \text{ integer} \quad \forall i \, \forall j \tag{27.4}$$

According to Liang (2008), in real-world transportation problems, constraints (27.2) and (27.3) are fuzzy in nature. Constraint (27.2) corresponds to the total available supply for each source i and constraint (27.3) is related to the total forecast demand for each destination j. The total available supply in constraint (27.2) for each source is commonly uncertain because available resources, worker skills, public policy and other factors are uncertain over the planning horizon. Additionally, the forecast demand in constraint (27.3) for each destination can never be determined precisely because the demand and supply in a dynamic market are uncertain. Moreover, transport costs are considered uncertain data and are modeled by fuzzy trapezoidal numbers $\tilde{c}_{ij} = (c_{ij1}, c_{ij2}, c_{ij3}, c_{ij4})$, as well as, available supply $\tilde{S}_i = (S_{i1}, S_{i2}, S_{i3}, S_{i4})$ and forecasted demand $\tilde{D}_j = (D_{j1}, D_{j2}, D_{j3}, D_{j4})$.

27.3 Solution of the Problem

27.3.1 Transformation of the Fuzzy Mixed-Integer Linear Programming Model into an Equivalent Crisp Model According to Jiménez et al. (2007)

In this section, to address the fuzzy costs and right-hand side parameters of the FITP model, and to transform it into an equivalent auxiliary crisp integer linear programming model, we consider firstly the approach by Jiménez et al. (2007). Let us consider the following linear programming problem with fuzzy parameters:

$$\begin{aligned} &\text{Min } z = \tilde{c}^t x \\ &\text{s.a. } x \in N(A,b) = \{x \in R^n | \tilde{a}_i x \geq \tilde{b}_i, \quad i = 1,\ldots,m, x \geq 0\} \end{aligned} \tag{27.5}$$

where $\tilde{c} = (\tilde{c}_1, \tilde{c}_2, \ldots, \tilde{c}_n)$, $\tilde{A} = [\tilde{a}_{ij}]_{mxn}$, $\tilde{b} = (\tilde{b}_1, \tilde{b}_2, \ldots, \tilde{b}_n)^t$ represent, respectively, fuzzy parameters involved in the objective function and constraints. The possibility distribution of fuzzy parameters is assumed to be characterized by fuzzy numbers. $x = (x_1, x_2, \ldots, x_n)$ is the crisp decision vector. We use a fuzzy relationship to compare fuzzy numbers that is computationally efficient to solve linear problems because it preserves its linearity (Jiménez 1996). Thus, by applying the approach described by Jiménez et al. (2007) the problem (27.5) is transformed into the crisp equivalent parametric linear programming problem defined in (27.6).

$$\begin{aligned} &\text{Min } EV(\tilde{c})x \\ &\text{s.a. } [(1-\alpha) E_2^{a_i} + \alpha E_1^{a_i}] x \geq \alpha E_2^{b_i} + (1-\alpha) E_1^{b_i}, \quad i = 1,\ldots,m, \quad x \geq 0, \quad \alpha \in [0,1] \end{aligned} \tag{27.6}$$

where α represents the degree that, at least, all the constraints are fulfilled; that is, α is the feasibility degree of a decision x. The expected value of a fuzzy number, noted $EV(\tilde{c})$, is the half point of its expected interval (Heilpern 1992):

$$EV(\tilde{c}) = \frac{E_1^c + E_2^c}{2} \tag{27.7}$$

and if the fuzzy number $\tilde{c}$ is trapezoidal, its expected interval is easily calculated as follows:

$$EI(\tilde{c}) = [E_1^c, E_2^c] = \left[\frac{1}{2}(c_1 + c_2), \frac{1}{2}(c_3 + c_4)\right] \tag{27.8}$$

As (27.5) is considered an equality type constraint, this could be transformed into two equivalent crisp constraints:

$$\begin{aligned} &\left[\left(1 - \frac{\alpha}{2}\right) E_1^{a_i} + \frac{\alpha}{2} E_2^{a_i}\right] x \leq \frac{\alpha}{2} E_1^{b_i} + \left(1 - \frac{\alpha}{2}\right) E_2^{b_i}, \quad i = 1,\ldots,m, \quad x \geq 0, \quad \alpha \in [0,1] \\ &\left[\left(1 - \frac{\alpha}{2}\right) E_2^{a_i} + \frac{\alpha}{2} E_1^{a_i}\right] x \geq \frac{\alpha}{2} E_2^{b_i} + \left(1 - \frac{\alpha}{2}\right) E_1^{b_i}, \quad i = 1,\ldots,m, \quad x \geq 0, \quad \alpha \in [0,1] \end{aligned} \tag{27.9}$$

Consequently by applying this approach to the previously defined FITP model, and by considering trapezoidal fuzzy numbers for the uncertain parameters, we obtain an auxiliary crisp integer linear programming model as follows:

$$\text{Minimize } z = \sum_{i=1}^{I} \sum_{j=1}^{J} \left(\frac{c_{ij1} + c_{ij2} + c_{ij3} + c_{ij4}}{4} \cdot X_{ij} \right) \tag{27.10}$$

Subject to

$$\sum_{j=1}^{J} X_{ij} \leq \frac{\alpha}{2} \cdot \frac{S_{i1} + S_{i2}}{2} + \left(1 - \frac{\alpha}{2}\right) \frac{S_{i3} + S_{i4}}{2} \quad \forall i \tag{27.11}$$

$$\sum_{j=1}^{J} X_{ij} \geq \frac{\alpha}{2} \cdot \frac{S_{i3} + S_{i4}}{2} + \left(1 - \frac{\alpha}{2}\right) \frac{S_{i1} + S_{i2}}{2} \quad \forall i \tag{27.12}$$

$$\sum_{i=1}^{I} X_{ij} \leq \frac{\alpha}{2} \cdot \frac{D_{j1} + D_{j2}}{2} + \left(1 - \frac{\alpha}{2}\right) \frac{D_{j3} + D_{j4}}{2} \quad \forall j \tag{27.13}$$

$$\sum_{i=1}^{I} X_{ij} \geq \frac{\alpha}{2} \cdot \frac{D_{j3} + D_{j4}}{2} + \left(1 - \frac{\alpha}{2}\right) \frac{D_{j1} + D_{j2}}{2} \quad \forall j \tag{27.14}$$

$$X_{ij} \geq 0, \text{ integer}, \alpha \in [0, 1] \quad \forall i \forall j \tag{27.15}$$

27.3.2 A Modified Approach Based on Fuzzy Ranking Numbers for Fuzzy Integer Programming Models with Equality Constraints

The previous approach is efficiently working for fuzzy linear programming problems (Peidro et al. 2010) but for fuzzy integer linear programming problems, where the integrity condition is imposed on the solution, there is a problem of unfeasibility of the solution. It happens because the right hand side of constraints (27.13) and (27.14) are equal fractional values, while the left hand side of these constraints, *Xij*, must be integer values, what could be infeasible for certain values of α. To face with it, we propose to substitute the right hand side terms of constraints (27.13) and (27.14) for the corresponding most nearby integer values. Therefore, we have to add new auxiliary decision variables to ensure that the right hand side of constraints (27.13) and (27.14) can be transformed into integer and fractional values with the aim of getting the most nearby integer values. The model comprises of constraints (27.10)–(27.15) is modified as follows.

$$\text{Minimize } z = \sum_{i=1}^{I} \sum_{j=1}^{J} \left(\frac{c_{ij1} + c_{ij2} + c_{ij3} + c_{ij4}}{4} \cdot X_{ij} \right) + \sum_{i=1}^{I} (S1_i^{ABS} + S2_i^{ABS}) + \sum_{j=1}^{J} (D1_j^{ABS} + D2_j^{ABS}) \tag{27.16}$$

Subject to

$$S1_i^{INT} + S1_i^{DEC} = \frac{\alpha}{2} \cdot \frac{S_{i1} + S_{i2}}{2} + \left(1 - \frac{\alpha}{2}\right) \frac{S_{i3} + S_{i4}}{2} \quad \forall i \tag{27.17}$$

$$S2_i^{INT} + S2_i^{DEC} = \frac{\alpha}{2} \cdot \frac{S_{i3} + S_{i4}}{2} + \left(1 - \frac{\alpha}{2}\right) \frac{S_{i1} + S_{i2}}{2} \quad \forall i \tag{27.18}$$

$$\sum_{j=1}^{J} X_{ij} \leq S1_i^{INT} \quad \forall i \tag{27.19}$$

$$\sum_{j=1}^{J} X_{ij} \geq S2_i^{INT} \quad \forall i \tag{27.20}$$

$$D1_j^{INT} + D1_j^{DEC} = \frac{\alpha}{2} \cdot \frac{D_{j1} + D_{j2}}{2} + \left(1 - \frac{\alpha}{2}\right) \frac{D_{j3} + D_{j4}}{2} \quad \forall j \tag{27.21}$$

$$D2_j^{INT} + D2_j^{DEC} = \frac{\alpha}{2} \cdot \frac{D_{j3} + D_{j4}}{2} + \left(1 - \frac{\alpha}{2}\right) \frac{D_{j1} + D_{j2}}{2} \quad \forall j \tag{27.22}$$

$$\sum_{i=1}^{I} X_{ij} \leq D1_j^{INT} \quad \forall j \tag{27.23}$$

$$\sum_{i=1}^{I} X_{ij} \geq D2_j^{INT} \quad \forall j \tag{27.24}$$

$$S1_i^{DEC} \leq S1_i^{ABS} \quad \forall i \tag{27.25}$$

$$-S1_i^{DEC} \leq S1_i^{ABS} \quad \forall i \tag{27.26}$$

$$S2_i^{DEC} \leq S2_i^{ABS} \quad \forall i \tag{27.27}$$

$$-S2_i^{DEC} \leq S2_i^{ABS} \quad \forall i \tag{27.28}$$

$$D1_j^{DEC} \leq D2_j^{ABS} \quad \forall j \tag{27.29}$$

$$-D1_j^{DEC} \leq D1_j^{ABS} \quad \forall j \tag{27.30}$$

$$D2_j^{DEC} \leq D2_j^{ABS} \quad \forall j \tag{27.31}$$

$$-D2_j^{DEC} \leq D2_j^{ABS} \quad \forall j \tag{27.32}$$

$$S1_i^{INT}, S2_i^{INT} \geq 0, \text{ integer} \quad \forall i \tag{27.33}$$

$$D1_i^{INT}, D2_i^{INT} \geq 0, \text{ integer} \quad \forall j \tag{27.34}$$

$$S1_i^{ABS}, S2_i^{ABS} \leq 0.999 \quad \forall i \tag{27.35}$$

$$D1_j^{ABS}, D2_j^{ABS} \leq 0.999 \quad \forall j \tag{27.36}$$

$$S1_i^{ABS}, S2_i^{ABS} \geq 0 \quad \forall i \tag{27.37}$$

$$D1_j^{ABS}, D2_j^{ABS} \geq 0 \quad \forall j \tag{27.38}$$

$$X_{ij} \geq 0, \text{integer}, \alpha \in [0, 1] \quad \forall i \forall j \tag{27.39}$$

where the right-hand side coefficients of constraints (27.11)–(27.14) are represented by a sum of an integer variable and a real variable. For instance, the right-side hand coefficient of constraint (27.11) is equivalent to the sum of $S1_i^{INT}$ and $S1_i^{DEC}$. The same to constraint (27.12) and $S1_i^{INT}$ and $S2_i^{DEC}$ and consequently with constraints (27.13, 27.14) and $D1_j^{INT}$, $D1_j^{DEC}$, $D2_j^{INT}$, $D2_j^{DEC}$. Then, right-hand side coefficients of constraints (27.11–27.14) are replaced by these integer variables in constraints (27.19, 27.20) and (27.23, 27.24). Hence, $S1_i^{DEC}$, $S2_i^{DEC}$, $D1_j^{DEC}$, $D2_j^{DEC}$ represent the deviation from original values in constraints (27.11–27.14) to integer values in constraints (27.19, 27.20) and (27.23, 27.24) and will be lower than 1. These deviations are expressed in a linear form of absolute value in constraints (27.25–27.28) and (27.29–27.32), respectively, by incorporating the variables $S1_i^{ABS}$, $S2_i^{ABS}$, $D1_j^{ABS}$, $D2_j^{ABS}$. Finally, the total sum of the absolute value of these deviations is added to the objective function to be minimized.

27.4 Numerical Example

The proposed approach based on ranking fuzzy numbers will be illustrated at the following numerical example. We consider a network consisting of 3 sources and 3 destinations. Transport costs from sources to destinations, available supply and forecast demand are shown in Tables 27.2, 27.3 and 27.4 as trapezoidal fuzzy numbers.

The model has been implemented with the MPL 4.2 modelling language (2010). Resolution has been carried out with the optimisation solver Gurobi 4.6.1. Finally, a Microsoft Access 2010 database manages the input and output data of the model. Table 27.5 compares the expected values of total transportation costs,

Table 27.2 Fuzzy transport costs from sources to destinations (in euros)

	Destination 1	Destination 2	Destination 3
Source 1	(1, 1.25, 1.5, 2)	(2, 2.5, 3, 3.25)	(3, 3.5, 3.75, 4.25)
Source 2	(2, 2.25, 2.75, 3)	(1, 1.25, 1.75, 2)	(2, 2.75, 3.5, 3.75)
Source 3	(3, 3.25, 3.75, 4)	(2, 2.25, 2.5, 2.75)	(1, 1.25, 1.75, 2)

Table 27.3 Fuzzy values of available supply at sources

	Available supply
Source 1	(2, 4, 6, 8)
Source 2	(3, 4, 7, 10)
Source 3	(4, 5, 7, 10)

Table 27.4 Fuzzy values of forecast demand at destinations

	Forecast demand
Destination 1	(5, 6, 9, 10)
Destination 2	(2, 4, 6, 7)
Destination 3	(2, 5, 8, 10)

Table 27.5 Expected values of total transportation cost (in euros)

α	MRFN	LFRN	IFRN
0	17.69	19.69	21.69
0.1	17.69	20.62	22.13
0.2	18.75	21.55	22.13
0.3	21.69	22.48	26.13
0.4	21.69	23.41	26.13
0.5	22.13	24.34	26.13
0.6	23.19	25.27	28.69
0.7	23.19	26.32	29.56
0.8	26.13	27.51	Infeasible
0.9	27.19	28.92	Infeasible
1	27.19	27.66	Infeasible

for several values of α, obtained from MFRN, LFRN and IFRN. The lowest expected values of total transportation costs are obtained by our modified approach, MRFN. The IFRN method obtains infeasible solutions for three values of α.

27.5 Conclusions

We have identified the unfeasibility of the solution for certain values of α, the feasibility degree of a decision x, when applying the approach based on ranking fuzzy numbers by Jiménez (1996) and Jiménez et al. (2007) for solving fuzzy integer linear programming problems with equality constraints. With the aim to cope with it, we have modified this approach, which has provided lower transportation costs for the FITP. A forthcoming work is applying this new modified approach for solving fuzzy goal programming models for material requirement planning under uncertainty and integrity conditions.

Acknowledgments Mariano Jiménez wish to gratefully acknowledge financial support from the Spanish Ministry of Education, project ECO2011-26499.

References

Chanas S, Kuchta D (1998) Fuzzy integer transportation problem. Fuzzy Sets Syst 98:291–298

Dubois D, Prade H (1988) Possibility theory. Plenum Press, New York

Heilpern S (1992) The expected value of a fuzzy number. Fuzzy Sets Syst 47:81–86

Herrera F, Verdegay JL (1995) Three models of fuzzy integer linear programming. Eur J Oper Res 83:581–593

Jimenez M (1996) Ranking fuzzy numbers through the comparison of its expected intervals. Int J Uncertainty Fuzziness Knowl Based Syst 4:379–388

Jiménez M, Arenas M, Bilbao A (2007) Linear programming with fuzzy parameters: an interactive method resolution. Eur J Oper Res 177:1599–1609

Liang TF (2008) Interactive multi-objective transportation planning decisions using fuzzy, linear programming. Asia Pac J Oper Res 25:11

Mula J, Poler R, Garcia JP (2006a) MRP with flexible constraints: a fuzzy mathematical programming approach. Fuzzy Sets Syst 157:74–97

Mula J, Poler R, Garcia JP, Lario FC (2006b) Models for production planning under uncertainty: a review. Int J Prod Econ 103:271–285

Peidro D, Mula J, Jiménez M, del Mar Botella M (2010) A fuzzy linear programming based approach for tactical supply chain planning in an uncertainty environment. Eur J Oper Res 205:65–80

Zadeh LA (1978) Fuzzy sets as a basis for a theory of possibility. Fuzzy Sets Syst 1:3–28

Chapter 28
Modeling and Solving a Variant of *MMSP-W* Problem with Production Mix Restrictions

Joaquín Bautista, Alberto Cano and Rocío Alfaro

28.1 Introduction

In mixed-model manufacturing lines, which are common in Just-in-time (*JIT*) and Douki Seisan (*DS*) ideologies, several variants of one or more products can be handled. This flexibility determines the order in which the units are treated to drastically reduce intermediate stocks and to capitalise on the time available for manufacturing. In this context, there are three classes of sequencing mixed products problems (Boysen et al. 2009): (1) Mixed-model sequencing, (2) Car sequencing and (3) Level scheduling. The Mixed-Model Sequencing Problem with Work overload Minimisation (*MMSP-W*) (Yano and Rachamadugu 1991; Scholl et al. 1998) belongs to the first class.

The *MMSP-W* consists of sequencing T products, of which d_i are of type i ($i = 1, \ldots, |I|$). A unit of product type i requires to each processor (operator, robot, etc..) of the workstation k ($k = 1, \ldots, |K|$) a standard processing time, $p_{i,k}$. The standard time assigned to each processor to work on any product unit is the cycle time c. When a cycle ends at the workstation k, the station can work on the product in progress an additional positive time $l_k - c$, being l_k the time window. When it is not possible to complete all of the work required by the demand plan, overload is

URL: http://www.prothius.com (J.Bautista).This work is supported by the Spanish Ministerio de Educación y Ciencia under project DPI2010-16759 (PROTHIUS-III) including EDRF fundings.

J. Bautista (✉) · A. Cano · R. Alfaro
Prothius Cathedra, Universitat Politècnica de Catalunya, Avda. Diagonal 647, 7th Floor
08028 Barcelona, Spain
e-mail: joaquin.bautista@upc.edu

A. Cano
e-mail: alberto.cano-perez@upc.edu

R. Alfaro
e-mail: rocio.alfaro@upc.edu

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_28,

generated. The objective of the problem is to maximise the total work performed which is equivalent to minimising the total overload generated (see Theorem 1 in Bautista and Cano 2011).

On the other hand, the Level scheduling problems class focuses on obtaining regular sequences in production and consumption of components, among them are: (1) Product Rate Variation (*PRV*), which is used to preserve the production mix (Miltenburg 1989) and (2) Output Rate Variation (*ORV*), based on the manner of sequencing the mixed products units, used at Toyota plants to maintain a constant consumption of components over time (Monden 1983).

Our proposal is organised as follows. Section 28.2 extends the mathematical program proposed in Bautista et al. (2011) for the *MMSP-W*, with the incorporation of the preservation of the production mix. Section 28.3 presents a procedure based on Bounded Dynamic Programming (*BDP*) that combines features of dynamic programming with features of branch and bound algorithms (Bautista 1993; Bautista et al. 1996). In Sect. 28.4, we perform an experiment with reference instances using the *BDP* procedure and the Gurobi solver. Finally, some conclusions about this work are collected in 28.5.

28.2 Model for MMSP-W with Serial Workstations and Unrestricted Interruption of the Operations and Production Mix Restrictions

For the *MMSP-W* with serial workstations, unrestricted interruption of the operations, production mix restrictions (*pmr*) and work overload minimisation, we take as reference the *M4′* model, proposed by Bautista et al. (2011). The parameters and variables of the extended model *M4′_pmr* are presented below.

Parameters

- K Set of workstations ($k = 1, \ldots, |K|$)
- b_k Number of homogeneous processors at workstation k
- I Set of product types ($i = 1, \ldots, |I|$)
- d_i Programmed demand of product type i
- $p_{i,k}$ Processing time required by a unit of type i at workstation k for each homogeneous processor (at normal activity)
- T Total demand. Obviously: $\sum_{i=1}^{|I|} d_i = T$
- t Position index in the sequence ($t = 1, \ldots, T$)
- c Cycle time, the standard time assigned to workstations to process any product unit
- l_k Time window, the maximum time that the workstation k is allowed to work on any product unit, where $l_k - c > 0$ is the maximum time that the work in process is held at workstation k

Variables

$x_{i,t}$ Binary variable equal to 1 if a product unit i ($i = 1, \ldots, |I|$) is assigned to the position t ($t = 1, \ldots, T$) of the sequence, and 0 otherwise

$s_{k,t}$ Start instant of the operation in t^{th} unit of the sequence of products at workstation k ($k = 1, \ldots, |K|$)

$w_{k,t}$ Overload generated for the t^{th} unit of the product sequence at workstation k for each homogeneous processor (at normal activity); measured in time.

$\hat{s}_{k,t}$ Positive difference between the start instant and the minimum start instant of the t^{th} operation at workstation k. $\hat{s}_{k,t} = [s_{k,t} - (t + k - 2)c]^+$ (with $[x]^+ = \max\{0, x\}$)

$\rho_{k,t}$ Processing time required by the t^{th} unit of the sequence of products at workstation k

Model *M4′_pmr:*

$$Min\, W = \sum_{k=1}^{|K|} \left(b_k \sum_{t=1}^{T} w_{k,t} \right) \tag{28.1}$$

subject to:

$$\sum\nolimits_{t=1}^{T} x_{i,t} = d_i \quad \forall i = 1, \ldots, |I| \tag{28.2}$$

$$\sum\nolimits_{i=1}^{|I|} x_{i,t} = 1 \quad \forall t = 1, \ldots, T \tag{28.3}$$

$$\rho_{k,t} = \sum\nolimits_{i=1}^{|I|} p_{i,k}\, x_{i,t} \quad \forall k = 1, \ldots, |K|;\ \forall t = 1, \ldots, T \tag{28.4}$$

$$\rho_{k,t} - w_{k,t} \geq 0 \quad \forall k = 1, \ldots, |K|;\ \forall t = 1, \ldots, T \tag{28.5}$$

$$\hat{s}_{k,t} \geq \hat{s}_{k,t-1} + \rho_{k,t-1} - w_{k,t-1} - c \quad \forall k = 1, \ldots, |K|;\ \forall t = 2, \ldots, T \tag{28.6}$$

$$\hat{s}_{k,t} \geq \hat{s}_{k-1,t} + \rho_{k-1,t} - w_{k-1,t} - c \quad \forall k = 2, \ldots, |K|;\ \forall t = 1, \ldots, T \tag{28.7}$$

$$\hat{s}_{k,t} + \rho_{k,t} - w_{k,t} \leq l_k \ \forall k = 1, \ldots, |K|; \quad \forall t = 1, \ldots, T \tag{28.8}$$

$$\hat{s}_{k,t} \geq 0 \quad \forall k = 1, \ldots, |K|;\ \forall t = 1, \ldots, T \tag{28.9}$$

$$w_{k,t} \geq 0 \quad \forall k = 1, \ldots, |K|;\ \forall t = 1, \ldots, T \tag{28.10}$$

$$x_{i,t} \in \{0, 1\} \quad \forall i = 1, \ldots, |I|;\ \forall t = 1, \ldots, T \tag{28.11}$$

$$\hat{s}_{1,1} = 0 \tag{28.12}$$

$$\sum_{\tau=1}^{t} x_{i,\tau} \geq \left\lfloor t \cdot \frac{d_i}{T} \right\rfloor \quad \forall i = 1, \ldots, |I|; \ \forall t = 1, \ldots, T \tag{28.13}$$

$$\sum_{\tau=1}^{t} x_{i,\tau} \leq \left\lceil t \cdot \frac{d_i}{T} \right\rceil \quad \forall i = 1, \ldots, |I|; \ \forall t = 1, \ldots, T \tag{28.14}$$

Objective function (28.1) and constraints (28.2–28.12) correspond to the mathematical program *M4′* proposed in Bautista et al. (2011), while the constraints (28.13) and (28.14) are those that incorporate the preservation property of the production mix desired in *JIT* (Toyota) and *Douki Seisan* (Nissan) philosophies. Therefore, an alternative to formulate our problem is to replace the objective function (28.1) by the following bi-objective function:

$$Min\, W = \sum_{k=1}^{|K|} \left(b_k \sum_{t=1}^{T} w_{k,t} \right) \quad \wedge \quad Min\, \Delta_Q(X)) = \sum_{i=1}^{|I|} \sum_{t=1}^{T} \left(\sum_{\tau=1}^{t} x_{i,\tau} - t \frac{d_i}{T} \right)^2 \tag{28.15}$$

28.3 BDP for the MMSP-W

This section presents the basic elements of the *BDP* procedure applied to the resolution of *MMSP-W* with serial workstations, unrestricted interruption of the operations and production mix restrictions.

28.3.1 Global and Partial Bounds

Similar to Bautista et al. (2011), to obtain the bounds of the overloads associated to partial sequence $\pi(t) = \{\pi_1, \pi_2, \ldots, \pi_t\}$ and a partial bound for the complement $R(\pi(t))$ associated to the sequence or segment $\pi(t)$, we impose the following conditions to *M4′_pmr*: (1) the values of the variables $x_{i,\tau}$ $(i = 1, \ldots, |I|;$ $\tau = 1, \ldots, t)$ are fixed by $\pi(t)$ and (2) the binary condition is relaxed for the variables $x_{i,\tau}$ $(i = 1, \ldots, |I|;\ \tau = t+1, \ldots, T)$.

The result is the following linear program, *LB_M4′_pmr*:

$$Min \quad LB(W(\pi(t))) = \sum\nolimits_{k=1}^{|K|} \left(b_k \sum_{t=1}^{T} w_{k,t} \right) \tag{28.16}$$

Subject to:(28.2–28.10) and (28.12–28.14) from *M4′_pmr*

$$x_{\pi_\tau,\tau} = 1 \quad \forall \tau = 1, \ldots, t \tag{28.17}$$

$$0 \le x_{i,\tau} \le 1 \quad \forall i = 1, \ldots, |I|;\ \forall \tau = t+1, \ldots, T \tag{28.18}$$

The previous linear program provides an overall bound of the total overload ($LB(W(\pi(t)))$), the value of the overload associated to the segment $\pi(t)$ ($W(\pi(t))$) and a bound of the overload associated to the complement $R(\pi(t))$ ($LB(R(\pi(t)))$). These values can be calculated as follows:

$$W(\pi(t)) = \sum\nolimits_{k=1}^{|K|} \left(b_k \sum\nolimits_{\tau=1}^{t} w_{k,\tau} \right) \tag{28.19}$$

$$LB(R(\pi(t))) = \sum\nolimits_{k=1}^{|K|} \left(b_k \sum\nolimits_{\tau=t+1}^{T} w_{k,\tau} \right) \tag{28.20}$$

The relative completion instants ($\hat{e}_{k,t}$) of the last operation of the partial sequence $\pi(t)$, in each workstation, can be obtained as follows:

$$\hat{e}_{k,t} = \hat{s}_{k,t} + \rho_{k,t} - w_{k,t} \quad \forall k = 1, \ldots, |K| \tag{28.21}$$

28.3.2 Graph Associated with the Problem

Similar to Bautista and Cano (2011) and Bautista et al. (2011), we can build a linked graph without loops or direct cycles of $T+1$ stages. The set of vertices in level t ($t = 0, \ldots, T$) will be noted as $J(t)$. $J(t,j)$ ($j = 1, \ldots, |J(t)|$) being a vertex of level t, which will be represented as follows:

$$J(t,j) = \{(t,j),\ \vec{q}(t,j),\ \pi(t,j),\ LB(W(\pi(t,j))),\ \vec{e}(t,j),\ \vec{e}^{\,c}(t,j)\} \tag{28.22}$$

where:

- $\vec{q}(t,j) = (q_1(t,j), \ldots q_{|I|}(t,j))$ represents the vector of demand satisfied.
- $\vec{e}(t,j) = (e_1(t,j), \ldots, e_{|K|}(t,j))$ is the vector of absolute completion instants of the operations at the workstations and $\vec{e}^{\,c}(t,j) = (e_1^c(t,j), \ldots, e_{|K|}^c(t,j))$ is the vector of corrected completion instants in accordance with the cycle time.
- $\pi(t,j)$ represents the sequence of t units of product associated to the vertex.
- $LB(W(\pi(t,j)))$ is the bound of the overall overload of the sequence $\pi(t,j)$, given by the linear programs LB_M4' (Bautista et al. 2011) and $LB\_M4'\_pmr$.

And the vertex $J(t,j)$ has the following properties:

$$\sum\nolimits_{i=1}^{|I|} q_i(t,j) = t \tag{28.23}$$

$$\left\lfloor \frac{d_i}{T} \cdot t \right\rfloor \le q_i(t,j) \le \left\lceil \frac{d_i}{T} \cdot t \right\rceil \tag{28.24}$$

$$e_k^c(t,j) = \max\left\{(t+k-2)c + \hat{e}_{k,t}\,,\ (t+k-1)c\right\} \tag{28.25}$$

At level 0 of the graph, there is only one $J(0)$ vertex. Initially, we may consider that at level t, $J(t)$ contains the vertices associated to all of the sub-sequences that can be built with t products that satisfy properties (28.23–28.25). However, it is easy to reduce the cardinal that $J(t)$ may present a priori, establishing the following definition of pseudo-dominance:

$$\pi(t,j_1) \prec \pi(t,j_2) \Leftrightarrow \left\{ \begin{array}{l} [\vec{q}(t,j_1) = \vec{q}(t,j_2)] \; \wedge [W(\pi(t,j_1)) \leq W(\pi(t,j_2))] \\ \wedge [\vec{e}^{c}(t,j_1) \leq \vec{e}^{c}(t,j_2)] \end{array} \right\} \tag{28.26}$$

28.3.3 The Use of BDP

For this study, we used a procedure based on *BDP*. This procedure combines features of dynamic programming with features of branch and bound algorithms. The principles of *BDP* have been described by Bautista (1993) and Bautista et al. (1996).

The procedure has the following functions: (1) Select_vertex (t): selects, following a nondecreasing ordering of the $LB(W(\pi(t-1,j)))$ values, one of the vertices consolidated in stage $t-1$; (2) Develop_vertex (t): develops the selected vertex in previous function adding a new product unit with pending demand; (3) Filter_vertices (Z_0, H, $LBZ_{\min}$): chooses, from all the vertices developed in the previous function, a maximum number H of the most promising vertices (according to the lowest values of $LB(W(\pi(t,j)))$), and removing those vertices in which their lower bound is greater than Z_0 (known initial solution); and (4) End_stage (): consolidates the most promising vertices in stage t (H vertices as maximum).

The scheme of the procedure is described below (Bautista and Cano 2011):

```
BDP – MMSPW
Input: T, |I|, |K|, d_i (∀i), l_k, b_k (∀k), p_ik (∀i, ∀k), c, Z_0, H
Output: list of sequences obtained by BDP
    Initialization: t = 0; LBZ_min = ∞
    While (t < T) do
        t = t+1
        While (list of consolidated vertices in stage t-1 not empty) do
            Select_vertex (t)
            Develop_vertex (t)
            Filter_vertices ( Z_0, H, LBZ_min )
        end while
        End_stage ()
    end while
end BDP – MMSPW
```

28.4 Computational Experiment

225 reference instances (Bautista and Cano 2008) are used (see Tables 2 and 3 from Bautista and Cano 2011), which are built from 45 demand plans grouped in 5 blocks (*B*) and 5 process time structures (*E*).

To obtain the optimal solutions for the instances from models *M4′* and *M4′_pmr,* the Gurobi v4.5.0 solver was used. Those solutions were compared with the solutions offered by the proposed *BDP* procedures from both models, *M4′* and *M4′_pmr*, under the following conditions: (1) *BDP* procedure programmed in C++, using gcc v4.2.1, (2) five windows width (*H*) were used, with values 1, 6, 16, 32, 64. The initial solution, Z_0, for each window width was the solution obtained by *BDP* with the previous window width, except for $H = 1$, where Z_0 was established as ∞; and (3) to calculate the lower bounds, $LB(W(\pi(t,j)))$, of the overload associated to each vertex in the *BDP* procedure, the Gurobi v4.5.0 solver was used, solving the linear programs associated to *LB_M4′* and *LB_M4′_pmr*. Both procedures have been run on an Apple Macintosh iMac computer with an Intel Core i7 2.93 GHz processor and 8 GB RAM using MAC OS X 10.6.7.

The results obtained by the experiment are collect in Tables 28.1 and 28.2.

Table 28.1 shows that the incorporation of restrictions (28.13) and (28.14), into the original model *M4′* (Bautista et al. 2011), to preserve the production mix, reduces the average CPU time required to obtain the optimal solutions using Gurobi by a factor of five; also we can see that the CPU time needed by *BDP* to obtain the best solutions with a window width of 64, is reduced by half. Additionally, regarding the average CPU time, with *M4′* model the *BDP* is 40 times faster than Gurobi, and 15 times faster with *M4′_pmr* model.

Regarding the quality of the solutions, in each instance, we take as starting point the best solution (minimum) given by *M4′* and *M4′_pmr* using Gurobi and *BDP*. From these solutions, we determine three types of relative percentage deviations (*RPD*) applied to *W* and $\Delta_Q(X)$: RPD_1 compares the solutions offered by *M4′* and *M4′_pmr* with Gurobi, RPD_2 compares the solutions offered by M4′ and *M4′_pmr* with *BDP* and RPD_3 compares the solutions offered by *M4′_pmr* with both procedures.

Table 28.2 shows: (1) using Gurobi, the solutions for overall overload (*W*) offered by *M4′_pmr* are worse, by an average of 1.34 %, than those offered by *M4′*, and a 0,85 % using *BDP*; (2) due to the pseudo-dominances (28.26) the overall overload offered by *M4′_pmr* through the *BDP* is, on average 0.03 %

Table 28.1 Minimum, maximum and average CPU times needed to obtain optimal solutions for the 225 instances given by models *M4′* and *M4_pmr′* using Gurobi and *BDP*

	$M4'_{Gurobi}$	$M4'\_pmr_{Gurobi}$	$M4'_{BDP}$	$M4'\_pmr_{BDP}$
$CPU_{\min}$	0.04	0.03	0.04	0.06
$CPU_{\max}$	2224.98	110.53	5.50	2.72
$\overline{CPU}$	59.95	11.79	1.58	0.78

Table 1.2 RPD_1, RPD_2 and RPD_3 values by structures, blocks and average (225 instances), of the solutions, given by *M4′* and *M4′_pmr*, of *W* and $\Delta_Q(X)$ from Gurobi and *BDP*

	W			$\Delta_Q(X)$		
	RPD_1	RPD_2	RPD_3	RPD_1	RPD_2	RPD_3
E1	−3.74	−3.11	−0.09	46.89	39.62	−6.22
E2	−1.25	−1.06	−0.02	25.79	25.15	0.82
E3	−0.69	0.24	0.00	34.24	46.91	0.56
E4	−0.01	0.36	0.00	36.16	63.17	−1.25
E5	−1.00	−0.69	−0.01	23.10	32.92	−0.90
B1	−0.04	−0.04	0.00	17.45	32.52	−3.87
B2	−1.31	−1.14	0.00	25.33	35.62	−2.80
B3	−2.57	−1.31	0.00	45.49	46.19	−0.56
B4	−1.84	−1.57	−0.11	41.44	40.21	−2.00
B5	−1.12	−0.66	−0.03	32.90	43.41	−0.78
Average	−1.34	−0.85	−0.03	33.24	41.55	−1.40

worse, compared to the solutions obtained by Gurobi; (3) the incorporation of constraints (28.13) and (28.14) into *M4′*, gives improvements in the preservation of production mix by an average of 33.24 and 41.55 % using Gurobi and *BDP*, respectively; and (4) the performance of Gurobi is insignificantly better than *BDP* with respect to the preservation of mix production by an average of 1.40 %.

28.5 Conclusions

We presented the model *M4′_pmr* that corresponds to the *MMSP-W* problem with serial workstations, unrestricted interruption of the operations, with production mix restrictions (*pmr*) and work overload minimisation, taking as reference the model *M*4′, proposed by Bautista et al. (2011).

For the new problem, we propose two methods of resolution: mathematical programming (Gurobi v4.5.0 solver) and bounded dynamic programming (*BDP*).

A computational experience is made with 225 intances from the literature. All the optima are obtained with Gurobi for both models. In addition, these instances are solved with *BDP* ($H = 64$) reaching 175 optimal solutions through *M4′* (average worsening of 0.51 %) and 221 optima through *M4′_pmr*, due to the pseudo-dominances.

In average CPU times, *BDP* spends, on average, in *M4′*, a fortieth of the time spent by Gurobi, and a fifteenth in *M4'_pmr*. In addition, the incorporation, into *M4′*, of the production mix restrictions, reduces to one fifth of the average CPU time with Gurobi and in half with *BDP*.

The worsening, in overall overload, by an average of 1.34 and 0.85 % of *M4′_pmr* over *M4′*, obtained by Gurobi and *BDP*, respectively, are offset by the gains of preservation of production mix of 33.24 % (Gurobi) and 41.55 % (*BDP*).

References

Bautista J (1993) Procedimientos heurísticos y exactos para la secuenciación en sistemas productivos de unidades homogéneas (contexto J.I.T.). Doctoral Thesis, DOE, ETSEIB-UPC

Bautista J, Companys R, Corominas A (1996) Heuristics and exact algorithms for solving the Monden problem. Eur J Oper Res 88(1):101–113

Bautista J, Cano J (2008) Minimizing work overload in mixed-model assembly lines. Int J Prod Econ 112(1):177–191

Bautista J, Cano A (2011) Solving mixed model sequencing problem in assembly lines with serial workstations with work overload minimisation and interruption rules. Eur J Oper Res 210(3):495–513

Bautista J, Cano A, Alfaro R (2011) A bounded dynamic programming algorithm for the MMSP-W considering workstation dependencies and unrestricted interruption of the operations. In: Proceedings (CD). ISBN: 978-1-4577-1675-1, 11th international conference on intelligent systems design and applications (ISDA 2011), Córdoba, Spain

Boysen N, Fliedner M, Scholl A (2009) Sequencing mixed-model assembly lines: survey, classification and model critique. Eur J Oper Res 192(2):349–373

Miltenburg J (1989) Scheduling mixed-model assembly lines for just-in-time production systems. Manage Sci 35(2):192–207

Monden Y (1983) Toyota production system. Industrial Engineering and Management Press, Norcross

Scholl A, Klein R, Domschke W (1998) Pattern based vocabulary building for effectively sequencing mixed-model assembly lines. J Heuristics 4(4):359–381

Yano CA, Rachamadugu R (1991) Sequencing to minimize work overload in assembly lines with product options. Manage Sci 37(5):572–586

Chapter 29
Coordination Mechanism for MILP Models to Plan Operations Within an Advanced Planning and Scheduling System in a Motor Company: A Case Study

J. Maheut, J. P. Garcia-Sabater, J. J. Garcia-Sabater and J. Marin-Garcia

29.1 Introduction

Supply Chain Management is defined in (Stadtler and Kilger 2002) as the task of integrating organizational units through the supply chain (SC) and of coordinating the flow of material, information and financing for the purpose of fulfilling the client's demands. Coordinating the SC is, in turn, based on: using information and technology to improve the flow of information and materials; process orientation in order to accelerate the execution of processes and associated activities; and Advanced Planning (Stadtler and Kilger 2005). Advanced Planning of the SC addresses decisions regarding SC design, its mid-term coordination and the short-term planning of processes. Advanced Planning systems attempt to fulfill the aforementioned objectives by using specific software (Fleischmann et al. 2005).

Many managers tend to think that Enterprise Requirement Planning (ERP) systems will solve their planning issues. Yet despite its name, ERP systems are usually transaction-based systems rather than planning systems (Chen 2001).

The work described in this paper has been partially supported by the Spanish Ministry of Science and Innovation within the Program "Proyectos de Investigación Fundamental No Orientada" through the project "CORSARI MAGIC DPI2010-18243" and through the project "Programacion de produccion en cadenas de suministro sincronizada multietapa con ensamblajes/desemsamblajes con renovacion constante de productos en un contexto de inovacion DPI2011-27633". Julien Maheut holds a VALi+d grant funded by the Generalitat Valenciana (Regional Valencian Government, Spain) (Ref. ACIF/2010/222).

J. Maheut (✉) · J. P. Garcia-Sabater · J. J. Garcia-Sabater · J. Marin-Garcia
Reengineering Operations Group Work Logistics Excellence (ROGLE),
Universitat Politècnica de València, Camino de Vera S/N 46022 Valencia, Spain
e-mail: juma2@upv.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_29,

The broad extension of ERP systems has brought about the emergence of the so-called Advanced Planning and Scheduling Systems (APS) which may be viewed as "add-ons" of the ERP system to plan and optimize the SC (Rashid et al. 2002).

The appeal of APS to manufacturers is obvious: companies can optimize their SCs to cut costs, improve product margins, lower inventories and increase manufacturing throughput (Lee et al. 2002). APS extract data from the ERP systems, and support decision making. Once the decision has been made, it is sent back to the ERP system for its final execution. For this support, APS use optimization techniques to model and determine the quantities to be produced, stored, transported, and procured by respecting real constraints of the SC (Günther and Meyr 2009). APS might help with the management of the whole SC, specifically its operations (Parush et al. 2007).

There are many commercially available software programs with well-differentiated characteristics (David et al. 2006). The various software modules cover all the segments of the operations planning throughout the SC, in all the planning horizons. However, the use of advanced planning tools in the automotive industry is minimal.

Many Lean companies now use ERP/MRP methods to communicate demand through SC, and hybrid situations have become common in the automotive industry (Riezebos et al. 2009). Indeed, the need to coordinate capacitated transport and production together with low stock levels, and its relation with lean systems, is probably no small concern. MRP does not offer planning tasks in this sense (Drexl and Fleischmann 1994); instead, it supports planning, but only to a limited extent (Chung and Snyder 2000).

In (Garcia-Sabater et al. 2012), the APS that solves the operations planning using integrated models to solve at each time level is presented. However, because of the constantly increasing complexity of operations (number of derivatives to be produced, number of customers and/or suppliers to be served, new restrictions, etc.), these integrated models become terribly difficult to resolve in adequate resolution time. For this reason, during the implementation of the tool, small models were generated for each domain and each horizon. This explosion is the creation of coordination mechanisms for the models to find an optimum result close to the integrated model result. And that is the purpose of this paper, to present the coordination mechanism that was implemented. The mechanism has not only allows coordination at two levels (horizons and domains) but also integrates the temporal aspect of the previous planning to deliver results expected by users.

Section 29.2 introduces a brief problem description. Section 29.3 proposes the coordination mechanism. And finally, Sect. 29.4 proposes a conclusion.

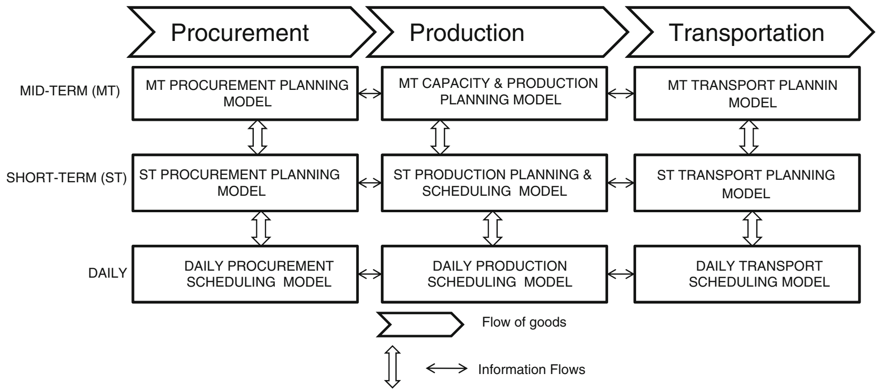


Fig. 29.1 Coverage of the mathematic models implemented in the APS in this case study

29.2 Problem Definition

An overview of the planning needs in this case study is presented. The framework presented by Meyr et al. (2005), as seen in Fig. 29.1, was used to cover the main system areas.

In the company, mid-term corresponds to the mid-term planning horizon with bucket periods of weeks, while short-term planning corresponds to a short-term planning horizon with daily buckets. Lastly, the daily scheduling tasks are solved with a 2-day horizon with variable buckets.

The structure of this section goes through the different planning levels, and covers domains such as the Supply Chain Planning matrix modules. The particular characteristics of the different APS modules implemented are highlighted.

29.2.1 The Mid-Term Planning

Mid-term planning (MTP) is usually divided into two main modules: Master Planning and Demand Planning. Demand Planning has been not treated in this case study since it was defined by the other firm's levels. The MTP synchronize the whole network flow of materials on a mid-term basis and interact with the 4-week operations planning.

In our work, the MTP is solved with three MILP models. To better understand the planning tasks, objectives, constraints and decisions to be taken at this level, a summary is proposed in Table 29.1. This table describes it by separating the functional areas of procurement, production and distribution that are considered in the same model.

Table 29.1 MTP characteristics

	MT procurement planning model	MT production planning model	MT capacity production planning model	MT transportation planning model
Tasks	• Raw material requirement planning for short-distance suppliers • Ordering raw material for long-distance suppliers	• MT production planning	• MT capacity production planning	• Component Transport Planning (FTL)
Objectives	• Minimize raw material stock levels	• Minimize storage costs • Maximize the stability of the plans	• Minimize total operating costs (minimization of productive days and extra days production)	• Maximize component delivery fulfillment
Constraints	• Working calendars • Lead time of long-distance suppliers • Raw material in transit	• Working calendars • Production rates • Safety stocks levels • Storage capacity limits • Availability of raw materials and components	• Previous working calendars • Previous production rates	• Working calendars • FTL Strategy • Forecast demand fulfillment
Decisions	• MT material requirements plan for short-distance suppliers • MT detailed material procurement plan for long-distance suppliers	• MT production plans for each line	• MT capacity production plans (new working calendars; adjustments in production rates capacity)	• MT Transport plan

The MTP process is in four models:

- MT transportation planning model that aggregated transportation plans for all the products.
- MT capacity production model that determines production rates and the working calendars for all five production lines and the assembly line.
- MT production plans that determines production levels and set stock levels at the end of each week for each line.
- MT material requirements model for short-distance suppliers and a MT detailed material procurement model for long-distance suppliers.

29.2.2 Short-Term Planning

The STP process must satisfy the requirements of the logistics department, but must also take into account the constraints that the production department defines. Both these departments have contradictory objectives and different constraints, and the trade-off that usually occurs in real meetings has to be considered with the implemented model.

Using the same approach as for the MTP, Table 29.2 summarizes the case of the STP and some of the characteristics considered.

Table 29.2 STP characteristics

	ST procurement planning model	ST production planning model	ST distribution planning model
Tasks	• Ordering materials for short-distance suppliers	• Engine production planning	• Engine transport planning
	• Material requirements planning	• Detailed component production plans	• Component transport planning
Objectives	• Minimize raw material stock levels	• Maximize production leveling	• Maximize engine delivery fulfillment
		• Minimize inventory faults	• Minimize backlog costs
		• Minimize set-ups costs	
Constraints	• Working calendars	• Safety stock level constraints	• Working calendars
	• Working calendars	• Maximum stock level limits	• FTL strategy
	• Truck and rack capacity	• Max/Min number of derivate products manufactured	• Truck and rack capacity
		• Daily production capacity	• Demand fulfillment
		• Availability of raw materials and components	
Decisions	• ST material requirements plan	• ST engine production plan	• ST transport plan
		• ST detailed component production plans	

In this case study, the STP process is performed by three main models.

1. ST transport model aimed at optimizing products and component shipping costs.
2. ST production and schedule model aimed at ensuring stability, leveling and cutting setup costs and inventory costs.
3. ST material requirements model aimed at scheduling production quantities to short-distance suppliers, and at ordering shipping quantities to long-distance suppliers.

In each case, the objective is to minimize total costs.

29.3 The Coordination Mechanism

In the APS, each model cannot be executed in a separate way. The first step is the MTP. Then the STP is performed and then the SSTP. In order to maintain consistent results, the different plans should be related with the other results/plans in three dimensions (hierarchy, domain and temporal). Figure 29.2 represents the relations among planning models. The notation is the same like in (Garcia-Sabater et al. 2012). Variables from other plans (from both previous executions and previous stages) are converted into parameters in subsequent models.

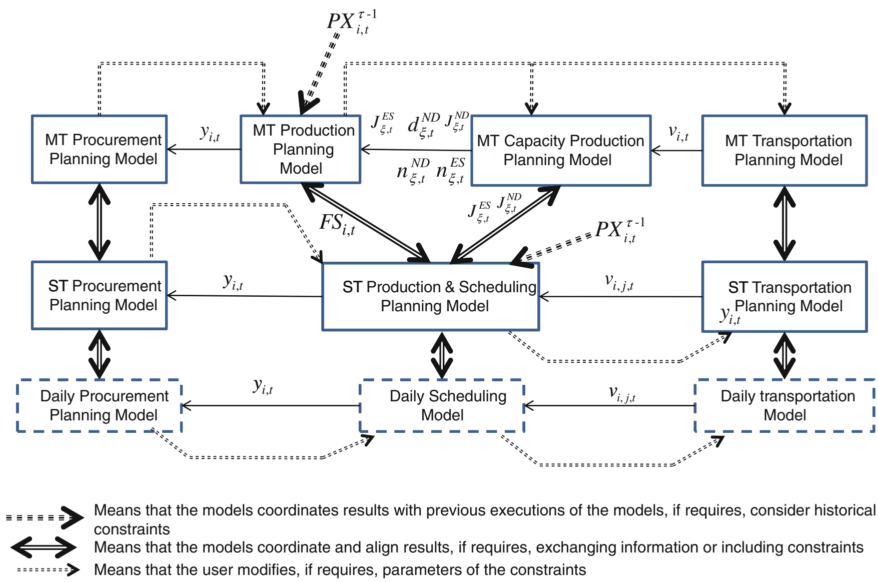


Fig. 29.2 Coordination mechanism between planning models

29.3.1 Hierarchical Coordination

The integration of the different hierarchical models (downward and upward co-ordination) has been done using constraints and objective parameters that limit the "autonomy" of each decision level and ensure an integration and cohesion between plans.

Downward coordination MTP and STP is done for production plans with the so-called Intended Stock $FS_{i,t}$. It helps coordinate MTP with STP since it was (together with limited capacity) the relation that states what is to be produced by looking at the future beyond the first 4 weeks.

Upward coordination is considered in some cases. For example, the stake-holders can manually include new constraints in the mid-term models, such as limiting the number of derivatives or limiting raw material availability in specific periods, if necessary however those constraints are typically for the STP models.

29.3.2 Domain Coordination

The coordination mechanism (business functions integration) between the different domain models in each planning horizon has been done using parameters and the possibility to incorporate constraints. It allows business functions to relate to each other.

In our case study, the approach consists in giving valuable information to align plans. For example, between transport models and productions models, the coordination mechanism consist in the downstream exchange of information (e.g. accumulated shipping quantities, accumulated production quantities).

Upstream coordination consists in the integration of restrictions about accumulated quantities when plans are infeasible. Another concern is about some raw materials that arrive from (long distance) suppliers. In some cases, upstream coordination consists in establishing a frozen period. So some changes are not allowed.

This coordination is a major concern since objectives between domains can be conflictive and some constraints are, in some cases, not compatible. Besides, it is far more difficult to solve models with more restrictions because the number of integers and binary variables can be quite high.

29.3.3 Temporal Coordination

A temporal coordination mechanism had to be design because some of the KPIs used by the company deal with the leveling of the production levels of each derivates and the plans' stability (Build to Schedule).

For instance, in the capacity production plan in the MTP, it exists a limit about the maximum number of production rate () changes and working calendars parameters changes during a whole year.

Moreover, production models need to relate to the previous decisions. This integration is considered with the parameter that represents previous production quantities for each product. This data has been specifically considered into the APS. This temporal mechanism ensures a control of the stability of the plans which is commonly control with the KPIs like the Build to Schedule. Stability is not only a matter of planning stable plans; indeed, today's plan has to be similar to the plans of previous days. This concept is basic in the automotive sector and, in fact, there are specific performance measurements that are used only to evaluate stability. This is mainly justified by the fact that the SC cannot, or finds it difficult to, respond to major changes in production levels (Hüttmeir et al. 2009).

29.4 Conclusion

As a general conclusion of this research work, a new coordination mechanism considering three dimensions (hierarchy, domain and temporal) is proposed in this paper. The mechanism allows the stakeholders of different business functions to generate plans that are used each day. The mechanism proposed has been successfully implemented in an Advanced Planning and Scheduling system for a motor company.

Further research has been identified throughout this work, as follows: (1) Providing users the ability to know which data (demand, stocks, production rates, etc.) is inaccurate would be the next good step to take; (2) designing a more data-resilient model and a resolution procedure are to be built (3) incorporating uncertainty in data (it may be stochastic or uses fuzzy methods) is another future research line.

References

Chen IJ (2001) Planning for ERP systems: analysis and future trend. Bus Process Manage J 7:374–386

Chung SH, Snyder CA (2000) ERP adoption: a technological evolution approach. Int J Agile Manage Syst 2:24–32

David F, Pierreval H, Caux C (2006) Advanced planning and scheduling systems in aluminium conversion industry. Int J Comput Integr Manuf 19:705–715

Drexl A, Fleischmann B, Gunther H.-O, Stadtler H, Tempelmeier H, (1994) Konzeptionelle Grundlagen kapazitatsorientierter PPS-Systeme. Zeitschrift fur betriebswirtschaftliche Forschung 46:1022–1045

Fleischmann B, Meyr H, Wagner M (2005) Advanced planning. In: Stadtler H, Kilger C (eds) Supply chain management and advanced planning: concepts, models software and case studies, 3rd edn. Springer, Berlin

Garcia-Sabater JP, Maheut J, Garcia-Sabater JJ (2012) A two-stage sequential planning scheme for integrated operations planning and scheduling system using MILP: the case of an engine assembler. Flex Serv and Manuf J,24(2):171–209
Günther HO, Meyr H (2009) Supply chain planning and advanced planning systems. OR Spectrum 31:1–3
Hüttmeir A, de Treville S, van Ackere A, Monnier L, Prenninger J (2009) Trading off between heijunka and just-in-sequence. Int J Prod Econ 118(2):501–507
Lee YH, Jeong CS, Moon C (2002) Advanced planning and scheduling with outsourcing in manufacturing supply chain. Comput Ind Eng 43:351–374
Meyr H, Wagner M, Rohde J (2005) Structure of advanced planning systems. In: Staedtler H, Kilger C (eds) Supply chain management and advanced planning: concepts, models, software and case studies, 3rd edn. Springer, Berlin, pp 109–115
Parush A, Hod A, Shtub A (2007) Impact of visualization type and contextual factors on performance with enterprise resource planning systems. Comput Ind Eng 52:133–142
Rashid MA, Hossain L, Patrick J (2002) Enterprise resource planning solutions and management. IRM Press, USA
Riezebos J, Klingenberg W, Hicks C (2009) Lean production and information technology: connection or contradiction? Comput Ind 60:237–247
Stadtler H, Kilger C (2002) Supply chain management and advanced planning: concepts, models, software and case studies. Springer, Berlin
Stadtler H, Kilger C (2005) Supply chain management and advanced planning: concepts, models software and case studies. Springer, Berlin

Chapter 30
Lean-Six Sigma Approach put into Practice in an Empirical Study

Martínez S. Miguélez, A. Errasti and J. A. Alberto

30.1 Introduction

Customers want reduced costs and, at the same time, they require higher levels of quality and value. This notorious phenomenon results in a race for survival and profitability as companies attempt to meet these customer needs. In today's environment, in an effort to please customers, businesses often will employ different approaches such as Lean and Six Sigma.

Lean is a philosophy that incorporates a collection of tools and techniques into the business processes to optimize time, human resources, assets, and productivity while improving the quality level of products and services for customers.

Six Sigma is recognised as a meticulous approach to reduce a variation in all critical business processes towards performance improvements that can generate financial savings in an organisation (Antony et al. 2006). Moreover, it is a discipline that helps to identify the root causes of variation in processes (manufacturing, service or transactional) using factual data and a rigorous methodology, rather than experience, abstract data or assumptions.

The Lean production and Six Sigma approaches have gained importance in recent years. Many companies have reported on their implementation of practices commonly associated with a Lean production system and the positive impact those practices have on manufacturing performance. However, Lean principles of waste reduction do not completely address the costs associated with inconsistency in terms of either quality or the time performance of activities or processes (Mena et al. 2002). Thus, Lean production and Six Sigma principles have significant overlap, although there are unique aspects to each of them.

The purpose of this paper is to demonstrate the advantages of applying Six Sigma with a DMAIC methodology approach in order to make progress in a Lean

M. S. Miguélez (✉) · A. Errasti · J. A. Alberto
Tecnun, Engineering School at University of Navarra, Paseo Manuel Lardizábal,
13 20018 San Sebastián, Spain
e-mail: smartinez@tecnun.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_30,

improvement program. DMAIC is a top down approach that allows an enhanced Lean process to be achieved. For this purpose, Lean techniques are not very appropriate for reducing variability, whereas DMAIC and associated techniques could aid in improving manufacturing processes in order to get a continuous flow in the third stage of the Lean thinking methodology "make the activities flow". To demonstrate the effectiveness of the proposed techniques, the researchers have been involved in a case study of a company engaged in the manufacture and sale of components for central heating, domestic hot water, water heating and domestic appliances.

30.2 Literature Review

30.2.1 Lean Thinking

Over the last twenty years, small and large business have intensively applied the Lean approach. This methodology is sometimes called lean manufacturing or the Toyota Production System (TPS), among other names. The origins of lean manufacturing can be attributed to the TPS, which is a Japanese method focused on the 3M's. These Ms are: *muda*, the Japanese word for waste, *mura*, the Japanese word for inconsistency, and *muri*, the Japanese word for unreasonableness. *Muda* specifically focuses on activities that should be eliminated. Within manufacturing, there are categories of waste.

Taiichi Ohno identified seven common forms of waste, which are defined as activities that add cost but no value: production of goods not yet ordered; waiting; rectification of mistakes; excess processing; excess movement; excess transport; and excess stock (Ohno 1988; Monden 1993; Japan Management Association 1985). It is common to find that in a factory less that 5 % of the activities add value, 35 % are necessary non-value-adding activities and 60 % add no value at all (Womack and Jones 1994, 1996). It is easy to see the steps that add value, but it is much more difficult to see all the waste that exists in a factory because *muda* is everywhere.

Fortunately, there is an effective methodology for eliminating *muda*: lean thinking. It provides a way to specify value, line up value-creation actions in the best sequence, conduct these activities without interruption whenever someone requests them, and perform them more and more effectively. In short, lean thinking is lean because it provides a way to do more with less (less human effort, less equipment, less time, and less space) while coming closer and closer to providing customers with exactly what they want. Moreover, lean thinking also provides a way to make work more satisfying by providing immediate feedback on efforts to convert *muda* into value. And, in striking contrast with the recent craze for process reengineering, it provides a way to create new work rather than simply destroying jobs in the name of efficiency (Womack and Jones 2005).

In order to eliminate the existing waste during the manufacture flow of a product or a family of products, the value-creating steps must be distinguished from those which do not add any value. Frequently, lean's focus is manifested in an emphasis on flow. Lean manufacturing has evolved into the lean thinking principles whose implementation methodology can be resumed as (Womack and Jones 2005): identify which features create value, identify the sequence of activities that make up the value stream, make the activities flow, let the customer pull the product or service through the process and perfect the process.

30.2.2 Six Sigma

Even though Lean thinking is a powerful approach based mainly on the elimination of *muda*, there is another approach that is more focused on the elimination of *mura,* or process variation. Six Sigma has been used all over the world and many companies have testified to its important role in their success (Hutchins 2000).

Six Sigma claims that focusing on the reduction of variation will solve process and business problems. By using a set of statistical tools to understand the fluctuation of a process, management can begin to predict the expected outcome of that process. If the outcome is not satisfactory, associated tools can be used to identify the elements influencing that process. The assumption is that the out-come of the entire process will be improved by reducing the variation of multiple elements.

Moreover, Six Sigma offers many effective tools that provide the controls and assurance needed to achieve the desired levels of quality and control over process variation. Reducing unwanted variation occurs by following a structured problem solving method known as DMAIC, which provides the basis for continuous improvement (Shewart 1931; Harry and Schroeder 2000).

These DMAIC tools are one of the most effective methods for eliminating product defects and speeding up processes, which translates directly into increased throughput (Lynn Northrup 2004). However, it is really important that companies determine how to focus and deploy the Six Sigma breakthrough strategy in order to achieve Six Sigma quality to address key business priorities and strategy issues. Organizations must embrace some specific elements within the DMAIC model as prerequisites to success in the pursuit of becoming a Six Sigma (Eguren et al. 2011).

30.2.3 Lean-Six Sigma Integration

Considering the fact that the Six Sigma programs adhere strictly to a system's perspective towards quality improvements, it is quite natural to observe the trend of integrating Six Sigma with other business improvement tools and methods such as Lean Manufacturing (Tang et al. 2007).

It is evident that both Lean and Six Sigma can be characterized in terms of their underlying philosophy and a set of practices, tools/techniques, implementation orientation, units of analysis, and performance measures associated with them. In addition, it is important to underscore the value of management and employee involvement in improving performance, though the nature of involvement differs considerably in the two approaches.

Lean is a bottom up approach where management plays a supportive and facilitating role in engaging shop-floor workers in forming work teams and applying Lean tools. On the other hand in Six Sigma management plays a more active role, often selecting improvement projects based on financial and strategic goals and championing and monitoring improvement projects.

Hence, the following questions rise:

- Can the Six Sigma-DMAIC methodology be implemented in order to make progress in a Lean improvement program?
- Can Lean and Six Sigma techniques both complement each other in order to reduce process variation and allow the elimination of waste?

30.3 Case Study

Yin, in *Case Study Research Design and Methods* (2003), defines case study research as "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident." According to this author, the single-case research design is useful if the case is a representative and revelatory case.

The researchers have chosen the action research process to develop and refine the DMAIC methodology within a Lean improvement program. Action research is a variation of the case study where the researcher is not an independent observer but a participant in the process (Eguren et al. 2011; Prybutok and Ramasesh 2005; Schein 2008). Unlike other research methodologies, action research is concerned with creating organizational change and simultaneously studying the process involved (Avison et al. 2001). Therefore, members from the organization under study actively participate in the process.

The study was carried out in a domestic appliance manufacturing facility with a functional organization which is a leader in its sector and has facilities located in different countries. More specifically, the research study was developed in the valve manufacturing section and was focused on the meis that there were so-mechanized and assembly stages. When the study began, these sections worked independently with a push functional organization, weekly planning and stock-based management. Through this project, the company wanted to become a lean organization so that the facility worked in a cell with a pull system and customer-based demand.

To visualize the different states in terms of Lean approach, the researchers have mapped the processes using value stream mapping (VSM). It is a functional method to help practitioners rearrange manufacturing systems according to a Lean perspective (Rother and Shook 2003; Womack et al. 2002; Pavnaskar et al. 2003). Furthermore, according to Pavnaskar et al. (2003), VSM has great potential to improve Lean productive systems. The arguments given are: simplicity and objectivity, the systemic vision provided for each product family reflects manufacturing system inefficiencies, the unification of Lean concepts and techniques in a unique body and the possibility of being the starting point of a strategic improvement plan.

The manufacturing process consists of three stages: stamping, mechanized and assembly. The first stage consists of stamping the valve's body, to be driven to interim storage. In the second stage, based on the weekly planning, valves are taken from the interim storage to be mechanized and then stored again while waiting for assembly. In the final stage, valves are sent to the assembly stage. The manufacturing process in terms of lead time, inventory, production efficiency and batching are shown.

When mapping the process the researchers realized that there were some barriers to implement an ideal pull system. The reason is that there were some factors that produced variability. These factors were founded thanks to different used tools, for instance, in the DEFINE phase it could be emphasized, Quality Function Deployment (QFD) where it has been identified the key features, highlighting the need for linearizing the process by customer demand, the zero transfers, the zero ergonomic problems and a minimum efficiency level 80 %. Moreover, thanks to the SIPOC the suppliers and the inputs that they generate, the general phases of the process itself, outputs and customers were identified. To conclude the definition phase, the Project Charter was developed which collected in a summary way the problem description, quantitative goals, the impact on the business, the project leader and the team that makes up, resources, restrictions and stakeholders.

Meanwhile the MEASURE phase objective is to identify the initial situation. Firstly, the researchers started to develop a series of questions related to the Y's outputs of the process which facilitate the departure diagnosis. Subsequently, the previous questions were responded through data analysis. For this purpose a flow chart was developed detailing for each process stage and the X's factors such as incidences, maintenance issues, changeover times, etc. were identified which affected the Y‘s outputs like efficiency, number of manufactured pieces, etc. In addition, using a Pareto diagram, statistical graphics of unit values and capability studies graphics, it has identified the references to analyze, the variability levels of output and the variables that affected the process such as efficiency, changeover times, number of manufactured pieces, lot sizes, lead time, etc.

To conclude, in the ANALYZE phase, which main objective is to identify the vital few X's that affect the process, the researchers developed appropriate hypotheses such as "The efficiency level depends on the incidences of the assembly lines and mechanized". By means of Paret diagram, the incidents were classified where it is important to highlight the stops for reference changeover, breakdowns

Table 30.1 Summary table of each phase

Phase	Goal	Tools	Limitations	Learned lessons
Define (D)	Validate the project rigorously	VOC, SIPOC, project charter	Selecting and defining an project with the organization aligned strategy specifying the participants	The importance of defining the project objectives and identifying customer critical characteristics
Measure (M)	Identifying the initial situation and making a diagnosis that reflects the environment reality	Flow diagram, Ishikawa, Pareto, control graphs, time graphs, VSM, histograms and data collection sheets	Identifying the right questions to make a reliable diagnosis	The importance of defining the right metrics and collecting reliable data thinks to be able to define an initial, real and reliable situation
			Collecting quality data	
			Working data properly	
Analyze (A)	Identifying critical factors that affect in the project objectives	Control graphs, histograms, pareto diagram, simulations, data collection sheets, statistical calculation of the number of tests to confirm the hypothesis, VSM	Being able to test hypotheses and confirm the results run the simulations properly	The importance of validating the hypothesis by testing statistically validated. The test execution following some standard methods
			Involvement of everybody	
Improve (I)	Defining and implementing the solutions which are validated in the hypothesis	Control graphs, time graphs, capacity studies	Being rigorous in implementing the actions	The importance of defining how to validate the improvement
			The improvements must be accepted	
Control (C)	Standardizing and defining the control system	Control graphs, time series, capacity studies, audit formats, procedure formats to change plans, Pareto diagram	Following the discipline to keep the results over time	The importance of standardizing and implementing the new routines
				The importance of monitoring the levels of achieved improvement

and minor stoppages. Then, the variability level was seen through capability studies and statistical studies using SPC graphics of unit values. After that, the actions were planned to face the hypothesis and the relevant tests in order to contrast them. All of this, it was defined in detail with statistical criteria. Finally, the experiments were tested and measured the variability, the efficiency level and the number of manufactured pieces in the new process using SPC graphics.

The first stage, which is called the flow stage, consists of synchronizing the assembly and mechanize manufacturing processes, reducing the production lead time and allowing the possibility in the near future to implement a pull demand oriented system once the process variation is reduced. The data showed that process variation remained and it was a barrier to implementing it.

Thus, at this moment is when it is necessary to apply the DMAIC methodology which was carried out by the researchers. Incorporating DMAIC helped with the project's implementation, since it allowed researchers to visualize and manage data quickly and accurately. Due to the DMAIC methodology implementation the facility reached the expected state, that is to say, the flow stage.

30.4 Conclusions

This case study has demonstrated that the integration of Lean-Six Sigma can be an effective and useful approach to eliminate inefficiencies and inconsistencies.

The researchers highlighted a number of questions regarding the implementation of DMAIC such as: define and set project goals, identify key characteristics, the importance of collecting data to monitor the process and convince workers, the use of simulation to test the proposed improvements, the necessity of setting a transition period to validate the improvements and people's resistance to change, the standardization of routines and operative process once the improvements have been demonstrated, the monitoring of indicators and the definition of improving responsibilities for implanting a continuous improvement program.

In addition, the researchers have found that visualizing the current state of a process with VSM techniques allows companies to assess whether the DMAIC-Six Sigma approach could be needed. Moreover, the Table 30.1 is a summary of the phases, goals, tools selected, limitations and learned lessons after using the DMAIC methodology.

At this point, it should be borne in mind that in order to implement a pull system, first all inconsistencies must be eliminated. For this purpose the DMAIC-Six Sigma could be profitable. Nevertheless, in order to apply the pull principles, other techniques such as SMED, TPM and Kanban are necessary.

References

Antony J, Bañuelas R, Kumar A (2006) World class applications of six sigma: real world examples of success. Butterworth-Heinemann, Oxford

Avison D, Baskerville R, Myers M (2001) Controlling action research projects. Inf Technol People 14(1):28–45

Eguren JA, Goti A, Pozueta L (2011) Diseño, aplicación y evaluación de un modelo de Me-jora Continua, DYNA Ingenieria e Industria

Harry M, Schoroeder R (2000) Six sigma: the breakthrough management strategy revolutionizing the world's top corporations. Doubleday & Company, New York

Hutchins D (2000) The power of six sigma in practice. Qual Focus 4(2):26–33

Japan Management Association (1985) Kanban: just-in-time at Toyota. Productivity Press, Cambridge, MA

Lynn Northrup C (2004) Dynamics of profit-focused accounting. Attaining sustained value and bottom-line improvement, J. Ross Publishing, USA

Mena C, Whicker L, Templar S, Bernon M (2002) Costing the supply chain. Manufact Eng 81(5):225–228

Monden Y (1993) Toyota production system: an integrated approach to just-in-time, 2nd edn. Industrial Engineering and Management Press, Norcross, GA

Ohno T (1988) Toyota production system: beyond large-scale production. Productivity Press, New York

Pavnaskar SJ, Gershenson JK, Jambekar AB (2003) Classification scheme for Lean manufacturing tools. Int J Prod Res 41(13):3075–3090

Prybutok VR, Ramasesh R (2005) An action-research based instrument for monitoring continuous quality improvement. Eur J Oper Res 166(2):293–309

Rother M, Shook J (2003) Learning to see: Value-stream mapping to create value and eliminate muda. The Lean Enterprise Institute

Schein EH (2008) Clinical inquiry/research. In: Reason P, Bradbury H (eds) The sage handbook of action research: participative inquiry and practice. Sage, Thousand Oaks, CA, pp 266–279

Shewhart WA (1931) Economic control of quality of manufactured product. D. Van Nostrand Company, Inc., New York

Tang LC, Goh TN, Lam SW, Zhang CW (2007) Fortification of six sigma: expanding the DMAIC toolset. Qual Reliab Eng Int 23(1):3–18

Womack J, Jones D (1994) From lean production to the lean enterprise. Harvard Bus Rev 72(2):93–103

Womack J, Jones D (1996) Beyond Toyota: how to root out waste and pursue perfection. Harvard Bus Rev 74:140–172

Womack J, Jones D (2005) Lean thinking, Free press

Womack JP, Womack J, Jones DT (2002) Seeing the whole. Mapping the extended value stream. The Lean Enterprise Institute, Massachusetts

Yin RK (2003) Case study research design and methods. Sage Publications, Thousand Oaks, California

Chapter 31
Lean Toolbox for Seasonal Process Industries: A Nougat Fabrication Case Study

M. Tanco, J. Santos, J. L. Rodríguez and J. Reich

31.1 Introduction

During the second half of the last century, industrial companies worldwide have adopted continuous improvement systems to improve their competitiveness. Initially driven by the automotive industry, continuous improvement has expanded rapidly over the past 30 years.

One of the most widespread proposals for continuous improvement is the Lean Manufacturing philosophy, which was derived mostly from the Toyota Production System (TPS). Lean is a method for thoroughly eliminating waste and enhancing productivity (Ohno 1988). The literature defines waste as everything that increases cost without adding value for the customer (Ohno 1988).

There are seven types of waste (Ohno 1988): overproduction, waiting, transportation, inadequate processes, excess inventory, unproductive movement and defective products. Recently, an eighth type of waste was added (Bicheno and Holweg 2008): unused human talent. Through the effective use of human talent the company can engage in the elimination of other types of waste more easily (Womack and Jones 2003).

These types of waste are very common in all types of businesses. Consequently, the main purpose of any lean tool is to draw attention to waste, by giving workers the tools to solve problems in any type of business.

However, there is still surprisingly little use of lean manufacturing techniques in the chemical and process industries (Melton 2005; Floyd 2010). This is mainly due to the fact that the process industry needs a special version of lean

M. Tanco · J. L. Rodríguez · J. Reich
CITEM, Universidad de Montevideo, Luis P. Ponce 1307, 11300 Montevideo, Uruguay

J. Santos (✉)
Departamento de Organización Industrial, Tecnun (Escuela de Ingenieros—Universidad de Navarra), P Manuel Lardizabal 13, 20018 San Sebastian, Spain
e-mail: jsantos@tecnun.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_31,

manufacturing because there are critical differences between process manufacturing and mechanical manufacturing (Floyd 2010).

Since there is little research available in the scientific literature on applying lean manufacturing techniques in food industries, the aim of this study is to expand the body of knowledge on lean manufacturing by focusing on the applicability of lean tools to process industries, particularly seasonal industries, using a chocolate factory as a case study. Once the lean toolbox for the seasonal process industry is set, several lean tools were applied to an important SME company from the chocolate industry in South America.

31.2 Lean Manufacturing in Seasonal Industries

In recent years a wide range of literature associated with lean production has emerged, beginning with the study by Womack et al. (1990) that looked at the differences between mass production and lean production and highlighted the advantages of the latter. Several books were later published, presenting the whole system or specific Lean tools from a theoretical and practical perspective (Rother and Shook 1999; Liker 2004; Santos et al. 2006; Shook 2008; Hoeft 2010; Wilson 2010; Womack and Jones 2003, 2005).

With each year, an increasing number of research papers related to Lean have been published although most of them are about the use of Lean in highly automated repetitive production environments.

However, there are few publications dealing with the application of Lean Manufacturing to seasonal industries, and to the food industry in particular. Alfnes et al. (2000) proposed lean production as the solution to the flexibility requirements in the food industry. Fuentes et al. (2007) studied the applicability of lean production in the egg industry, concluding that it was indeed possible. Finally, Zokaei and Simons (2006) studied the implementation of Lean in the UK red meat industry. Unfortunately, no article related to the chocolate industry or nougat production was found in the literature.

31.2.1 Lean Toolbox for Seasonal Process Industry

The lean principles proposed by Womack and Jones (2003) can be grouped into different aspects that are focused on production improvement. All of them suppose employee participation in eliminating waste. This section analyses the applicability of these principles to the seasonal process industry and chooses a group of tools to facilitate the implementation of lean principles.

31.2.1.1 Identifying the Value Stream

The first group of tools are oriented towards distinguishing between value and waste. Their objective is to identify the sources of waste and variability in the transformation process. These tools can be applied in any process, including the seasonal process industry, and the most useful tool is Value Stream Mapping.

Value Stream Mapping (VSM). VSM is a visual tool that helps managers to see and understand the material and information flow as the product passes through the value chain. The key benefit of value stream mapping is that it focuses on the entire value stream to find system-wide waste and tries to avoid the pitfall of optimizing some local situations at the expense of the overall optimization of the entire value stream (Wilson 2010).

Through the analysis of the value stream, a company can understand customer demand and provide value-added activities in order to meet customer demand. There are some applications of VSM in the literature, although it is most frequently applied in highly automated processes or in assembly environments (Hines et al. 1998; McDonald et al. 2002; Braglia et al. 2006; Abdulmaleka and Rajgopalb 2007; Sahoo et al. 2008; Alvarez et al. 2009; Liu and Chiang 2009).

31.2.1.2 Improving Materials Flow

There are several explanations for the high levels of inventory in the process industry. For example, most of the raw material must be purchased in large quantities so as to supply the entire season with a single order because providers necessarily provide smaller amounts when needed. As a result, reducing the inventory of raw materials and packaging material must not be emphasized. However, reducing Work-in-Process and finished products is within the scope of most companies and therefore it should be done.

At the same time, in the process industry material flow is determined by batch size and thus it is not possible to propose a one-piece-flow strategy in the same way proposed for the assembly lines. However, there are many movements involving workers that can be analysed using tools such as Spaghetti Diagrams.

Spaghetti Diagram. The spaghetti diagram is a simple yet powerful tool for visualizing movements and transportations (Wilson 2010). When the transportation paths are seen, it is often easy to spot opportunities to reduce these wastes. It is especially useful to follow and draw worker movements to try to find and remove unnecessary movements. Moreover, analysing the current situation can be useful when comparing it to the proposed improvements.

31.2.1.3 Increasing Equipment Effectiveness

The main set of lean tools is focused on increasing equipment effectiveness (SMED, Poka-Yoke, TPM, Jodika, etc.), and all of them can be applied to any type

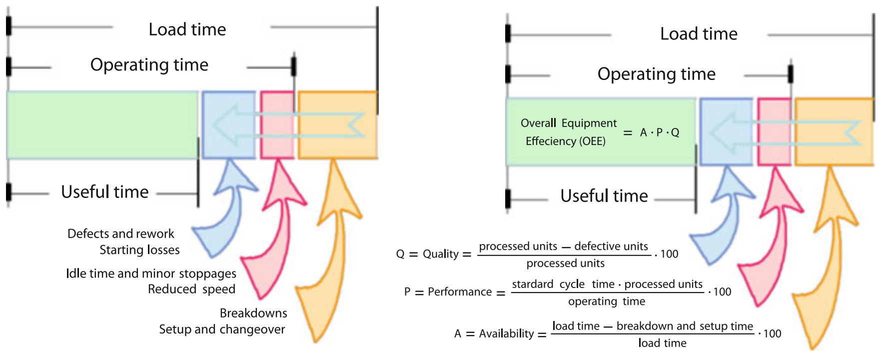


Fig. 31.1 Grouping causes to obtain the useful time (*left*) and the three main rates (*right*)

of company. In this toolbox, the OEE rate, which is included in TPM philosophy, is proposed as the key tool for equipment improvement.

OEE (Overall Equipment Efficiency). This is an equipment efficiency indicator, developed by Nakajima (1988). The objective of OEE is to numerically describe production effectiveness. It can be used for value stream or individual workstations. OEE is characterized by the key production losses. Figure 31.1 illustrates how these six main losses are grouped together. In addition, the grouped losses define three basic indicators: availability, performance and quality, all of which lead to an expression for overall equipment efficiency (OEE).

31.2.1.4 Rationalizing Work Balance

Work balance refers to a situation where all the operators along the production line require the same amount of time to perform their tasks. Ideally, the work content is distributed evenly between workstations to meet the Tact-time. The idea is to balance the assignment of operations to workstations so that idle time and the number of people working on the line are minimized (Liu and Chiang 2009).

Time study. A time study can be defined as the methodology used to determine the time that is required for a skilled operator to perform a specific task, working at a normal pace during the work day (Niebel and Freivalds 2003). A time study provides information that can be used to minimize idle time and balance the production line.

31.2.1.5 Simulation for the Analysis of Proposed Improvements

The main problem in seasonal production is the limited amount of time available to implement improvements when the floor is running. Similar to an F1 race, where drivers use simulators to obtain information in several trials before the actual race, in the production floor of a seasonal factory, the improvements to be tested in the “trial” had to be chosen so that they could be implemented with the available resources. Consequently, simulation software is recommended to present the current state of the factory and try to define as many experiments as possible to determine the best production flow.

31.3 Case Study

The case study was carried out at a major chocolate plant in the Mercosur region (the economic and political agreement among Argentina, Brazil, Paraguay and Uruguay). The aim was to improve the productivity of the nougat production processes in the plant through the application of the proposed lean toolbox.

The first tool that was applied was a “door to door” VSM of the nougat production process. The entire nougat production could be considered as a single product family since it passes through similar processing steps and common equipment in the downstream processes (Braglia et al. 2006).

The current state VSM shows the actual process is as follow: The mass of nougat obtained from the “pot” is then used in the so-called “kitchen” so that after several processes nougat bars are fashioned. They are cooled to room temperature and then each one can be dipped in chocolate and directly packaged into flow packs. After this the nougat bar is placed inside a cardboard case. The latter two processes are carried out with machinery (called cartoners), while the processes in the kitchen are manual.

Figures 31.2 and 31.3 show the current and the future VSM. The size of the figures is too small to be read but they are included simply to compare visually both situations. The following paragraphs will summarize the improvements to achieve this future state. Due to the length of the present paper it is not possible to describe in detail the applications of those tools, but the results will be presented.

By comparing future state lead time with the current state, an expected decrease from 18 to 3 days can be demonstrated. This major improvement of 15 days is mainly brought about through lower WIP inventories before going to the cartoner and smaller finished product inventories waiting for expedition. This reduction in lead time could easily translate to lower financial costs and lower inventory management cost.

In addition, a metric to measure the efficiency of an organization in delivery value added is called Work Cycle efficiency (WCE), and it can be easily obtained from the VSM (Ballis 2001). WCE can be defined as the amount of Value-adding time divided by the total cycle time. The WCE for the current situation was extremely low: 1.17 %. This means that the rest of the time, that is 98.83 %, does not add value to the final product. The future state VSM shows a big but not yet sufficient improvement in the WCE metric.

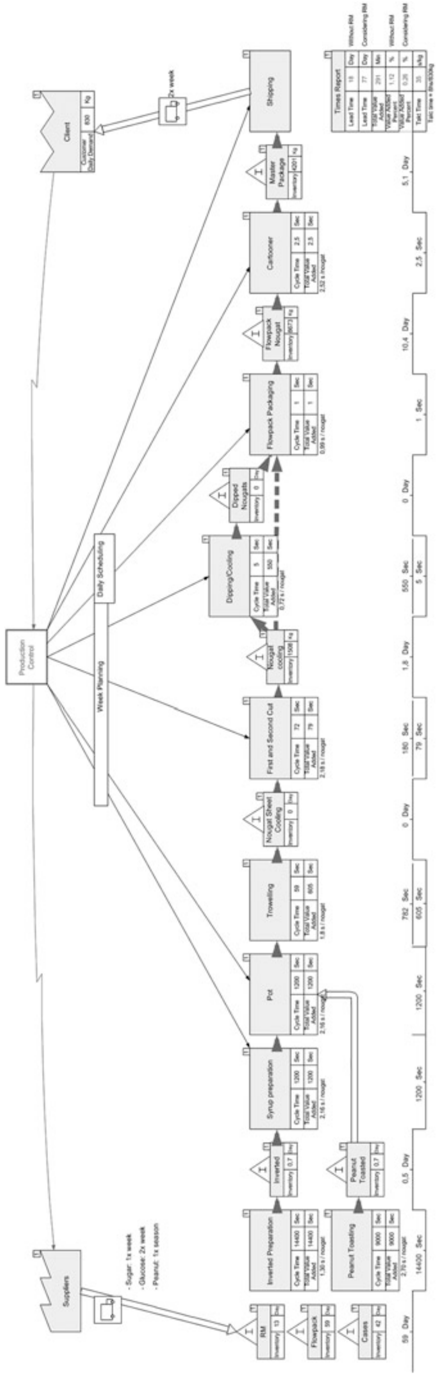


Fig. 31.2 Current state VSM

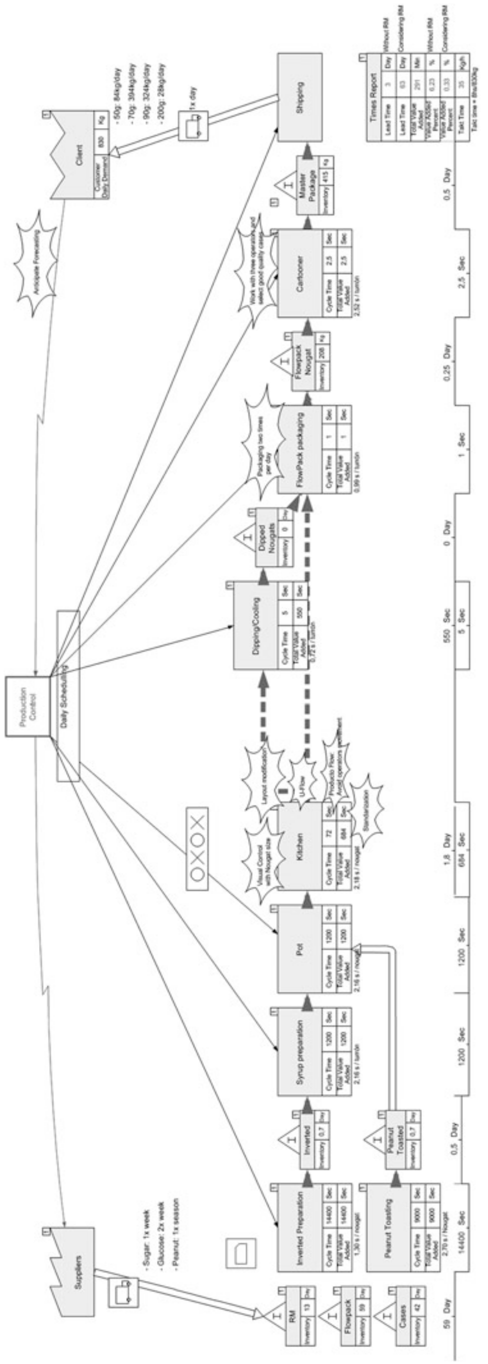


Fig. 31.3 Future state VSM

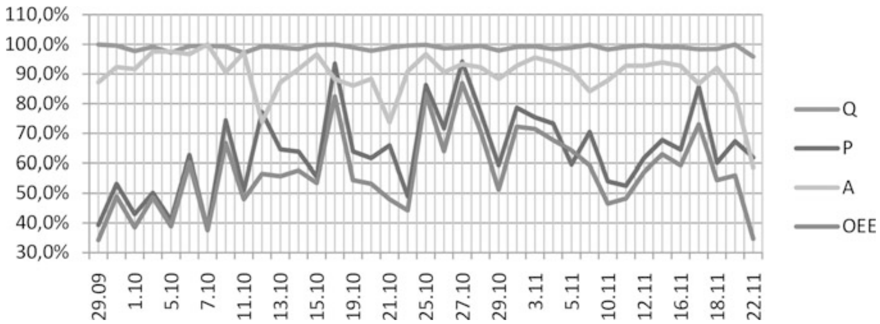


Fig. 31.4 Evolution of the OEE rate

This metric also indicates where attention should be directed in order to significantly improve the percentage of value added time. Consequently, the value stream map allowed us to identify the major non-value added steps, concluding that the days of stock generated prior to using the cartoner have the most influence on WCE. The generation of high stock levels before using the cartoner can indicate that it is the bottleneck in the chain, so we undertook an analysis of this machine.

The cartoner's average values for the OEE rates for this period were Q = 98.9 %, P = 64.0 % and A = 89.9 %. As Fig. 31.4 shows, both the quality and availability of the machine are close to target levels. However, performance is the element that is detrimental to the OEE.

Initially we studied the effect of case quality and the number of operators on the performance metric, obtaining an effect of 20 and 28 %. However, we decided to study how production is affected by these two factors together. Therefore, a General Linear Model (GLM) was used to analyse this issue. This model, developed with Minitab®, clearly illustrates how the use of high quality cardboard cases and three operators leads to an improvement of about 48 %, as compared to the performance obtained by using two operators and bad quality cardboard cases.

Once the cartoner was analysed and improved—improvement was soon noted since the WIP upstream had decreased—the bottleneck moved to the "kitchen" production process. In this case, once the time study was carried out, a balancing diagram and a spaghetti diagram could be constructed with this data. An analysis of this diagram indicated that several of these movements could be reduced by making improvements to the layout.

Those improvements where tested in several experiments simulated with Arena®, a software application that simulates discrete events. After implementing the proposals the number of kilograms produced daily in the simulation differed 6 % from the real values. Since the value added time remained constant and lead time was reduced, the improvement of WCE went from the initial 1.12–6.23 %.

31.4 Conclusions

This paper presented a lean toolbox for seasonal industry and applied it in a case study. This application has demonstrated that although process industries need a special version of the lean manufacturing tools, several lean manufacturing tools could be applied in the traditional seasonal industry. Several techniques and analyses were carried out through this case study such as Value Stream Mapping (VSM), implementation of the Overall Equipment Efficiency (OEE), Spaghetti diagrams, Work Balance, and discrete event simulation (those last three tools were not been presented in the paper). This case study presented promising improvements mainly in lead time and Work Cycle Efficiency.

References

Abdulmaleka F, Rajgopalb J (2007) Analyzing the benefits of lean manufacturing and value stream mapping via simulation: a process sector case study. Int J Prod Econ 107(1):223–236

Alfnes E, Rostad CC et al. (2000). Flexibility requirements in the food industry and How to meet them. 4th International conference on chain management in agribusiness and the food industries. Wageningne, The Netherlands

Alvarez R, Calvo R et al (2009) Redesigning an assembly line through lean manufacturing tools. Int J Adv Manuf Technol 43:949–958

Ballis JP (2001) Managing flow: achieving lean in the new millennium to the gold. Dallas, Brown Brooks

Bicheno J, Holweg M (2008) The lean toolbox. Picsie Books, Buckingham

Braglia M, Carmignani G et al (2006) A new value stream mapping approach for complex production systems. Int J Prod Res 44(18–19):3929–3952

Floyd RC (2010) Liquid lean: developing lean culture in the process industries. Taylor and Francis Group, New York

Fuentes J, Rodríguez C et al (2007) Designing food supply chains: an application of lean manufacturing and lean supply chain paradigms to the Spanish egg industry. Innsbruck-Igls, European Association of Agricultural Economists

Hines P, Rich N et al (1998) Value stream management. Int J Logistics Manage 9(1):25–42

Hoeft S (2010) Stories from my Sensei. Productivity Press, New York

Liker J (2004) The Toyota way. McGraw-Hill, New York

Liu C-M, Chiang M-S (2009) Systematic lean techniques for Improving Honeycomb bonding process. Advanced concurrent engineering. Springer, Berlin, pp 267–269

McDonald T, Aken EM et al (2002) Utilising simulation to Enhace value stream mapping: a manufacturing case application. Int J Logistics Res Appl 5(2):213–232

Melton T (2005) The benefits of lean manufacturing: what lean thinking has to offer the process industries. Chem Eng Res Des **83**(A6):662–673

Nakajima S (1988) Introduction to TPM: total productive maintenance. Productivity Press, New York

Niebel A, Freivalds A (2003) Methods, standards and work design. McGraw Hill, New York

Ohno T (1988) Toyota production system. Productivity Press, New York

Rother M, Shook J (1999) Learning to see: value stream mapping to add value and eliminate MUDA. The Lean Enterprise Institute

Sahoo AK, Singh NK et al (2008) Lean philosophy: implementation in a forging company. Int J Adv Manuf Technol 36:451–462

Santos J, Wysk R et al (2006) Improving production with lean thinking. Wiley, New York
Shook J (2008) Managing to learn: using the A3 management process. Lean Enterprise Institute Inc
Wilson L (2010) How to implement lean manufacturing. McGraw-Hill, New York
Womack J, Jones D (2003) Lean thinking. Free Press, New York
Womack J, Jones D (2005) Lean solutions: how companies and customers can creator benefits and wealth together. Free Press, New York
Womack J, Jones DT et al (1990) The machine that changed the world: the story of lean production. Free Press, New York
Zokaei K, Simons D (2006) Performance improvements through implementation of lean practices: a study of the UK red meat industry. Int Food Agribusiness Manage Rev 9(2):30–53

Chapter 32
Systematic Improvement of IT Processes: Application of CMMI.DEV in Implementation of ERP

M. Grijalvo Martín, A. Ocampo Aguirre and Ana M. Vargas

32.1 Introduction

ERP systems (Enterprise Resource Planning) have an enormous potential to promote the improvement of the competitive position of companies. Successful implementation of an ERP system can afford to cut operating costs, have tighter demand forecasts, speed production cycles and improve customer service (Umble et al. 2003).

However, the results obtained with its implementation aren't often so positive. Studies like the Langenwaltre (2000) indicate that between 40 and 60 % of implementation projects of ERP systems can be classified as failures.

Although these data can be questioned, if we regard that too often companies have dealt with these projects without fully assess what should be its rate of return (Umble et al. 2003) or that IT investments involve for business improvements that hardly can be assessed by ROI (Peerstone Research 2004). On the other hand, it also highlights that the positive results in implementing ERP systems doesn't occur automatically but they need to be given certain circumstances linked mainly by the implementation process itself.

The participation of the authors of this paper in the implementation of ERP's and methodologies of process improvement, has allowed to set some of the key factors to consider in carrying out this process of integration successfully.

M. Grijalvo Martín (✉) · A. Ocampo Aguirre · A. M. Vargas
Escuela Técnica Superior de Ingenieros Industriales, Calle de José Gutierrez Abascal, Madrid, Spain
e-mail: mercedes.grijalvo@upm.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_32,

32.2 Antecedents: Implementation of ERP

The implementation of an ERP system is, first and foremost, a project. Because although the effort required for system analysis and software development has been done, even it's necessary the analysis of business processes to adapt it and get all the rate of return possible. A survey published in Information Week points out that managers assert, among others, as triggering keys of the failure the bad planning or management of the project (77 %) and the alteration of the targets during its implementation (75 %).

And is that based on the premise that the client in an ERP implementation is aware that this is a standard, it is very common as to which progress on the project and consultants services provider enters the customer processes, are generated or modifying the initial requirements obtained in the stage of making requirements.

But we can't think that the only source of these changes or new requirements are customer requests, there're many other sources as the impossibility of the implementation service provider to consider in the ERP standard the necessities of the processes, the discovering, while the project is progressing, of the limitations of the software, or even in some cases the review, unplanned, internal processes of the client organization to improve its effectiveness/efficiency taking advantage of the implementation of the ERP standard processes.

Apart from that these new requests or modifications aren't generated at the same time (or at least not completely) or by the same means, because the speakers aren't usually the same in the different processes: consultant of logistics ERP is difference of financial ERP, and of course the key user at the client isn't the same in both processes.

In general, this situation is multiplied insofar as that more organization processes are being implemented at the same time, because it generates the logical bi-directional exchange of information customer and service provider, not managed and/or controlled, at different times (taking requirements, solution design, prototype, prototype changes, training, etc.) and from different pathways (purchases, sales, production, CRM,…).

The combination of at least these three "axes" (processes/origin, different times/project phases, bi-directional exchange of information/customer–supplier) makes not only the management/planning of the project will be a task rather complicated, but also increases their complexity as they increase in magnitude, i.e. to take part a third actor as a supplier of other applications to integrate with ERP, to extend the deadline of the project will, to broaden the scope of the project to implement new processes, to incorporate new partners, etc.

Additionally, if the implementation service provider of does not have set processes that enable him effective management of ERP implementation project, certainly the interaction of these axes can jeopardize the success of the project: status unknown of parameterization, much amount of information without management, documentation of date, etc.

In practice most of the services providers of implementation take the necessary steps to manage and control the projects, but only to a certain level of detail. The tasks carried out by the consultants to overcome the abovementioned situations, usually lost in the control overview of the project. These tasks that individually observed, from the point of view of resources, in some cases seem negligible, added up can be a huge number of hours consultant on various programs, modules, at different stages of the project or in different documents and applications, or what is the same increase in project cost, failure to comply with the project deadlines, quality problems, etc.

That ineffective management of the implementation project, the lack of control, brings consequences unwanted, from the increase of working hours in parameterization/re-configuration, to in some cases, unnecessary developments.

From this perspective, this paper presents and analyzes the experience of a IT European multinational company in the analysis, evaluation and improvement of their implementation internal processes of ERP tools, considering as reference model good practices within their system quality management the standard CMMI (Chrissis 2006).

32.3 Capability Maturity Model Integration

The initiatives that have been emerging around the world about software process assessment and improvement, have led to the development of several models which propound different methods of self-assessing the process capacity, different ways of representing the activities necessary for the improvement and different ways to guide the organization to maturity, and one of the best known and currently applied in the IT sector is CMMI (Athos et al. 2006).

Currently the model, which is oriented to the evaluation, change and improvement organization, is divided into three "constellations"

- CMMI-DEV model is used for process improvement in organizations that develop products and services
- CMMI-SVC model provides guidance to organizations that establish, manage, and deliver services
- CMMI-ACQ model provides guidance to organizations that manage the supply chain to acquire and integrate products and services

The improvement in the model is based on a set of progressive steps, in contrast to the dramatic transformation that other quality models such as ISO 9000 propose. In this sense, CMMI provides a framework for organizing these steps gradually by selecting one or more process areas in order to improve their processes, the continuous representation, or by using predefined sets of process areas that define the improvement way, the staged representation.

Both representations are equivalent and differ in the selected process area to the improvement approach. CMMI model suggests specific process areas according to the approach and the level goal choose.

Regardless of which representation is chosen, the CMMI assessment follows an approach of levels that wants to characterize the improvement in terms of the evolution from an improvised and chaotic process to a mature one with adequate discipline and greater ability:

In CMMI, unlike other models, these requirements are not a prescriptive, but provide a disciplined approach to process improvement based on the objectives and priorities of the organization.

This, for the reasons will be stated below, facilitates both its adoption, because it allows the company to set the pace of change and improvement, and its integration with other standards, that sometimes the organization must have implemented by a requirement of their customers, either general like ISO 9000 or specific like ISO 20000, ISO 27002 or ISO/IEC 12207.

32.4 Methodology for IT Process Improvement

The division in charge of ERP tools implementation in the company when the study was carried out isn't indifferent to the current facts in which the quality of the software provided to customers is becoming increasingly important both as a differentiating factor as f its influence on the final costs.

This project arises from the sum of the search of opportunities to improve processes in this division and the intention to continue spreading throughout the organization using the CMMI methodology for evaluating and improving processes and more specifically the standard CMMI-DEV representing the domain for development.

A model that although is designed for software development and the company activities are ERP parameterization, a standard, changes in the initial requirements motivated by the interaction of the three areas mentioned: processes/origin, different times/project phases, bi-directional exchange of information/customer—supplier, means an update of the parameters and therefore an update of the documentation at the different stages of the project.

In this sense, the application of the CMMI.DEV tools (process areas and their practices) provide a proven methodology to maintain, among other things, the "baseline" and carry out the "monitoring and configuration control "so the interaction between information (requirements), configuration (current status and evolution of software) and documentation (of support and revisions) can be managed effectively and the concordance of states throughout all the ERP implementation project.

From this perspective, we analyzed the ERP implementation procedure of the company, which is based on the methodology of a globally recognized brand in implementing ERP solution.

The study analyzes according to requirement for a CMMI maturity level II as a goal: the implantation procedure of the ERP, the institutionalized practices in the company and the practices not documented in procedures but used by the organization.

This level includes, all process areas related to the implementation of an ERP. Moreover according to the model to achieve the maturity level II all process areas must achieve capability level 2 or higher.

The requirements, goals and practices both specific and generic that process areas must satisfy at this level are directed to ensuring that organization manages its processes and establishes monitors and maintains the resulting products.

This framework is the starting point of the empirical work that was formalized in the following stages:

- Diagnosis, is the initial assessment of the practices applied by the company about the satisfaction of the model requirements and it was carried out by different check-list.
- Analysis, is the preparation of the progress report that contains diagnosis information in relation to compliance with the practices of the model for the different process areas and besides the actions needed to develop and reach the maturity level II.

This report provided, for each process area of ERP division, the definition of the causes of the deviations between the target profile and the profile reached, and recommendations (action needed) to get the first one.

- Evaluation, is the determination of the degree of approach, deployment and results evidenced for each specific and generic practice of the model, this work allowed quantitative evidence of the diagnosis findings and the vision of where the improvement efforts should be directed.
- Assessment is the establishment of performance indicators found in the earlier phases for each of the areas of process: the diagnosis, analysis and evaluation. The graphical representation provided a quick overview of the capacity level of each one of the process areas, besides their maturity level.
- Improvement proposals, are the definition of actions to be undertaken to reach maturity level II in the ERP division.

Finally, all actions required as necessary were set in a matrix to facilitate the "navigation" between the practices required by the model and the proposed measures, which also included an assessment based on immediate need or otherwise of its implementation according to their impact with respect to achieving the target level, and its difficulty of execution according to company culture and staff, and investment and training required.

32.5 Analysis and Conclusions

As expected the study has shown weaknesses in business processes that justified the initial idea of the necessity of good practices (some existing, some existing but non-standard, and other only non-existent) in implantations and which correspond with the main causes that didn't allow the fulfillment of the goals and practices of both generic and specific CMMI.DEV model.

The implementation of recommendations arising from the study will enable to make a qualitative step forward in improving the processes of division, highlight that for the purposes of requirement fulfillment of the CMMI standard for Level II of maturity is necessary to implement all the recommendations without exception.

Note that in general, these proposals don't require significant initial financial investment like the procurement of technology, outsourcing, etc. or training on a large scale, and its implementation doesn't assume complex a priori.

Common organizational culture in a company of this type and the structure of the standard, with different levels, makes it possible to think about a certain ease or little difficulty to carry out successfully, although its implementation will require time and especially the involvement of all staff.

In fact the analysis showed the effort made by the organization on standardization of processes and the development of procedures throughout years: sometimes by internal initiative (implementation of a standard), other times by customer demand (procurement of services only if you have implemented "X" standard) and in others by the same market demand (possible public procurement only if you have "Z" certificate).

In this sense affect the need to address the process improvement process in a comprehensive manner, the fact of implementing different methodologies or standards should not lead to the coexistence of separate management systems within the organization, but must seek a single process map to ensure that the requirements of the models in question are coordinated and avoid duplication by reducing disparate systems, bureaucracies and especially discrepancies.

One aspect that there should be emphasized of CMMI, is its ability to incorporate other quality standards, but that is based less on sharing requirements, EN-9100 or TS 16946 are based on ISO 9000, but on their integration as part of a scheme of goals and practices within the different process areas.

Moreover the model doesn't indicate in what order processes should be carried out, it only defines and depicts them, which allows the organization to establish its own pace in the improvement process based on their objectives and priorities and facilitates the necessary cultural change in the organization. It takes a long time to involve people in using and improving the system as part of their daily work.

And despite this implicit recognition that if you want to improve, is necessary to impact on the way of working on certain products, is also obvious that often influence on the design of the organization of work is avoided and assuring quality is limited to the control of the process by setting certain standards or guides of good practice that are slowly converging to international recognition models but are made outside the system itself which they are applied to (though often sectoral specificities are recognized, of organizational size, etc.) and to which are incorporated a certification scheme for its audit and evaluation (Prida and Grijalvo 2008).

Besides, the values placed by the market for quality system certification has resulted in implementations based on impose certain requirements on the organization, regardless of their own culture. This has led not to internalize the new routines and once achieved the certification of the quality system it can only be maintained through strict and often expensive control system, focused mainly on what that is measurable within the system.

Simple tools such as Kankan or suggestion systems have taken 10 years for its adoption in Japanese corporations. The implementation of these techniques requires time not only for training people in new skills, but also for undertaking them and putting them into practice (Galgano 1993; Fortuna 1991; Camison et al. 2007).

In this sense, highlight that the model assessment framework based on the five (maturity) levels introduced by Phil Crosby Cros80, Chap. 3 not only promotes the development of a disciplined approach for improvement but allows that the efforts to formalize and integrate the IT service management have visibility and recognition within and outside the organization.

The certification is a key as has shown up the implementation of other standards such as ISO 9000, EN 9100 or TS 16496, and which is motivated by the quality assurance goal from the industry, in fact audits have kept on an element of control to determine the conformity or not conformity of suppliers quality management systems (Nanda 2005; Duran 2005; Grijalvo and Prida 2005; Martinez 2004).

One area that the Scheme developed by the CMMI model stands out from the initiatives taken in recent years from different sectors: automotive, aerospace, defense and more recently tourism, to develop their Certification Schemes have been oriented more to define and control its operation through various organizations than to promote appropriate management commitment and improvement project.

References

Atos, Ita, Tid, Andago. Análisis de estándares de certificación de madurez del proceso de desarrollo. Proyecto Vulcano, Forja de proyectos software de calidad. Entregable D5. España. 2006

Camison C, Cruz S, Gonzalez T (2007) Gestión de la calidad: Conceptos, enfoques, modelos y sistemas. Pearson Educación, Madrid

Chrissis, Konrad, Shrum CMMI.DEV versión 1.2. Software Engineering Institute, SEI. 2006

Duran A (2005) Análisis del proceso de elaboración e implantación de instrumentos de Responsabilidad Social Corporativa. PhD. Universidad Carlos III. Madrid

Fortuna RM (1991) El imperativo de la calidad. En Grupo de Consultoría de Mejora de la Calidad de Ernest & Young. Calidad Total. Una guía para directivos de los años 90. Capítulo 1. 3ª Ed. Tecnologías de Gerencia y Producción. Madrid

Galgano A (1993) Calidad Total. Díaz de Santos. Madrid

Grijalvo M, Prida B (2005) La implantación de las normas EN 9100 y el Esquema de Certificación "Other Party" en España. DYNA, Nov, pp 37–41

Langelwalter G (2000) Enterprise resource planning and beyond: integrating your entire organization. St Lucie Press, Boca Ratón

Martínez I (2004) Principales consecuencias de la implantación del Esquema de Certificación Aerospacial. Final Project. School of Engineering. University Carlos III. Leganés. Madrid

Nanda V (2005) ISO 9001:2000. Lograr la conformidad y la mejora continua en empresas de desarrollo de software. AENOR. Madrid

Peerstone Reseach (2004) ERP ROI: Myth or Reality. A Peerstone Research Report, Peerstone Research, accesible en la red en la dirección http://216.197.101.108/pdfs/

Prida B, Grijalvo M (2008) The socio-technical approach to work organization. An essential element in quality management systems. Total Qual Manage Bus Excellence 19(4):343–352

Umble EJ, Haft RR, Umble MM (2003) Enterprise resource planning: implementation procedures and critical success factors. Eur J Oper Res 146:241–257

Part V
Management Systems and Sustainability

Chapter 33
Quality, Environment and Safety: From Individual Systems to Integration—A Portuguese Case Study

Gilberto Santos, Síria Barros and Manuel Rebelo

33.1 Introduction

According to the ISO—IMS publication (The integrated use of management systems standards) (ISO 2008), a common objective of management system standards is to assist organizations to manage the risks associated with providing products and services to customers and other stakeholders.

The following questions may arise: How can these three management systems be integrated? Can they be integrated? According to Santos and Mendes (2009), this is a problem that the most developed companies started to experience some time ago, and it has been discussed by various authors, McDonald et al. (2003), Arifin et al. (2009) and Bernardo et al. (2009), the last one provides a summary of the degrees of integration according to some authors, and Labodová (2004), who reported on the implementation of integrated management systems using a risk analyses based approach.

In accordance with the ISO 72: Guide (2001), the experience with management system standards issued by the ISO shows that there is a number of common elements, which can be arranged under the following main subjects: policy; planning; implementation and operation; performance assessment; improvement and management review, as stated by Rebelo (2011). Therefore, the idea of an IMS—Integrated Management System consists of establishing correspondences and combining two or more independent management systems, for example in accordance to ISO 9001, ISO 14001, and OHSAS 18001. Evidence of this can be

M. Rebelo
CLEGI - Engineering and Industrial Management Research and Development Centre, Lusíada University, Largo Tinoco de Sousa, V. N. de Famalicão 4760-108, Portugal
e-mail: manuel.f.rebelo@gmail.com

G. Santos (✉) · S. Barros
College of Technology—Polytechnic Institute Cávado e Ave, Campus do IPCA, Lugar do Aldão, Barcelos 4750-810 Vila Frescaínha S. Martinho, Portugal
e-mail: gsantos@ipca.pt

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*, DOI: 10.1007/978-1-4471-5349-8_33,

seen in Table A.1—of the annex A-of OHSAS 18001:2007. Despite having their origins in different aspects of the company performance, the Quality, Environment and Safety Management Systems have a lot in common, as mentioned by Block and Marash (2002). According to Santos et al. (2011) the future lies in the integration of these Management Systems, managed by only one multidisciplinary team with training and skills in several areas, thereby economizing both financial and human resources. As can be expected, there are several difficulties involved with implementing an Integrated Management System (IMS). However, Beckmerhageni et al. (2003) points out that the management separately in an incompatible way results in costs, an increased probability of faults and errors, duplicated efforts, the creation of unnecessary bureaucracy and a negative impact near the Stakeholders, particularly "Employees and Costumers". According to Salomone (2008), a cultural shift is underway and the number of companies with more than one certification is constantly on the increase. Many of them are advancing towards integration. According to this author and others like, Karapetrovic and Casadesús (2009), several countries like England—PAS 99 (PAS 2012), New Zealand, Australia, France, The Netherlands, Denmark—DS 8001 IMS (2005) and Spain—UNE 66177 (2005), have developed or are in the process of developing their own national standards on IMS, encompassing various references, functions of the organizations and stakeholders. Besides that, the responsibilities for the quality, the environment, health, safety and social aspects have to be integrated into the culture of the organization, due to the fact that these responsibilities are inherent to all aspects of the activities of organizations, from procurement to design and development, production, sales and marketing.

33.2 Work Methodology

All the work was developed and the obtained model tested at a Portuguese SME, localized in the Municipality of Vila Nova de Famalicão, Portugal, that is a trusted partner dedicated to delivering, products and smart distribution solutions to electric, natural gas and water utilities.

The evolution of the QES Management Systems and the different certifications achieved by the company over the years are shown in Fig. 33.1. It is in this sense that, over the years the Quality, the Environment and the Safety have been integrated into the strategy of change and evolution of the Company. An internal research was developed to assess the perception of the Collaborators.

For that a questionnaire was drafted, tested, validated and distributed to a representative sample of Collaborators from different Departments of the Company. The main topics of the questionnaire were: 1—Importance of motivation factors for the implementation of the IMS-QES; 2—Stakeholder influences on the performance and evolution of an IMS-QES; 3—Main Internal difficulties for the development of the IMS-QES model and its implementation; 4—Potential benefits resulting from the implementation of the IMS-QES. One of the activities that also

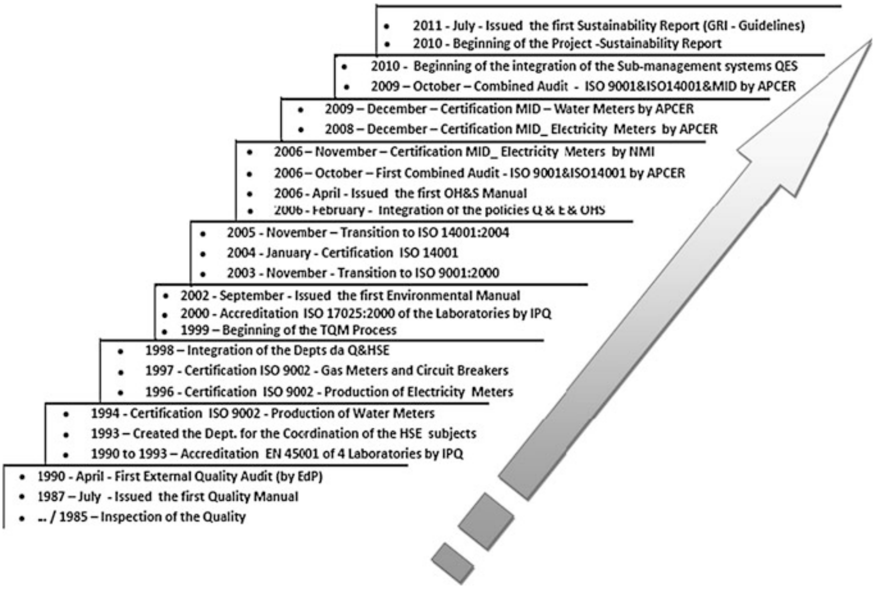


Fig. 33.1 Milestones related to the evolution of the company's QES management systems (Rebelo 2011)

supported the study was the analyze of the compatibility of the several requirements of each involved standard, in context and framework of the characterization of the company's situation, backed up by an analysis of these standards. This compatibility represents, at our understanding, the starting point for consequents activities of integration, simplification and optimization, to achieve a strictly necessary level and consequently three subsystems—Quality Management System (QMS), Environmental Management System (EMS) and Occupational Health and Safety Management Systems (OHSMS)which are integrated to the maximum extent possible.

The main objective of the study was to obtain a structured model of an IMS-QES, supported on the characterization of the real organizational situation of the Company as well as on the evolution of the management systems standards from individual systems to integration.

33.3 Investigation Results

The synergy that an Integrated Management System (IMS) can offer have driven organizations into higher levels of performance at a lower cost than that associated to independent certification management systems. The simple schematic Fig. 33.2 represents the vision of an IMS-QES, suggesting that they have common information and procedures.

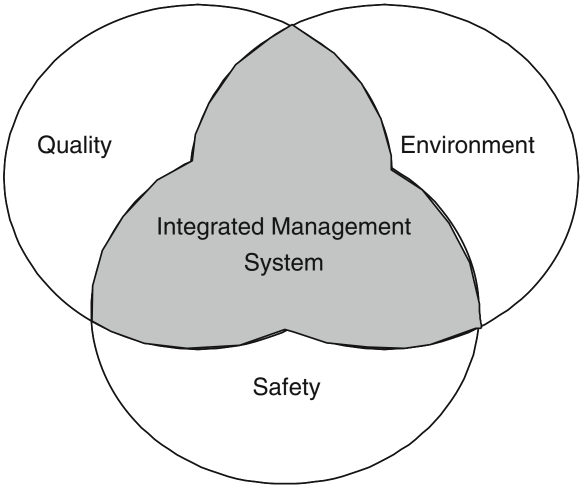


Fig. 33.2 Schematic representation of an integrated management system (Santos et al. 2011)

Integration can be achieved at different levels, leading to partially or fully integrated systems. A partial integrated system keeps their manuals separated using, as far as possible, integrated procedures. A fully integrated system is based on a single manual that integrates unified management systems requirements.

The emphasis placed by the respondents, both for the present and fundamentally for the future, is on the range of potential benefits identified and evaluated as being the result of the implementation of an IMS-QES, which justifies and validates the implementation of such system making it a high priority.

The benefits of IMS-QES, identified by the respondents are: The elimination of conflicts between individual systems and the optimization of resources, specifically human resources related to management and operationalization; The integrated management of sustainability components in a global market, where quality no longer makes a competitive difference and is now just a starting point for a business; the improvement of partnerships with suppliers of goods and services; Dialogue with our main stakeholders and commitment to their ongoing satisfaction and increased contribution to the company's competitiveness; Common management policy, objectives, targets and KPIs—Key Process Indicators related to QES performance; The creation of added value for the business through the elimination of waste, especially that of bureaucracy associated with independent management systems and their certifications, including the laboratories and MID; Improvement to the company's internal and external image and to its credibility in QES areas, specifically in relationships with Clients, Official Entities and other Stakeholders; Improvements to the coordinated and integrated management of risks to the safety of people and property, the environment and the quality of products from "cradle to grave"; A reduction in the number of internal and/or external audits and audits of suppliers and the consequential amount of time taken and associated costs; Greater valuation and motivation of employees as a result of the expansion of their skill base, actions and responsibilities, with their resulting empowerment; The integrated management of sustainability components.

A set of management system standards that apply to any type of organization and activity were considered. Others exist. Others will certainly be created. These standards cover a wide array of different disciplines, aims and activities of organization and operation of the Enterprises including the interfaces and satisfaction of all theirs stakeholders.

33.3.1 From Individual Systems to Integration: Observed Integration Level

There are various standards for individual management systems: QMS according ISO 9001; EMS according ISO 14001; OHSMS according OHSAS 18001; Social Responsibility management—SA 8000, and others. The organizational structure of the QES Management includes a coordination and a group of functional and operational areas whose managers have responsibility for, and authority over ensuring that the requirements of each Subsystem, either operated in an isolated way or in interaction with others, are understood by all employees and implemented at the Company, in a coherent manner as established.

It has been observed that there is an integrated QES management policy. This policy figures in each of the QES Manuals, and establishes coherent and defining principles and proposals for common actions and responsibilities for the Integrated Management of Quality, the Environmental and Occupational Health & Safety issues. In the Fig. 33.3 is shown a result of the natural evolution of integration of the IMS-QES, which made relevant the step of finalization of the structure.

For a better integration of the different existing subsystems and consequent development of the respective model, it turned out to be fundamental to structure an specific action plan, consisting of four fundamental phases supported on an approach based on the Deming Cycle—PDCA–Planning; Execution; Implementation; Monitoring and assessment for continuous improvement.

33.4 Discussion

This research reveals that integration of Management Systems brings fundamental improvements which we can highlight: The elimination of conflicts between individual systems and the optimization of resources; The integrated management of sustainability components in a global market; Common management policy, objectives, targets and KPIs—Key Process Indicators related to QES performance; The integrated management of sustainability components. To achieve this results,

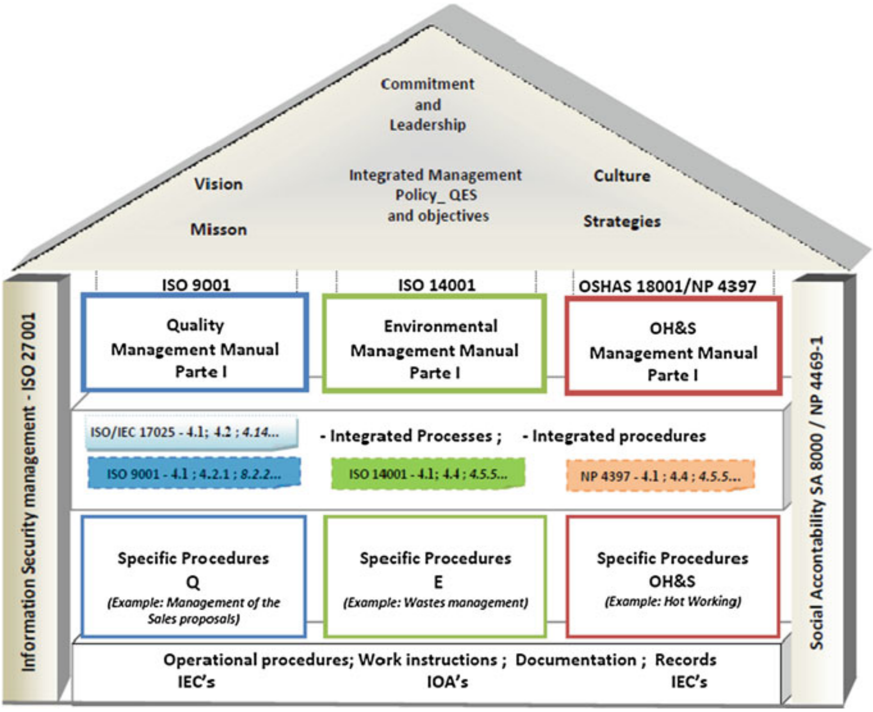


Fig. 33.3 From individual systems to integration—observed integration level (Rebelo 2011)

this research and the respective observed integration level is in line with PAS 99 (2012), where many of the requirements of multiple management system standards may be integrated into one common system, which could be the best option for a specific organization. Similarly, in accordance with that set out in Annex D of UNE 66177 (2005), the structure of common and specific processes and documents in an IMS may be configured as processes and documents that are common to the three management systems.

Another model for an IMS in accordance with DS 8001 (2005) is mentioned by Jørgensen et al. (2006) and the observed integration level presented in this work is in line with him. However, other IMS models are referenced or presented by other authors, such as, Arifin et al. (2009) and Santos et al. (2011). According to Rasmussen (2007), the common elements/requirements of the different standards could be identified using ISO Guide 72 (2001). This was also considered in PAS 99 (2012), the model of which was recommended for an integrated management structure, is configured with the six main requirements of ISO Guide 72: Policy; Planning; Implementation and operation; Performance assessment; improvement and management review, following the Plan, Do, Check, Act cycle. Therefore, Table B.1 in Annex B of ISO Guide 72 (2001) identifies common management system requirements in ISO standards, which are structured/grouped into six components: B1—Policy, B2—Planning, B3—Implementation and Operation, B4—Performance assessment, B5—Improvement and B6—Management review. It recommends to follow this common structure when developing and reviewing management system standards, in order to guarantee their compatibility and to improve their alignment. This was our main worry when the model presented in this work was designed. To conclude this discussion, we would like to emphasize that, according to Fig. 33.3, we consider Information Security Management (ISO 27001) and Social Accountability (SA 8000) (2008) as two fundamental pillars for successful Integration of Management Systems and consequent sustainability.

33.5 Conclusions

There is no an international ISO standard with a specific structural model for Integrated Management Systems for Quality, Environment and Safety, or for other management areas such as: Risk Management; Information Security Management; RDI Management; and Social Responsibility Management, among others. The observed integration level follows this path.

As greatest benefits of IMS we highlight, among others: the elimination of conflicts between individual systems with optimization of Resources; integrated management of the components of Sustainability in a Global Market; common management policy, objectives, targets and KPI's—Key Process Indicators of QES performance; the creation of added value for the business through the elimination of several organizational wastes.

The proposed objectives and goals were achieved. Specifically, the Company has now an adequate model for its IMS-QES, structured based on the Lean philosophy and its individual management systems, with real usefulness and added value to the Company's business, and globally more easily manageable.

The development, implementation, maintenance and improvement of IMSs in Organizations require that they affect Human Resources with multifaceted competences, what is not always possible for numerous reasons.

References

Arifin K, Aiyub K, Awang A, Jahi JM, Iten R (2009) Implementation of integrated management system in Malaysia: The Level of Organization's Understanding and Awareness European J Sci Res ISSN 1450-216X 31(2):188–195

Beckmerhageni A, Berg HP, Karapetrovic SV, Willborn WO (2003) Integration of Standardized Management Systems: focus on safety in the nuclear industry. Int J Qual Reliab Manage 20(2):210–228.

Bernardo M, Casadesus M, Karapetrovic S, Heras I (2009) How integrated are environmental, quality and other standardized management systems? An empirical study. J Cleaner Prod 17:742–750

Block MR, Marash IR (2002) Integrating ISO 14001 into a quality management system. ASQ—Second edition. Milwaukee

DS 8001 (2005) Integrated management systems –Approval date—11 July 2005 (Denmark)

Guide ISO 72 (2001) Guidelines for justification and development of management System standards

ISO (2008) The integrated use of management system standards—Switzerland

Jørgensen TH, Remmen A, Mellado MD (2006) Integrated management systems—three different levels of integration. J Cleaner Prod 14:713–722

Karapetrovic S, Casadesús M (2009) Implementing environmental with other standardized management systems: Scope, sequence, time and integration. J Cleaner Prod 17:533–540

Labodová A (2004) Implementing integrated management systems using a risk analysis based approach. J Cleaner Prod 12:571–580

McDonald M, Mors TA, Phillips A (2003) Management system integration: can it be done? Quality progress; 67–74

PAS 99 (2012) Specification of common management system requirements as a framework for integration—BSI, second edition

OHSAS 18001 (2007). Occupational Health and Safety Management Systems – Requirements - BSI, first published July

Rasmussen JM (2007) Integrated management systems—An analysis of best practice in Danish Companies. Master Thesis, Aalborg University

Rebelo MF (2011) Contribution to the structuring of a model of integrated management system QES. Master Thesis. Polyt Inst Cavado Ave, Portugal

SA 8000 (2008). Social accountability 8000. Social accountability international

Salomone R (2008) Integrated management systems: experiences in Italian organizations. J Cleaner Prod 16:1786–1806

Santos G, Mendes F (2009) Impacto de la certificacion de los sistemas integrados de gestion en las PMEs portuguesas. Forum Calidadn 198:46–51

Santos G, Mendes F, Barbosa J (2011) Certification and integration of management systems: the experience of Portuguese small and medium enterprises. J Cleaner Prod 19:1965–1974

UNE 66177 (2005). Sistemas de Gestión – Guía para la integración de los sistemas de gestión – AENOR, M 27098:2005 (Spain)

Chapter 34
Evaluation of the Business Process Management Practices: An Application in the Company of Oil and Gas Exploration and Production

Moacyr A. D. Figueiredo, Gilson Brito Lima, José Rodrigues de Farias Filho, Debora A. Herkenhoff, Lívia C. Figueiredo and Carolina C. Figueiredo

34.1 Introduction

Especially since the 1990s, as the result of the increase of the organizations interest in the business process management, several maturity models were designed and improved. The main goal of an evaluation maturity model is to identify the level of maturity in the practices of business process management, in terms of the capacity of the business processes to be defined, used, managed and repeated, contributing to their results to be continuously improved (Quintella and Rocha 2007). These models use attributes to the business processes evaluation and, by the analysis of

M. A. D. Figueiredo (✉)
Department of Engineering, Institute of Science and Technology,
Universidade Federal Fluminense, Campus Rio das Ostras, Rio de Janeiro,
Rua Recife, s/n, Jardim Bela Vista, Rio das Ostras, Rio de Janeiro, Brazil
e-mail: moacyrfigueiredo@gmail.com

G. B. Lima · J. R. de Farias Filho · D. A. Herkenhoff · C. C. Figueiredo
Department of Engineering, School of Engineering, Universidade Federal Fluminense,
Campus da Praia Vermelha, Rua Passo da Pátria, 156, São Domingos, Niterói,
Rio de Janeiro, Brazil
e-mail: gbal.sms@gmail.com

J. R. de Farias Filho
e-mail: fariasfilho@gmail.com

D. A. Herkenhoff
e-mail: debora.herkenhoff@gmail.com

C. C. Figueiredo
e-mail: c.figueiredo03@gmail.com

L. C. Figueiredo
Department of Administration, Faculdade Professor Miguel Ângelo da Silva Santos,
Rua Alfredo Backer, 363, Macaé, Rio de Janeiro, Brazil
e-mail: liviacavalcantil2@gmail.com

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_34,

the stage in which the organization is compared to these attributes, arrangements can be taken and action plans can be designed in order to reach the excellence of the business processes.

In this context, the present paper has the goal to present the results of a quality research about the evaluation of the business process management practices of a large company of oil and gas exploration and production in relation with a group of criteria and observable variables for the evaluation of the maturity of the business process management and offerdifferent ways to improve their results, either by reducing cost and investment.

34.2 Literature Review

The bibliographical research aims to identify the attributes used by the main evaluation models used to evaluate the maturity business processes in the literature. This study sought to explore the full potential of the bibliographic database available and the tools of the information technology for its treatment. The next items will present the main results of the literature review.

34.2.1 The Main Models to Evaluate the Maturity

The first maturity model mentioned was developed by Crosby (1985) and was called the “Quality Management Maturity Grid” (QMMG). For its generic nature and intrinsic structure of evolution, the Crosby (1985) model became reference for several maturity models (Valadares 2001). The main principles were adapted by SEI (Software Engineering Institute) to develop the CMM (Capability Maturity Model) to evaluate the software development processes.

Based on the CMM, an abundance of models guided to the measurement of the maturity of the process management were launched. The main models identified in the literature were (CIP E&P 2009):

- Maturity Models for Quality Management
  - QMMG (Quality Management Maturity Grid)
- Maturity models for Software Process Management
  - CMMI (Capability Maturity Model Integration)
- Maturity models for Business Process Management
  - PEMM (Process and Enterprise Maturity Model)
  - BPMM (Business Process Maturity Model)
  - CEMO (Checklist for Evaluating the Maturity of an Organization/Process)
  - BPOMM (Business Process Orientation Maturity Model)
  - BPMM (Business Process Maturity Model)

- Maturity models for Management Projects
  - OPM3 (Organizational project management maturity model) – PMI
  - PMMM (Project Management Maturity Model)
- Maturity models for the Chain of Supply Management
  - SCOR (Supply Chain Operations Reference).

34.2.2 Criteria for the Maturity Evaluation

Among the ten models identified in the literature, four were selected to serve as base for the definition of the criteria for the evaluation of the business process management maturity: the CMMI, the PEMM, the BPMM and the BPOMM. These models were selected because they have a clear set of attributes for the specific evaluation of the business process management.

From the analysis of the attributes used by the four selected models, six criteria were defined for the evaluation of the maturity in the the business process, management Process Mapping, Indicators, Process Improvement, Process Manager, People Management and Leadership.

34.3 Methodology

In this item the phases of research will be presented. The universe of the research is defined and the procedures to select the sample and the data collection, the instrument for data collection and the profile of the respondents are presented. Then, the procedures used to the treatment and analysis of the collected data will be explained.

The research was divided into four stages. During the first stage a bibliographical research was made to identify the attributes used in the main maturity models and to define a group of criteria and observable variables to evaluate the maturity of the business process management. During the second stage, from the defined criteria a research instrument to evaluate the business process management practices of a large company of oil and gas exploration and production was created.

During the third stage, initially a pilot test was applied with the purpose to evaluate the research instrument and makes the final adjustments needed. Then, a sample was selected and a data collection was performed. Finally the data collected were processed and treated statistically, and then anevaluation of the validity and reliability of the constructs was performed and the sypnosis of the data, using simple statistics, together with a descriptive synthesis of qualitative nature were presented.

34.3.1 Universe of the Research and Sample

The main goal of this research was to collect information about the perception of the collaborators of the company in relation to the practices of business process management. The studied universe was defined with the group of collaborators of the company.

After the definition of the universe to be researched, the procedures to the selection of the sample were defined. In this study, a non-probability convenience sample was chosen, because the database of the process management area of the company was used, in other words, only the members of this base had the opportunity to participate of this research. The size of the sample was set at about one hundred and sixty two respondents, which correspond to the collaborators, with the knowledge of the process management practices in the field of exploration and production of oil and gas indicated by the leadership of company.

34.3.2 Research Instrument

The research instrument was elaborated from the defined criteria for the maturity evaluation of the process management and can be found at CIP E&P (2009). It was used to collect data about the perception of the collaborators related to the process management practices of the large company of oil and gas exploration and production.

The research instrument was divided into criteria and observable variables and, before its implementation, was adapted to the reality of the company. The research instrument has six criteria and forty three observable variables.

34.3.3 Respondents profile

The field research was held during the action of the authors of the Research Project in the CIP—Centro de Inovação e Produtividade (Innovation and Productivity Center)—in the Performance Evaluation Pillar (CIP E&P 2009), particularly in the perception of the business process management practices and the business process maturity evaluation inside a large company from the segment of oil and gas in Brazil.

The profile defined for the respondents was: collaborators with experience in applying the business process management practices in the exploration and production of oil and gas area. The company leadership provided one hundred and sixty collaborators with experience and knowledge in the application of the business process management practices to answer the questionnaire.

34.3.4 Gathering of data

In this study, the gathering of data was chosen through a questionnaire available in the company's intranet. The instrument was provided in the intranet and all the respondents received an email inviting them to participate in this research.

The instrument was divided in two parts. The first one had as an objective,that is, the gathering personal data of the respondent and the second part the gathering of respondent opinion in relation to a set of affirmatives related to the process management practices in the company.

The measurement scale used in the second part of the instrument was Likert's, with five points that goes from 1 ("Strongly Disagree") to 5 ("Strongly Agree"). The scale was chosen because it is the most used in this type of research, since it reflects the variability of the values that result from the scale, and because it has greater reliability as it permits more options of answer as well as the possibility to determine the percentage of the positive and negative answers on the aspect evaluated.

34.3.5 Data Processing and Analysis

In this phase, it was possible to verify the impact of the missing data and of the extreme values and to evaluate the compliance with the premises of multivariate analysis, to ensure the validity of the results obtained.

The analysis process of the data was performed in three stages. In the first stage, the collected data obtained in the pilot test were verified with the purpose to achieve an initial analysis of the understanding of the affirmatives and the evaluation of the reliability of the constructs.

In the second stage, it was verified the validity and the reliability of the proposed criteria.

In the third stage the results of the evaluation were presented using simple statistics, together with a descriptive synthesis of qualitative nature.

34.4 Results

In this item, the main results of the evaluation will be presented. The results related to the data treatment and the evaluation of the reliability and validity of the criteria can be found at CIP E&P (2009).

The percentages presented in the Table 34.1 indicate the Agreement Degree (AD) that is the sum of the percentage of the respondents that selected the options "Agree" and "Strongly Agree".

Table 34.1 Attributes used by the evaluation models of the business process management maturity

Criteria	Observable variable (OV)—AD—Rating
Process mapping	Average—51.8 %—Regular
Indicators	Average—53.2 %—Regular
Process improvement	Average—47.3 %—Bad
Process manager	Average—49.9 %—Bad
People management	Average—27.9 %—Very Bad
Leadership	Average—42.4 %—Bad
	Average Geral—47.16 % Bad

The results were classified using the following percentage ranges: 80–100 % (Excellent); 70–79.9 % (Very Good); 60–69.9 % (Good); 50–59.9 % (Regular); 40–49.9 % (Bad); and Below 40 % (Very Bad).

The respondents made an overall negative evaluation of the process management practices of the company (overall average of the six criteria evaluated = 47.2 %), result considered Bad.

Then, the results of the evaluation of each one of the criteria evaluated will be presented.

34.4.1 Process Mapping

In this criteria the company had a positive evaluation (overall average of the observable variables = 51.8 %), result considered Regular. From the results obtained in relation to these criteria, it can be concluded that the company clearly identified its processes and the collaborators can describe how they operate. However its IT systems aren't aligned with its processes and its process models, despite the fact that they were defined, they still weren't disseminated through the whole company, and weren't used for the definition of their priorities.

34.4.2 Indicators

The company obtained its best result in this criteria (overall average of the observable variables = 53.2 %), result considered Regular. From the obtained results in relation to this criteria, it can be concluded that the process indicators from the company derivate from its strategy and its collaborators know the process indicators with which they work directly and use these indicators to measure the efficiency and efficacy of the processes. However, the indicator used don't seem to accomplish the purpose for which they were created.

34.4.3 Process Improvement

The evaluation of this criteria was negative (overall average of the observable variables = 47.4 %), result considered Bad. The results of the evaluation of this criteria reveal that the company uses regularly the teamwork in the organization and in the process improvement initiatives. Its collaborators have the habit to provide suggestions for the improvement. However, the company hasn't adopted a methodology for the analysis and the process improvement. In the company there isn't a formal process for the capacitation in process management, mostly in improvement techniques and in tools to resolve problems.

34.4.4 Process Manager

In this criteria the company had a negative evaluation (overall average of the observable variables = 48.9 %), result considered Bad. From the obtained results in relation to this criteria, it can be concluded that the process managers are engaged in the process improvement, have authority over the processes, participate in the allocation and validation of the personnel that work in their processes, evaluate, update and disseminate the results to their collaborators. They also use these results to detect performance flaws, identify and document their processes. However, they don't have autonomy to assign the improvement teams of their processes,they aren't formally nominated by the leadership, don't use comparative references of the processes with the strategic goals of the company and don't have control over the alteration projects and over the allocated budget for their processes.

34.4.5 People Management

The company obtained its worst result in this criteria (overall average of the observable variables = 27.3 %), result considered Very Bad. The results of the evaluation of the practices revealed that the company doesn't do the definition of roles, the description of the job and the competency profile according to the process mapping. Its people management system doesn't consider the needs and the results of the process and doesn't use the formal mechanisms for the retention of personnel specialized in process management.

34.4.6 Leadership

In this criteria the company had a negative evaluation (overall average of the observable variables = 42.4 %), result considered Bad. Although the company recognized the need to improve the process performance and to promote the process management, it doesn't provide support for these initiatives and the process management is not one of its basic attributions. The leadership sees the process management only as a project, not as a definitive way of business management. It doesn't have a process office established to coordinate and to integrate all the process management projects of the company.

34.5 Conclusion

This paper presented a group of criteria and observable variables for the evaluation of the maturity of the process management business process management practices.

From the literature review about the attributes used by the maturity models, six criteria and forty three observable variables for evaluation were proposed. The group proposed was used for the evaluation of the business process management practices of a large oil and gas company.

The practices related to the Process Mapping and Indicators criteria were evaluated positively and can be considered as strong points of the process management of the company. However, the practices related to the Process Improvement, Process Manager, People Management and Leadership criteria presented several opportunities of improvement.

The main limitation of this paper concerns to the fact that there may be other characteristics that were not included in this study.

As guidance for future researches related to the present theme, it is suggested the statistic validation of the group of criteria and subcriteria proposed in other organizations that are recognized by their excellent practices in business process management.

References

CIP E&P (2009). Relatório de atividades/produtos do Núcleo de Avaliação de Desempenho. (Tech Rep. No. 1). Brasil, Rio de Janeiro, Universidade Federal Fluminense, Núcleo de Competitividade Estratégia e Organização

Crosby P (1985) Qualidade é investimento J. Rio de Janeiro, Olimpio

PMI (2008) Organizational project management: maturity model (OPM3*)*. Knowledge foundation

Quintella H, Rocha M (2007) Automotive product development process: comparing and evaluating the maturity level. Revista Produção 17(1):199–215

Valadares A (2001) Modelagem de Processos para implementação de Workflow: avaliação crítica. Unpublished thesis (MD), Universidade Federal do Rio de Janeiro

Chapter 35
Safety Management Models in Manufacturing Companies

J. A. Carrillo, J. Guadix and L. Onieva

35.1 Introduction

In Spain, as part of the European Union, there are some mandatory elements of safety management according to the Framework Directive 89/391/EEC on the introduction of measures to encourage improvements in the safety and health of workers at work.

A management system is a network of interrelated elements. These elements include responsibilities, authorities, relationships, functions, activities, processes, practices, procedures, and resources. A management system uses these elements to establish policies, plans, programs, and objectives and to develop ways of implementing these policies, plans, and programs, and achieving these objectives (Cagno et al. 2011).

Previous surveys have been able to find evidence of the effect of adopting a safety management system (Bottani et al. 2009), as an evaluation of factors identified as performance in main attitudes to do active preventive activities (such as defining and communicating goals, updating risk, assessing and evaluating risks and training of workers).

However, safety management is more likely related to actual practices, roles and functions and it is an antecedent of safety climate as the system impacts employees' attitude and behaviour (Fernández-Muñiz et al. 2009). This safety climate is an intermediate outcome more useful to evaluate safety management than injury rates.

J. A. Carrillo (✉)
Dirección General de Seguridad y Salud Laboral, Avda. Hytasa, 14 P-1 41006 Sevilla, Spain
e-mail: jacarcas@gmail.com

J. Guadix · L. Onieva
Grupo de Investigación de Ingeniería de Organización, Universidad de Sevilla, Camino de los Descubrimientos s/n Isla de la Cartuja 41092 Sevilla, Spain
e-mail: guadix@esi.us.es

L. Onieva
e-mail: onieva@us.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_35,

35.2 Conceptual Model

In Spain, companies can decide how to manage safety. Although most safety activities are mandatory,[1] the management model can be decided in some extend by each company. Some companies decide to implement safety management standards as OSHAS 18001.[2] Understanding the managers motivations (Huang et al. 2011) can help to develop more effective promotion programs of those safety models and systems considered more suitable.

Another important company's decision is how technical assessment and preventive activities are assigned. According to Spanish regulations,[3] safety assessment and preventive activities can be organized both with internal resources or subcontracting an external preventive service. There are many possibilities depending on how many activities are subcontracted.

Our interest is to research about the factors that contributes in this important decision and how the different safety management models influence the development of safety activities and resources.

Safety management model can be chosen using four basic archetypes. Although a range of mixed solutions are possible, we assigned according to managers answers to each company only one model.

Models are related to what specific preventive resources are available. The first of those models is based in a personal assumption by the owner. This is only possible if the company has less than nine workers and there is no high hazard. In this model the main strength is the strong alignment of safety and management.

The second possible model is to have specific workers with safety assignment. Although this possibility can be found in the other models, here we include those companies who consider this resource as the main preventive mean.

The third possible model is to subcontract an external preventive service. This possibility is associated to a lack of integration of safety in the general management. There are also threats of lack of quality in some services. Again these subcontracts can be found in the rest of models but here we include those companies that consider this externalization as the main resource for prevention.

The last possibility is to have an internal preventive service with specialized safety advisors in the company. In this model there is still a strong integration of safety issues. We include in this model those preventive services that are shared by a set of companies in the same sector or industrial site. This model is only mandatory for big companies and it is considered by safety experts as the best in terms of integration and quality (Carrillo and Onieva 2011).

---

[1] Ley 31/1995 de Prevención de Riesgos Laborales, BOE número 269 de 10/11/1995, páginas 32590 a 32611. http://www.boe.es. Accessed 1 February 2012.

[2] OHSAS 18001:2007 "Occupational health and safety management systems. Requirements". Published by BSI, UK's National Standards Body.

[3] Real Decreto 39/1997 por el que se aprueba el Reglamento de Servicios de Prevención. BOE número 27 de 31/01/1997, páginas 3031 a 3045. http://www.boe.es. Accessed 1 February 2012.

A lot has been written about the advantages of certain safety management models whereas no scientific evidence has been published. Our hypothesis is that there are predictor factors that explain why companies chose one safety management model. Understanding this process can help to design public programs in case it is considered necessary to promote certain models.

Also we researched which factors influence implementing a safety management system (SMS).

There is a lot of evidence of the importance of organizational factors in safety and their relationship with injury rates (Arocena et al. 2008; Geldart et al. 2010; Carrillo and Onieva 2012). Safety models have influence on those organizational factors too.

35.3 Safety Models and Systems: The Benefits

It is necessary to know which benefits and which advantages can be expected depending on the safety model chosen. In the survey there is information about preventive activities achieved.

In order to understand how safety management model and safety management systems affect the development of preventive activities we have calculated the average number of activities (see Table 35.1), stratifying by company size (Sorensen et al. 2007). These indicators of preventive activities are intermediate indicators of safety management performance (Sgorou et al. 2010; Øien et al. 2011).

In spite of the limitations of injury rates as safety indicator, we have also compute injury rates for the different safety management models (see Table 35.2).

Table 35.1 Preventive practices and safety models

Company size[a]	Preventive activities[b]	Assumed by owner	Worker assigned	External prev. service	Internal prev. service	Without SMS	With SMS
Micro	Practices	1.35	3.11	3.40	2.13	1.92	3.97
	Assessments	2.00	3.42	3.81	1.63	2.81	3.87
	Measure	1.42	1.32	1.99	1.38	1.54	2.07
Small	Practices	–	5.38	3.89	6.80	3.33	4.80
	Assessments	–	4.12	3.44	2.17	2.88	4.16
	Measures	–	2.31	2.00	2.00	1.65	2.28
Medium	Practices	–	6.20	5.61	4.71	4.36	5.86
	Assessments	–	5.55	4.75	4.29	4.82	4.89
	Measures	–	3.82	2.89	3.71	3.45	3.05
Big	Practices	–	7.00	6.63	8.40	2.00	7.53
	Assessments	–	5.40	5.50	6.00	8.00	5.47
	Measures	–	4.40	4.75	6.00	8.00	4.82

[a] Size is determined by the number of workers
[b] Average number of preventive

Table 35.2 Injury rates and safety models

Company size	Assumed by owner	Worker assigned	External prev. service	Internal prev. service	Without SMS	With SMS
Micro	219.78	258.33	365.73	187.50	335.05	257.86
Small	90.17	192.51	141.84	–	144.30	160.97
Medium	–	217.68	137.49	71.18	161.65	151.07
Big	–	66.21	314.40	55.93	–	162.40

35.4 Data

The First Andalusian Safety Management Survey gathered data from a sample of companies selected randomly. All companies were visited by a professional interviewer. The total number of manufacturing companies was estimated at 30.296.

The number of companies surveyed from the industrial sector is 682, thus the expected error with P = Q is 3.82 %. In terms of company size, big companies were underrepresented in the sample (Instituto Andaluz de Prevención de Riesgos Laborales 2011). Industrial sector includes manufacturing activities, utilities and industrial outsourcing.

There are 503 cases from manufacturing companies available. As we are interested in the safety management models we decided only to considerer those cases with all questions about safety management fulfilled. With this criterion, there are 413 cases with information about their safety models and possible predictors (see Tables 35.3 and 35.4).

According to previous studies there are some characteristics of a company identified in this survey that can determine a safety management model: company and establishment size, number of years of the company and main activity.

Other important factors gathered are related to safety management complexity such as how likely safety accidents are, working in shifts, subcontracting, renewing machinery or certain high hazardous tasks.

Managers have also identified in the survey the company's strategies, company's opinion about safety regulations and company's motivation for safety commitment.

Finally, workers representation can influence in management the selection of safety management. Usually, worker representatives will demand internal resources instead of external ones.

Most of discrimination factors are determined as survey responses and they are objective data. The rest of them are Liker scale subjective questions about company's strategies, motivations for safety and opinion about safety regulations.

Table 35.3 Safety management model predictors: percentage of companies of each model

Variable	Anova (sig.)	Categories	Assumed by owner (%)	Worker assigned (%)	External prev. service (%)	Internal prev. service (%)
Activity	0.28	Consumer prod.	17	12	62	9
		Chemical	8	23	68	2
		Metal	17	11	64	7
		Rest of manuf.	14	18	66	2
Company size (number of workers)	0.00	Micro (1–9)	23	8	66	3
		Small (10–49)	9	21	66	5
		Medium (50–249)	4	23	58	15
		Big (>250)	0	28	44	28
Company years	0.31	New (<3)	21	8	65	6
		Young (3–10)	18	15	63	4
		Mature (>10)	13	16	64	7
Shifts	0.00	No	16	13	66	5
		Yes	4	43	26	26
Outsourcing workers	0.05	No	17	13	65	6
		Yes	11	24	57	9
Highly hazardous	0.02	No	18	14	61	6
		Yes	5	15	74	5
Safety management	0.00	No	26	12	57	5
		Yes	7	17	69	7
Risk of traumatic accidents	0.08	No				
		Yes				
Risk of musculo skeletal accidents	0.00	No				
		Yes				
New machinery in last 2 years	0.00	1	18	19	56	7
		2	13	8	73	5
Worker representation	0.00	0	19	6	72	3
		1	6	37	43	14

35.5 Methodology and Results: Discrimination Analysis

Although exploratory techniques can help to understand the different companies' profiles and their attitudes and safety management approaches, we have selected discrimination analysis because it provides the identification of a classification equation and deals with multivariate and multifactor nature of safety.

Discrimination analysis has been performed segmenting the cases using company size so four different sets of discrimination functions have been determined. SPSS v.18 was used. Both microdata and discrimination models are available upon

Table 35.4 Safety management model predictors: average for each safety model

Group	Question	Assumed by owner	Worker assigned	External prev. service	Internal prev. service
Strategies	Reduce prod. costs	3.66	4.07	3.32	3.50
	Improve safety	3.92	4.74	3.74	4.88
	Improve image	5.11	5.16	5.54	4.92
	Innovation	7.00	6.89	6.87	6.92
	Sustainability	8.11	8.10	7.57	7.92
Opinion about safety regulation	Difficult	2.77	2.54	2.29	2.38
	Adequate	2.60	2.36	2.32	2.35
	Complex	2.83	2.64	2.38	2.38
	Profitable	2.98	2.85	2.94	2.65
	For any activity	2.98	2.93	2.75	2.62
	For any company's size	3.11	2.87	2.97	2.73
	Effective	2.71	2.79	2.45	2.58
Motivation for safety	Comply	1.86	1.70	1.87	1.23
	Fines	1.52	0.74	0.95	1.12
	Petitions	0.35	0.43	0.48	0.58
	Goodwill	0.52	0.72	0.58	0.77
	Working conditions	1.05	1.13	1.01	1.23
	Economic	0.18	0.34	0.30	0.15
	Better climate	0.15	0.43	0.41	0.46
	Competitive	0.28	0.79	0.45	0.00

request. All possible predictor's variables were included with step by step option, with Wilkins Lambda as method with intra-groups covariance matrixes (see Tables 35.5 and 35.6).

35.6 Discussion

According to the First Andalusian Safety Management Survey, when a company has a safety management system, the number of preventive activities implemented is higher than those without a system. Moreover, companies with internal preventive resources, such as workers assigned or internal preventive services, show higher number of preventive activities. These phenomena are more significant for micro and small companies, but less significant as the size of the company grows.

Companies can choose different safety management models. A discrimination analysis shows that there are variables that more likely can predict which model is chosen.

Table 35.5 Discrimination analysis results: dependent variable "external preventive service"

Company Size	Predictors	(%) classification	St. Coef. (sig)
Micro (1–9)	Worker representation	87.7	0.74 (<0.01)
	Strategy is safety		0.34 (0.04)
	Regulation is effective		0.60 (0.02)
	Regulation is difficult		−0.50 (ns)
	New machinery		−0.34 (0.05)
Small (10–49)	Number of different sites	84.8	0.41 (0.06)
	Working in shifts		0.63 (<0.01)
	Worker representation		0.67 (<0.01)
	Strategy is sustainability		0.31 (0.05)
	Risk of musculo-skeletal acc.		0.35 (ns)
Medium (50–249)	Worker representation	81.3	0.54 (<0.01)
	Strategy is sustainability		0.49 (0.02)
	Motivation is image		0.64 (<0.01)
	Motivation is economic		0.54 (<0.01)
Big (>249)	Regulation is profitable	83.3	0.90 (0.02)
	New machinery		0.74 (0.03)

Table 35.6 Discrimination analysis results: dependent variable "safety management system"

Company size	Predictors	(%) Classification	St. coef. (sig)
Micro (1–9)	Motivation is comply regulation	58.5	0.97 (0.05)
	Motivation is economic		0.77 (0.23)
Small (10–49)	Strategy is reduce cost	64.0	−0.58 (0.01)
	Strategy is image		0.63 (<0.01)
	Risk of traumatic accidents		0.52 (0.02)
Medium (50–249)	Regulation is profitable	72.9	1.00 (0.02)
Big (>249)[a]	–	100	–

[a] There was only one case without safety management system

According to our study, the main reason for choosing an internal preventive model is having worker representation. But the rest of the predictors are related to each company size: for micro companies it is important to have safety as strategy and to view regulation as effective and not difficult; for small companies reasons are working in shifts and having more than one establishment; for medium companies it is important if their motivation is to improve company's image and economic; for big companies it is more important if they buy new machinery and considering regulation as profitable. Company's size as expected determines very different ways of understanding and facing safety issues.

On the other hand, safety management systems are more likely adopted by big and medium companies. Again, reasons to decide to implement safety management systems depend on company's size: for micro companies, main motivations is to comply with safety regulation and economic; small companies more likely implement a system if they have risk of accidents and their strategy is not reducing costs but improving company's image; medium companies need to find safety regulation as profitable.

Based on these results, specific research needs to be done in order to provide evidence about what facts or reasons can change manager's views about safety management and how to efficiently convince of the benefits of certain models.

References

Arocena P, Nuñez I, Villanueva M (2008) The impact of prevention measures and organizational factors on occupational injuries. Saf Sci 46(9):1369–1384

Bottani E, Monica L, Vignali G (2009) Safety management systems: performance differences between adopters and non-adopters. Saf Sci 47(2):155–162

Cagno E, Micheli GJ, Perotti S (2011) Identification of OHS-related factors and interactions among those and OHS performance in SMEs. Saf Sci 4(29):216–225

Carrillo JA, Onieva L (2011) Performance of external health and safety services in andalusia: evaluation of outcome. In: Proceedings of the 9th international conference on occupational risk prevention ORP2011. ISBN 978-84-934256-9-2

Carrillo JA, Onieva L (2012) Safety management in manufacturing and its influence in injury rates: evidences from Spanish national safety management survey 2009. In: industrial engineering: innovative networks. Springer. ISBN 978-1-4471-2320-0

Fernández-Muñiz B, Montes-Peón JM, Vázquez-Ordás CJ (2009) Relation between occupational safety management and firm performance. Saf Sci 47(7):980–991

Geldart S, Smith CA, Shannon HS, Lohfeld L (2010) Organizational practices and workplace health and safety: a cross-sectional study. Saf Sci 48(5):562–569

Huang YH, Leamon TB, Courtney TK et al (2011) A comparison of workplace safety perceptions among financial decision-makers of medium versus large-size companies. Accid Anal Prev 43(1):1–10

Instituto Andaluz de Prevención de Riesgos Laborales (2011) I Encuesta sobre Gestión Preventiva de Empresas Andaluzas. ISBN 978-84-615-0020-8

Øien K, Utne I, Herrera I (2011) Building safety indicators: part 1—theoretical foundation. Saf Sci 49(2):148–161

Sgorou E, Katsakiori P, Goutsos S et al (2010) Assessment of selected safety performance evaluation methods in regards. Saf Sci 48(8):1019–1025

Sorensen OH, Hasle P, Bach E (2007) Working in small enterprises: is there a special risk? Saf Sci 45(10):1044–1059

Chapter 36
Strategic Packaging Logistics: A Case Study from a Supply Chain Perspective

Jesús García-Arca, J. Carlos Prado-Prado and A. Trinidad González-Portela Garrido

36.1 Introduction

In the current competitive context, companies must deal with the challenges, not only in terms of new products and processes, shorter life cycles or increased commercial range, but also in terms of the demand for ever lower prices, with increasingly improved quality standards and service. This situation has forced many organizations to look for a source of competitive advantages, a better management of their processes, particularly those to do with supply chain management (Christopher 2005).

Alongside this scenario is the growing sensitivity in society as regards a responsible management or the ethics of entrepreneurial activities, meaning that the supply chain management should be enlarged to take in the concept of sustainability, which affects both the operational aspects of the logistics processes, as well as their strategic decisions. The field of sustainable development can be conceptually divided into three axes: environmental, economic and social. In this field, Corporate Social Responsibility (CSR) can be defined as active, voluntary contribution to social, economic and environmental improvement by companies, generally aimed at improving their competitive situation and added value, not limiting themselves to a strict compliance with the requirements (Ciliberti et al. 2008). All organizations in supply chain should take an active part in designing and implementing logistic processes that could be considered as sustainable (Carter and Rogers 2008; Seuring and Müller 2008; Andersen and Skjoett-Larsen 2009; Mejías-Sacaluga et al. 2011).

In this context, the organizational aspects for the sustainable improvement of supply chain, both within each company and between companies in the chain, is one of the issues that arouses most interest among researchers. This is due to the

J. García-Arca (✉) · J. C. Prado-Prado · A. T. González-Portela Garrido
Grupo de Ingeniería de Organización (GIO), Escola de Enxeñería Industrial, Campus Lagoas Marcosende, C/Maxwell, 36310 Vigo, Spain
e-mail: jgarca@uvigo.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_36,

fact that it is considered as a source of competitive advantages (Stank et al. 2001; Christopher 2005). But however, despite the competitive importance of the organizational aspects mentioned above, the results of numerous studies show very discrete values in terms of their development and improvement (Giménez 2006; Crnkovic et al. 2008; Germain et al. 2008; García-Arca et al. 2011).

Likewise, although these organizational aspects are important, equally so and in a complementary manner are the systematic search for efficient, sustainable alternatives to design and manage the supply chain (which could include the organizational aspects mentioned earlier), both at strategic and operational levels, with a view involving doing away with "waste". This view of doing away with waste is linked to the concept of "continuous improvement" or "Kaizen", and also entails a basis of different approaches such as Just in Time (JIT) or Lean Manufacturing. In these improvement approaches lies the need to extend the field of action beyond the frontiers of a company, taking in the entire supply chain. Unfortunately, many companies consider that implementing sustainability strategies involves a certain incompatibility with the search for efficiency improvement in logistics (Andersen and Skjoett-Larsen 2009).

36.2 Strategic Packaging Logistics

In the conceptual framework commented in the previous heading, packaging is one of the key elements that makes it possible to provide support for the combined action of efficiency and sustainability strategies. Thus, beyond the traditional (but nonetheless important) view of packaging as a means of protecting products, over the last few years, new design requirements have been added for packaging: on the one hand, to improve the differentiation capacity of the product, and on the other, to improve the efficiency of the product at logistic level. Furthermore, this contribution of packaging to efficiency in logistics should be considered not only in terms of its direct view (in the processes of supplying, packing, handling, storing and transport), but also reversely (re-use, recycling and/or recovery waste from packaging); this situation has meant, in practice, the development of specific legislations (e.g., those arising from the European Parliament and Council Directive 94/62/EC; 1994) linking packaging design to environmental conservation and, in short, to the improved sustainability of companies' activities.

Also, in order to put these functions into practice (the commercial function, the logistics function and the environmental function), it is essential to consider the packaging as a system comprising several levels. So three levels are to be established (Saghir 2002): the primary packaging (to protect the product and, in many cases, in contact with it; also known as the "consumer packaging"), the secondary packaging (designed to contain and group together several primary packages; known as "transport packaging") and the tertiary packaging (involving several primary or secondary packages grouped together on a pallet or load unit).

When contemplating packaging as a whole, the natural interaction among different levels would become manifest, depicting the important dependence among them (Saghir 2002; García-Arca and Prado-Prado 2008; Bramklev 2009). Nowadays, the choice of the type of packaging is usually subject only to considerations involving cost reduction. Thus, packaging design affects costs both directly (costs of purchasing and waste management) and indirectly (packing, handling, storage, transport and claims). It is precisely this indirect way that makes difficult an adequate understanding of the repercussions of certain decisions in designing the product related to packaging (García-Arca and Prado-Prado 2008). Besides, this cost reduction approach can be hazardous if not considered in an integral manner since, although an "economic" packaging would be linked to a standard format with an appropriate, tried and tested logistic efficiency. But however, it may be obliged to sacrifice some of its possibilities to be "different" and sustainable.

With this broader view of packaging, over the last few years, the integration of logistics and the packaging design has been conceptualized in the term "packaging logistics", particularly emphasizing the operational and organizational repercussions (Hellström and Saghir 2006; Shagir 2002) considers "packaging logistics" as "the process of planning, implementing and controlling the coordinated packaging system of preparing goods for safe, efficient and effective handling, storage, retailing, consumption and recovery, reuse or disposal and related information combined with maximizing consumer value, sales and hence profit".

Delving further into the previous concept, authors consider that a greater emphasis should be given to the important strategic connotations to do with packaging design, in many cases this being one of the supports of competitive advantages in the improvement of supply chain management from an overall perspective of efficiency and sustainability. We have called this broader view "Strategic Packaging Logistics". With this approach in mind, the design and development of packaging would be structured on three basic cornerstones (García-Arca and Prado-Prado 2008): The definition of the design requirements (based on packaging functions); the definition of an organizational structure integrating all the departments/areas involved (internally in the company and externally in the supply chain); and, finally, the application of "best practices" (in aspects such as palletization, modularity, standardization of formats and qualities, re-use, recycling …).

As a result of this analysis, it is possible to deal with the search for packaging able to meet the needs of the companies based on the numerous possibilities associated with the combinations in the packaging structure (primary packaging, secondary packaging and tertiary packaging) and with the four main decisions to be taken in terms of design: selection of the materials used, dimensions, groupings (the number of packs per package) and "graphic artwork" (or the aesthetic design of the packaging).

After justification and the conceptual development of the "Strategic Packaging Logistics" approach, the main objective of this paper is to illustrate, by means of case study methodology, the potential of applying this approach in the Spanish distribution company Mercadona. Mercadona is one of the frontline leaders in Spain of trade distribution, with an annual turnover of more than 17,000 million euros, employing over 70,000 workers, with 1,356 outlets in 2011.

36.3 A Case Study: Mercadona

At a global strategy level, it is noted that Mercadona applies a careful policy of creating value for its customers, by combining the search for efficiency in logistics with sustainability in all its processes; thus, the basis of its successful business model ("Always low prices") is structured on meeting the needs of its customers ("the boss"), the workers, the suppliers, the society and the ownership, thanks to a very "lean" vision of its process (doing away with waste), which can be summed up by the phrase of its Chairman, Juan Roig, "The lorry full, the pallet full, the cash till full, the line full and the product full too". This "lean" vision also reaches the commercial level, with a careful selection of the range of products offered, which combines well-known brand names with its own brands, but without the search for the best price being at odds with keeping up the quality perceived by the market.

In order to put this strategy of efficiency and sustainability into practice, the company takes on the management of its supply chain, especially the distribution and supplies transport chain (suppliers-logistics platforms-outlets); over 8,500 million "kilolitres" was sold in 2010 (the sum of kilograms and litres dispatched). In this line, for example, it succeeds in improving the occupancy level of its transport (especially on the return trips), making it easier to combine heavy goods with other less dense cargo (adjusting to the limitation of weight and volume in vehicles); also, it makes a careful selection of the location of its logistics platforms (in 2011, the company had a network of 10 logistics platforms with a total capacity of over 700,000 m^2), in order to reduce the final number of kilometres made by each product within the supply chain. Likewise, the company selects the most efficient modes of transport (in terms of the location of the suppliers), combining road, rail and sea transport.

At the same time, it makes a selection of just a few suppliers (over 100) with which it maintains a long-term relationship (a very "lean" vision), able to provide a careful, limited selection of products, with a special preponderance of Mercadona own brands. This way of working guarantees the supplier a volume of production and a long-term work horizon that allows it to obtain scale economies in purchases and production (transport is the responsibility of Mercadona, as commented earlier). The development of own brand products is carried out jointly between the supplier and Mercadona, which facilitates the solution adopted being efficient, not only for one part of the chain, but also for the chain as a whole; clearly, this development of new products affects to packaging design.

As commented earlier, one of the cornerstones of the logistics and sustainability strategy of Mercadona lies in improving the efficiency in goods transport throughout the chain. In this context, the search for efficiency in its palletized loads (on EUR pallet) is paramount, adopting the dimensions of packaging design that make it possible to take advantage of the maximum standardized base and height, reducing not only the amount of space transported, stored and handled, but also adjusting the weight and the amount of materials used in the packaging. All the measures outlined above make it possible not only to provide support for its environmental strategy (sustainability strategy; less consumption of materials and fewer vehicles used in transport), but also for its strategy of low prices (lower costs for materials, for transport, handling and storage).

In order to achieve these objectives, at organizational level, as noted above, Mercadona along with its suppliers, looks into the global impact of the decisions in packaging design, providing incentives in order to improve products on an on going basis, with a strategic vision of their supply chain and from an efficient and sustainable perspective (Strategic Packaging Logistics). In this context, the following measures are examples of how this works in practice: the reduction of grammage used in packaging formats (seafood, milk, yoghurts, water), the increase of units of packing per package (sliced bread, sausages), promotion of SRPs (“Shelf Ready Packaging”, e.g., in eggs, fresh pizzas, cold meats), changes in the packaging process (fresh fish, canned foods, hams, cellulose, the elimination of superfluous packaging (cheeses, canned foods, infusions, cold meats, animal food), the redesign, resizing and rationalization of pack formats (rice, shampoos, oils, wines, meats, water, dental gel, detergents or the reuse of plastic foldable packaging (see in Table 36.1 examples of changes in packaging).

In order to illustrate the process of improving Mercadona’ packaging, this part summarizes the methodology and the main results achieved in the packaging rationalization project carried out by one of its frozen products suppliers. Thus, with the structured approach outlined above for implementing “Strategic Packaging Logistics”, the three cornerstones are developed.

As regards defining the design requirements (the first cornerstone), in line with Mercadona’s global strategy and in accordance with the same, two basic principles were established: the optimization of the palletized units sent to the company (EUR pallet of less than 1,000 kg., with a height not greater than 2.1 m) and the optimization of packaging (less than 10 kg, but allowing for an increased number of packs per packaging, while not going over this maximum weight).

As regards the second cornerstone (organizational structure), it is noted that two work teams were set up to deal with the project: on the one hand, an operational team (responsible for analysing and proposing alternatives, involving the participation of the commercial, production and purchases departments). On the other hand, a follow-up team was set up (responsible for validating and the internal clarification of the proposals in which the industrial director and the company manager took part). In both teams, the authors of this paper acted as coordinators of the packaging changes, in line with the “action research” approach. The frequency of the meetings held by the operational team was weekly/fortnightly, whereas the follow-up team met on a monthly basis. Also, every two months, the company chairman reported to Mercadona.

Table 36.1 Examples of changes in the packaging of Mercadona products (compiled by the authors)

Changes made in packaging	Impact on the supply chain
Change from a round to a square base in bottles of olive oil, combined with SRP presentation	16 % improvement in the number of bottles per pallet (estimated saving of 0.01 euros per unit) Reduction of 122 tonnes of CO_2 per annum
Change in the arrangement of bottles of wine in each layer of SRP (from linear to "a staggered arrangement"); fitting between SRP layers	20 % improvement in the number of bottles per pallet Reduction of 26 tonnes of CO_2 per annum
Elimination of retailer packs (film and plastic trays) used in fruit, replaced by plastic reusable and foldable boxes	Improvement in the efficiency of palletizing 80 % saving on the volume of empty layers on the return (foldable)
Changes in the grouping unit from 12 to 15 units per box	Reduction of 1,900 tonnes of CO_2 per annum Amount of cardboard/packing is reduced Improved palletizing Estimated savings of 3.4 million euros per annum. Reduction of packaging material
Reduction in the top size in sunflower oil bottles	Improved palletizing (lower overall volume of the bottle)
	Estimated savings of 200,000 euros per annum
Change of material used in bottles of spices (plastic instead of glass)	Less weight and volume
	Estimated savings of 0.25 euros/unit
Change in the packaging of meat, from cardboard boxes to reusable foldable boxes	Estimated saving of 360,000 euros/year by adopting reusing foldable boxes
	80 % saving in volume of empty boxes on the return (foldable)
Also, in spicy pork sausages, minced meat and chicken, resizing the trays used as packaging	In spicy pork sausages and minced meat, reduction in the consumption of materials and improved palletizing with an estimated saving of 414,000 euros/year
	In trays of chicken, reduction in the consumption of materials and improved palletizing with an estimated saving of 914,000 euros/year
Replacing metal packing for a plastic packing in cans of anchovy; removing box	Reduction of materials and improved palletizing
	Estimated savings of 3 million euros/year
Change in the shape and size of the 2 litre bottle of water	Reduction of materials and improved palletizing
	Estimated annual savings of 1.125 million euros

Finally, in terms of the third cornerstone (the application of "best practices"), it is noted that the measures or changes adopted included resizing of the packaging, the increase in the number of packs per packaging, the increased number of layers per pallet or the improvement of the "mosaic" in the pallet.

Thanks to this rationalization project, an average 12.6 % increase in palletizing was achieved in Mercadona products (22 references with packaging changes, accounting for 85 % of the kilos dispatched by the supplier to Mercadona). Alongside this, consumption of materials used in packaging was reduced; this is estimated to be at least 2.5 tonnes/year in plastic, 36 tonnes/year in paperboard and 90 tonnes/year in cardboard. All this means that only in the part of the supply chain controlled by the supplier, savings in the order of 130,000 euros/year can be made (80 % in savings in packaging materials and 20 % in internal logistics savings arising from internal handling, storage and transport). Added to this are the savings linked to the supply chain controlled by Mercadona (transport between supplier, platforms and outlets, as well as in handling and storage on Mercadona platforms and outlets), which would double those attained internally by the supplier.

36.4 Conclusions

In a competitive scenario such as today's, companies should improve and innovate their processes (particularly in logistics) from a sustainable perspective. But however, many companies (especially SMEs) view this demand for sustainability more as a threat that hamper the productive/logistics efficiency, than as an opportunity to compete. The real challenge for companies is how to integrate, proactively and strategically, both concepts; thus, redesigning packaging by applying the "Strategic Packaging Logistics" concept is an example of this integration.

In this regard, the sustainable strategy implemented by Mercadona in its supply chain, underpinned by the application of this concept has actively contributed to its position of leadership in the Spanish distribution sector. As described in this paper, apart from cost savings associated with the rationalization of the materials used in packaging, the company has also succeeded in making substantial savings at logistics level, providing backing for its efficiency and sustainability strategy. In fact, its sustainability strategy was acknowledged by the European Commission, in 2010, for its good environmental practices.

So, thanks to the redesigning measures in its packaging, with the active participation of its suppliers, and from an integral and strategic vision of its supply chain, the company has managed to reduce consumption of packaging materials by 4.5 % between 2009 and 2010, which entails a saving of 23,000 tonnes of CO_2, thanks to the improved efficiency in palletizing and the reduction of materials. This improvement means an annual reduction of 7,000 tonnes of plastic, 8,000 tonnes of cardboard and 11,300 lorries less circulating on the roads. All this also has a direct beneficial impact on the company's exploitation account, entailing a real competitive advantage that is appreciated by the market (with a 14 % reduction in prices for its products during 2009 and 2010).

References

Andersen M, Skjoett-Larsen T (2009) Corporate social responsibility in global supply chains. Supply Chain Manag: Int J 14(2):77–87

Bramklev C (2009) On a proposal for a generic package development process. Packag Technol Sci 22:171–186

Carter CR, Rogers DS (2008) A framework of sustainable supply chain management: moving toward new theory. Int J Phys Distrib Logistics Manag 38(5):360–387

Ciliberti F, Portrandolfo P, Scozzi B (2008) Logistics social responsibility: standard adoption and practices in Italian companies. Int J Prod Econ 113:88–106

Christopher M (2005) Logistics and supply chain management strategies for reducing cost and improving service, 3ª edn. Financial Times Pitman Publishing, London

Crnkovic J, Tayi GK, Ballou DP (2008) A decision-support framework for exploring supply chain tradeoffs. Int J Prod Econ 115:28

García-Arca J, Prado-Prado JC (2008) Packaging design model from a supply chain approach. Supply Chain Manag: Int J 13(5):375–380

García-Arca J, Prado-Prado JC, Mejías-Sacaluga A (2011) El desarrollo de la fun-ción logística en la industria alimentaria y textil moda de España. Universia Business Review 31: 42–59

Germain R, Claycomb C, Dröge C (2008) Supply chain variability, organizational structure, and performance: the moderating effect of demand unpredictability. J Oper Manag 26:557–570

Giménez C (2006) Logistics integration processes in the food industry. Int J Phys Distrib Logistics Manag 36(3):231–249

Hellström D, Saghir M (2006) Packaging and logistics interactions in retail supply chain. Packag Technol Sci 20:197–216

Mejías-Sacaluga A, García-Arca J, Prado-Prado JC, Fernández-González AF (2011) Modelo para la aplicación de la Responsabilidad Social Corporativa en la Gestión de la Cadena de Suministro. Dirección y Organización 45:20–31

Saghir M (2002) Packaging logistics evaluation in the Swedish retail supply chain. Lund University, Lund

Stank TP, Keller S, Daugherty PJ (2001) Supply chain collaboration and logistical service performance. J Bus Logistics 22(1):29–48

Seuring S, Müller M (2008) From a literature review to a conceptual framework for sustainable supply chain management. J Cleaner Prod 16:1699–1710

Chapter 37
Insights into Corporate Social Responsibility Measurement

Diego Pérez López and Ana Moreno Romero

37.1 Introduction

In the last ten years, Corporate Social Responsibility (CSR) has become a mainstream topic in both management literature and practice (Bakker et al. 2005; Margolis and Walsh 2003). Nowadays, almost every large company currently discloses information concerning its environmental and social performance, in addition to its financial results. Even when the degrees of maturity of CSR policies are very different among countries, sectors and companies (Zadek 2004) the integration of CSR into the firm's strategy has been undertaken by a large number of them. This move seems to respond to a growing complexity of the context in which companies operate, where social and environmental concerns fostered by stakeholders and the society at large have become critical strategic issues in many cases. This is what a survey carried by IBM among over 1,000 top managers indicates (IBM 2010). Thus, the greater complexity of the context is also leading to an increasing need of specific techniques and mindsets (Snowden and Boone 2007) that can help to understand how non-financial value is created and how to integrate its several dimensions into strategic decisions.

This societal interest on non-financial performance has led to the emergence of a wide array of non-financial reporting standards and compliance codes (e.g. GRI, SA8000). In addition, there is also a trend to non-financial accountability requirements from specific stakeholders, such as capital markets (e.g. Dow Jones Sustainability Index, FTSE4GOOD) or the public sector, as it can be seen in the recent communication of the European Commission on CSR (2011).

D. Pérez López (✉) · A. Moreno Romero
Grupo de Investigación en Organizaciones Sostenibles (GIOS). Escuela Técnica Superior de Ingenieros Industriales, Universidad Politécnica de Madrid, C/José Gutiérrez Abascal 2, 28006 Madrid, Spain
e-mail: diego.perez.lopez@upm.es

A. Moreno Romero
e-mail: ana.moreno.romero@upm.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*, DOI: 10.1007/978-1-4471-5349-8_37,

However, the future of non-financial reporting seems unclear, since the costs associated with this wider accountability of companies remain to be calculated and the benefits will depend on the extent that accountability practices are integrated into the firm's strategy (International Integrated Reporting Committee 2011).

Thus, the aim of our article is to develop a measurement model of financial and non-financial impacts of CSR. This approach should provide a better understanding of how value is created through CSR policies and how non-financial outcomes could better inform strategic decision making.

The remainder of this article is organized as follows. First, we review CSR literature related to CSR strategy and its contribution to firm performance and sustainability. Second, we explicitly review company-level approximations to CSR outcomes measurement and we develop our model. Third, we illustrate the implications of our approach with a case example at Red Eléctrica de España (REE), where it has been implemented. Finally, we outline our conclusions and suggest future research areas.

37.2 Literature Review

The interactions between business and society have drawn a lot of research within the academic community since more than fifty years (Bowen 1953). Boulding's (1956) view of organizations as open systems can be considered the first attempt to stress the relevance for an organization of the various stakeholders that constitute its environment. This vision was also central in Thomson's Organization Theory (1967), which introduced the idea of protecting business core functions from unpredictable impacts of the broader context.

Since then, Corporate Social Responsibility (CSR)—and other related concepts like Corporate Social Performance (CSP) and Corporate Citizenship—have been developed and conceptualized by influent scholars like Carroll (1979) and Wartick and Cochran (1985), though there is still no single definition today.

37.2.1 The "Business Case" for CSR

Added to these general conceptualizations, the "business case" of CSR has generated a lot of research since the 1970s. On the one hand, empirical studies have tried to assess whether CSR contributes to the Financial Performance (FP) of the firm, by statistically exploring the causal link between CSR and FP. On the other hand, theoretically grounded studies have aimed to explain this value creation by means of different theories of the firm.

37.2.1.1 Quantitative Studies

Within the first group, scholars have used different quantitative aggregates to measure FP and CSR. For example, Orlitzky et al. (2003) categorized FP measurement proxies into: market measures (e.g. share value, Tobin's q), accounting measures (e.g. ROI, total profits) and perception measures. At the same time, they broke CSR measures down into company self-report information, reputational measures, 3rd party assessments (rating agencies) and perception measures (e.g. stakeholders' view of the firm).

Despite the number of studies devoted to this question, differences in measuring both CSR and FP have led to no single answer to the relationship between them, while it is true that a vast majority of this research has shown a positive correlation (Margolis et al. 2007).

This purely quantitative approach has been criticized by its weak results. Thus, some influent scholars have underlined the need for a theoretical focus that could shed more light into the nature of this relationship by exploring the various mediating mechanisms that allow for it (Wood 2010).

37.2.1.2 Theoretical Studies

Theoretically grounded research on the instrumental view of CSR assumes that CSR value creation is ultimately connected to the broader context in which the firm operates and thus, addressing stakeholders' concerns can bring bigger and more sustained financial returns to the company. In this sense, CSR is seen as being part of the firm strategy, and its design and deployment should contribute to the attainment of strategic goals set (Burke and Logsdon 1996).

This link to corporate strategy has been explored by different theories of the firm, including Stakeholder Management Theory (Freeman 1984) and the Resource Based View (RBV) of the firm (Wernerfelt 1984). Stakeholder Management Theory focuses on value creation as a consequence of meeting the societal (external) demands on the firm. The RBV of the firm states that the possession of rare, valuable, inimitable and not easily substitutable resources (Barney 1991) determines the ability to the firm to outperform others. The natural RBV (Hart 1995) extended the later by connecting social and environmental challenges to companies' resources, showing that CSR policies can contribute effectively to the firm's competitive advantage.

37.3 CSR Measurement Model

CSR literature offers a wide range of examples of the contribution of CSR to company value drivers, such as growth opportunities (Kurucz et al. 2008), consumer trust (Pivato et al. 2008) or employee attractiveness (Greening and

Turban 2000) [see Wood (2010) for a comprehensive review]. At the same time, the nature of CSR business outcomes has been conceptualized in different ways (Knox and Maklan 2004; Kurucz et al. 2008), most of them underlining its financial and non financial aspects.

From a company-level, there are some empirical attempts to evaluate outcomes of isolated CSR Projects (Weber 2008; Salazar et al. 2011). However, we argue that an integrated financial and non-financial approach to CSR impacts is missing, as well as their link to strategic management and external reporting.

Our model (see Fig. 37.1) considers three CSR layers within an organization: the CSR operational layer, where resources are effectively allocated to CSR projects (thus generating direct costs and revenues), the CSR strategic management level, where the full range of CSR outcomes, both financial and non-financial, must be measured and integrated into further decision-making, and the CSR reporting layer, where the information generated is also communicated to stakeholders and society.

37.3.1 Financial Outcomes of CSR

The most direct impact of CSR projects is the cost of resources associated (e.g., investments in the community, employee benefits). Nevertheless, some CSR projects can also raise direct revenues for the company (e.g., energy savings). If data are available, then the most common way to evaluate the attractiveness of an investment opportunity is the Net Present Value (NPV) method (Weber 2008), which we adopt at this point. Given that NPV has some limitations regarding the uncertainty of CSR-driven revenues, some alternative methods, like real options theory (Husted 2005), would also have to be considered.

37.3.2 Non-financial Outcomes of CSR

Non-financial outcomes of CSR constitute the broader range of impacts that CSR has within an organization, motivated both internally (e.g., employee commitment) and externally (e.g., corporate reputation). Some authors stress the role of CSR in

Fig. 37.1 CSR measurement model

enhancing firm intangible resources, such as innovation, human capital, reputation and culture (Surroca et al. 2010). Other approaches also include transforming non-financial impacts into monetary terms (Hahn and Figge 2011).

From a company-specific approach, the identification of relevant non-financial outcomes requires to gain deep knowledge about the company and its specific context, as well as a close interaction between researchers and the company staff. For this reason, action research methodology (Coughlan and Coghlan 2002) was chosen in our case example. Once company-specific non-financial outcomes of CSR are identified, quantitative indicators must also be given to allow for measurement. According to existing literature examples (Carlucci 2010; Hubbard 2009), Key Performance Indicators (KPI) are selected, following Carlucci (2010) criteria: relevance, reliability, comparability and consistency.

Once KPI data are available, their integration into strategic management can be accomplished by means of several techniques and tools. Among them, the adaptation of Kaplan and Norton's Balanced Scorecard (1992) to sustainability and CSR issues (Bieker 2003; Schaltegger and Burrit 2010) and the system dynamics perspective to identify the impacts associated with CSR policies (Santos et al. 2002, Parisi and Hockerts 2008) are specially well suited for the integration of KPIs.

37.4 Case Example: Red Eléctrica de España

Red Eléctrica de España (REE) is the transport and system operator of the Spanish electric network. It mission is to provide high voltage electric power transmission from generation plants to distribution substations and to operate the national electric system. The company, of over 1,700 employees and annual net sales (2010) of 1,400 Mo. €, shows a strong commitment to the grid integration of renewable energies (about 25 % of total in Spain).

REE's CSR practices have been widely acknowledged by both Spanish and international organisms. In 2011, REE has received the European Foundation for Quality Management (EFQM) Prize "Taking responsibility for a sustainable future", and its Sustainability Report has been recognized as the best one among the biggest 35 Spanish companies (IBEX-35).

37.4.1 Methodology

The objective of the case example was to test our CSR measurement approach and evaluate CSR contribution to both financial and non-financial performance of REE. Initial data sources included semi-structured interviews with department managers, as well as public documents (website releases and Sustainability Reports). Action research methodology (Coughlan and Coghlan 2002) was chosen in order to help the company to identify CSR impacts and implement the model.

37.4.2 CSR Outcomes

The first step of the case study was aimed at estimating the costs and revenues associated to existing REE's CSR projects. Costs identified included CSR Department operating costs, but also CSR projects across the whole company (e.g., CSR certification for suppliers, energy efficiency audits) as well as the labor costs associated. Direct revenues from CSR projects were also calculated.

Second, interviews with managers were conducted and CSR impacts on the organization were identified. These impacts were then assigned quantitative KPIs. At this step, an effort was explicitly made to consider indicators that already existed, so that the costs associated with measurement were kept as low as possible.

Measurement of both financial and non-financial CSR outcomes provided a comprehensive snapshot of CSR global performance, as well as a more accurate knowledge of the processes driving this value creation through the organization.

37.5 Conclusions

In this article we have proposed a measurement model for CSR impacts at the company-level. By reviewing the existing literature we showed that an integrated approach for assessing both financial and non-financial outcomes of CSR was missing. Our model considers three CSR layers within the organization: the CSR project layer, the CSR strategic management layer and the CSR reporting layer, and illustrates the relationship between CSR measurement and decision making.

An exploratory case study was conducted, which highlighted the usefulness of a company-level approach to fully understand CSR outcomes. However, its application to further examples in different business settings would certainly provide enriching insights and would help to refine and validate the approach.

Finally, given the complex nature of CSR outcomes, some interesting future developments could include the study of specific tools and techniques that are able to integrate them into strategic decision-making. The adaptation of the Balanced Scorecard, as well as other techniques from the system dynamics field, like causal and cognitive mapping, are thought to be promising research avenues.

References

Barney J (1991) Firm resources and sustained competitive advantage. J Manag 17(1):771–792
Bieker T (2003) Sustainability management with the balanced scorecard. Presentation at the International Summer Academy on Technology Studies, Graz
Boulding KE (1956) General systems theory: the skeleton of science. Manage Sci 2:197–208
Bowen HR (1953) Social responsibilities of the businessman. Harper, New York

Burke L, Logsdon J (1996) How corporate social responsibility pays off. Long Range Plan 29:495–502
Carlucci D (2010) Evaluating and selecting key performance indicators: an ANP-based model. Measuring Bus Excellence 14(2):66–76
Carroll AB (1979) A three-dimensional conceptual model of corporate performance. Acad Manag Rev 4:497–505
Coughlan P, Coghlan D (2002) Action research for operations management. Int J Oper Prod Manag 22(2):220–240
de Bakker FGA, Groenewegen P, den Hond F (2005) A bibliometric analysis of 30 years of research and theory on corporate social responsibility and corporate social performance. Bus Soc 44(3):283–317
European Commission (2011) A renewed EU strategy 2011–2014 for CSR. Brussels
Freeman RE (1984) Strategic management: a stakeholder approach. Pitman, Boston
Greening DW, Turban DB (2000) Corporate social performance as a competitive advantage in attracting a quality workforce. Bus Soc 39:254–280
Hahn T, Figge F (2011) Beyond the bounded instrumentality in current corporate sustainability research: toward an inclusive notion of profitability. J Bus Ethics 104:325–345
Hart SL (1995) A natural resource-based view of the firm. Acad Manag Rev 20(4):986–1014
Hubbard G (2009) Measuring organizational performance: beyond the triple bottom line. Bus Strategy Environ 18:177–191
Husted BW (2005) Risk management, real options, and corporate social responsibility. J Bus Ethics 60(2):175–183
IBM (2010) Capitalizing on complexity: insights from the global CEO study
International Integrated Reporting Committee (2011) The world is changing. Reporting must too
Kaplan RS, Norton DP (1992) The balanced scorecard—measures that drive performance. Harvard Bus Rev 70(1):71–79
Knox S, Maklan S (2004) Corporate social responsibility: moving beyond investment towards measuring outcomes. Eur Manage J 22(5):508–516
Kurucz E, Colbert B, Wheeler D (2008) The business case for corporate social responsibility. In: Crane A, McWilliams A, Matten D, Moon J, Siegel D (eds) The oxford handbook of corporate social responsibility. Oxford University Press, Oxford, pp 83–112
Margolis JD, Walsh JP (2003) Misery loves companies: rethinking social initiatives by business. Adm Sci Q 48(2):268–289
Margolis JD, Elfenbein HA, Walsh JP (2007) Does it pay to be good? A meta-analysis and redirection of research on the relationship between corporate social and financial performance. Presentation at the Academy of Management Meetings, Philadelphia
Orlitzky M, Schmidt FL, Rynes SL (2003) Corporate social and financial performance: a meta-analysis. Organ Stud 24:403–441
Parisi C, Hockerts KN (2008) Managerial mindsets and performance measurement systems of CSR-related intangibles. Measuring Bus Excellence 12(2):51–67
Pivato S, Misani N, Tencati A (2008) The impact of corporate social responsibility on consumer trust: the case of organic food. Bus Ethics 17:3–12
Salazar J, Husted B, Biehl M (2011) Thoughts on the evaluation of CSR through projects. J Bus Ethics 105:175–186
Santos SP, Belton V, Howick S (2002) Adding value to performance measurement by using system dynamics and multicriteria analysis. Int J Oper Prod Manag 22:1246–1272
Schaltegger S, Burrit RL (2010) Sustainability accounting for companies: catchphrase or decision support for business leaders? J World Bus 45:375–384
Snowden D, Boone M (2007) A leader's framework for decision making. Harvard Bus Rev 85(11):11–68
Surroca J, Tribó JA, Waddock S (2010) Corporate responsibility and financial performance: the role of intangible resources. Strateg Manag J 31:463–490
Thompson JD (1967) Organizations in action: social science bases of administrative theory. McGraw-Hill, New York

Wartick SL, Cochran PL (1985) The evolution of the corporate social performance model. Acad Manag Rev 10:758–769

Weber M (2008) The business case for corporate social responsibility: a company-level measurement approach for CSR. Eur Manag J 26(4):247–261

Wernerfelt B (1984) A resource-based view of the firm. Strateg Manag J 5(2):171–180

Wood D (2010) Measuring corporate social performance: a review. Int J Manag Rev 12:50–84

Zadek S (2004) The path to corporate responsibility. Harvard Bus Rev 82:159–172

Chapter 38
Personnel Participation: A Review of Its Role in Corporate Social Responsibility Models and Standards

A. J. Fernández-González, R. Fernández-Pérez and J. C. Prado-Prado

38.1 Introduction

38.1.1 Corporate Social Responsibility

Corporate social responsibility (CSR) is a business field on which much has been debated in the last years. This is a consequence of the increasing concern of society about the sustainability of the current business models and business activities, from diverse points of view, especially the environmental and the labour ones.

The majority of activities in a company have, direct or indirectly, a social, external and/or internal impact. Some of them, in fact, can be designated 'socially responsible activities', like the resources management, the minimization of the pollution, the preservation of equality of opportunities, or the increase of workers' welfare, that is to say, activities that show a commitment of the organization with the sustainable development, beyond the strictly legal fulfillment.

To facilitate to all-type organisations a socially responsible performance, several norms and guides have recently been published by various official entities or bodies directly or indirectly linked to CSR, such as AccountAbility, Social AccountAbility International (SAI), Global Reporting Initiative (GRI), the International Organisation for Standardization (ISO), the European Foundation for Quality Management (EFQM) or the United Nations, *inter alia*.

A. J. Fernández-González (✉) · R. Fernández-Pérez · J. C. Prado-Prado
Grupo de Ingeniería de Organización (GIO), Escuela de Ingeniería Industrial,
Campus Lagoas-Marcosende, Cl Maxwell, s/n 36310 Vigo, Spain
e-mail: ajfdez@uvigo.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_38,

38.1.2 CSR and Continuous Improvement

As regards the concept of continuous improvement (CI), Boer et al. (2000) define it as "the planned, organized and systematic process of ongoing, incremental and company-wide change of existing practices aimed at improving company performance". Indeed, the ultimate aim behind companies introducing CI is to increase their performance, by means of a systematic process of incremental improvement, which does not imply (or at least assume) consumption of resources (Terziovski and Sohal 2000). This improvement in performance could be attained based on improving productivity, quality and/or production time (Boer et al. 2000; Rapp and Eklund 2002), by cutting down costs (Bond 1999) or, more globally, by orientating towards a higher customer satisfaction, better workers' health and safety conditions, and environmental matters, which are a concern of main stakeholders, such as clients, workers, the society at large and the Administration.

38.1.3 CSR, CI and Personnel Participation

It is generally accepted nowadays that personnel participation becomes essential for CI in an organisation. Structured employee participation systems, both at individual and group level, are a vehicle with considerable potential for developing CI. They make it possible to have an active, systematic intervention in improvement processes of people belonging to different hierarchical levels in an organization. In many cases, they contribute to channelling the strategic objectives of numerous efficiency improvement approaches (JIT, Lean, TQM, etc.).

But, moreover, employee participation systems contribute to improve the workers' level of satisfaction. Contributing with ideas, developing and implanting them, obtaining improvements, sharing knowledge with other workers (many times belonging to other areas) etc., all of those allow a greater professional and personal development of the worker, and elevates his/her self-perception of utility to the company that he/she works for, improving his/her satisfaction with the work and his/her commitment with the organization. In this sense, the promotion of participation becomes, in our opinion, an important element of social responsibility, because of its orientation to the empowerment of the worker as an essential stakeholder of the firm, and because of its undoubted contribution to competitiveness and, therefore, to sustainability.

38.2 Standards Review

Starting from the premise that personnel participation in CI is a CSR issue, we wanted to check if the current international CSR standards take it into account.

The CSR standards checked are:

- AA1000 Series of Standards (from AccountAbility)
- SA8000 (from SAI, Social AccountAbility International)
- SGE 21 (from Forética)
- ISO 26000 (from ISO, International Organization for Standardization)

38.2.1 AA1000 Series of Standards (AccountAbility)

AccountAbility is a "leading global organisation providing innovative solutions to the most critical challenges in corporate responsibility and sustainable development" (AccountAbility 2012). The core of this entity's work is the AA1000 series of standards: AA1000APS (2008): AccountAbility Principles Standard; AA1000AS (2008): Assurance Standard, and AA1000SES (2011): Stakeholder Engagement Standard.

38.2.1.1 AA1000APS: AccountAbility Principles Standard (2008)

In AccountAbility words, "the purpose of the AA1000APS (2008) is to provide organisations with an internationally accepted, freely available set of principles to frame and structure the way in which they understand, govern, administer, implement, evaluate and communicate their accountability" (AccountAbility 2008a). This standard "provides a framework for an organisation to identify, prioritise and respond to its sustainability challenges" (AccountAbility 2012).

The standard establishes three principles: the foundation principle of inclusivity, the principle of materiality, and the principle of responsiveness. The Foundation Principle of Inclusivity directly refers to stakeholder participation processes (and not particularly to personnel participation) within the organization, as summarized in Table 38.1 below.

Nevertheless, despite these mentions of participation, there is no specific reference to the manner in which the stakeholders and, more specifically, the personnel in the organization, can develop the same in a structured way.

38.2.1.2 AA1000AS: Assurance Standard (2008)

This standard provides the necessary requirements for conducting an assurance of sustainability. The standard is designed for use by suppliers and professionals in sustainability assurance. It provides a methodology for assurance practitioners to evaluate the nature and extent to which an organisation adheres to the AccountAbility Principles and the quality of the information released on performance in sustainability (AccountAbility 2008b).

This standard makes no reference to personnel participation in CI.

Table 38.1 References to participation in AA1000APS (2008a)

AA1000APS (2008a) text	Chapter; epigraph
"For an organisation that accepts its accountability to those on whom it has an impact and who have an impact on it, inclusivity is the participation of stakeholders in developing and achieving an accountable and strategic response to sustainability."	2.1. The Foundation Principle of Inclusivity; Definition
"Inclusivity requires a defined process of engagement and participation that provides comprehensive and balanced involvement and results in strategies, plans, actions and outcomes that address and respond to issues and impacts in an accountable way"	2.1. The Foundation Principle of Inclusivity; Explanation
"An organisation will adhere to the principle of inclusivity when: (…) It has in place a process of stakeholder participation that: • is applied across the organisation (e.g. group and local level); • is integrated in the organisation, and • is ongoing and not 'one off'."	2.1. The Foundation Principle of Inclusivity; Criteria
"The stakeholder participation process: • identifies and understands stakeholders, their capacity to engage, and their views and expectations; • identifies, develops and implements appropriate, robust and balanced engagement strategies, plans and modes of engagement for stakeholders; • facilitates understanding, learning and improvement of the organisation; • establishes ways for stakeholders to be involved in decisions that will improve sustainability performance; • builds the capacity of internal stakeholders and supports building capacity for external stakeholders to engage, and • addresses conflicts or dilemmas between different stakeholder expectations."	2.1. The Foundation Principle of Inclusivity; Criteria

38.2.1.3 AA1000SES: Stakeholder Engagement Standard (2011)

In AccountAbility words, "the AA1000 Stakeholder Engagement Standard (AA1000SES) is a generally applicable framework for the design, implementation, assessment and communication of quality stakeholder engagement. It describes how to establish commitment to stakeholder engagement; how to integrate stakeholder engagement with governance, strategy and operations; how to determine the purpose, scope and stakeholders for engagement; and the processes that will deliver quality and inclusive engagement practice, and valued outcomes" (AccountAbility 2011).

Therefore, the standard develops aspects of interest for the "participation of stakeholders in developing and achieving an accountable and strategic response to sustainability. It is also a commitment to be accountable to those on whom the organisation has an impact and who have an impact on it, and to enable their participation in identifying issues and finding solutions. It is about engaging at all levels, including the organisation's governance, to achieve better outcomes" (AccountAbility 2011).

This standard identifies different levels of commitment of the stakeholders for/ to the organization (*consult, negotiate, involve, collaborate, empower*) and establishes possible methods for putting in place each of them. Specifically, personnel participation in the organization is not literally mentioned, although it can be interpreted as an option in several of these methods, specifically, 'meetings with selected stakeholder/s', 'workshops', 'online feedback mechanisms', 'multi-stakeholder forums', 'participatory decision making processes', 'focus groups', 'on-line feedback schemes', and 'integration of stakeholders into governance, strategy and operations management'.

Chapter 4 of the standard deals with *Stakeholders Engagement Process*, identifying four stages: *Plan, Prepare, Implement and Act, Review* and *Improve*. In all these stages, the standard includes useful comments for developing a personnel participation programme in CI (although this is not expressly mentioned), this being understood as a stakeholder (personnel) engagement system. Thus, aspects such as the following are mentioned: the degree of knowledge of the issues, willingness to engage, information sharing and boundaries of disclosure, anonymity, availability of time to participate, language and communication skills, individual personality, timing, tasks and timelines, ground rules, adopting a solutions oriented approach, budget, briefing materials, documentation, action plans, feedback, channels of communication, monitoring and evaluation, reporting the engagement outputs and outcomes, risks (such as unwillingness, participation fatigue, creating expectations of change that the organization is unwilling or unable to fulfil, etc.).

Therefore, although the standard does not specifically deal with personnel participation in CI, not even partially, we can find some useful indications for the design and implementation of structured personnel participation systems.

38.2.2 SA8000: 2008

This is a standard created by the Social AccountAbility International (SAI) organization, which defines it as "a credible, comprehensive and efficient tool for assuring human workplaces" (Social AccountAbility International, 2012). It is a standard, auditable by certifying bodies, establishing the voluntary requirements to be complied with by the employers in the workplace, regarding: child labour, forced and compulsory labour, health and safety, freedom of association and right to collective bargaining, discrimination, disciplinary practices, working hours, remuneration and management systems.

More specifically, personnel participation in CI is not covered by this standard.

38.2.3 SGE-21: 2008

SGE-21 is a standard created by the Spanish organization Forética, which defines it as a multi-stakeholder frame for developing the criteria that make possible to establish, develop and evaluate an Ethical and CSR Management System (Forética 2012).

It is standard auditable by certifying bodies. It covers 9 CSR management areas: top management, clients, suppliers, people in the organization, social environment, environment, investors, competency and public administrations. The standard requires the creation of a Code of Conduct and the implantation of an Ethical Committee in the organizations.

Although there is an area devoted to people in the organization, personnel participation in CI is not covered by this standard.

38.2.4 ISO 26000: 2010

ISO 26000 is an international standard, drafted by the International Organization for Standardization (ISO) that provides orientation of all types of organizations regarding: CSR concepts, terms and definitions; CSR antecedents, trends and features; CSR principles and practices; CSR foundation matters; CSR integration, implementation and promotion within the organization; stakeholders identification and engagement; and CSR commitments and performance communication (ISO 2010). It is not a standard orientated towards certification, nor to a regulatory or contractual use. This standard sets out to succeed in behaviour in CSR in the organization going beyond legal compliance (ISO 2010).

This standard ascribes an important role to the personnel in social dialogue, the aim being to assure compliance with human rights, equality in the work place, freedom of association, labour practices, ethical behaviour of the organization, etc. Furthermore, this standards considers participation as one of the benefits provided

Table 38.2 References to participation in ISO 26000: 2010

ISO 26000: 2010 text	Chapter; epigraph
"Social responsibility may provide numerous potential benefits for an organization. These include: (…) enhancing employee loyalty, involvement, participation and morale (…)"	Box 5
"An organization's decision-making processes and structures should enable it to: (…) encourage effective participation of all levels of employees in the organization's social responsibility activities"	6.2 Organizational governance; 6.2.3 decision-making processes and structures
"An organization should: (…) base its health, safety and environment systems on the participation of the workers concerned (…)"	6.4 Labour practices; 6.4.6 health and safety at work

by CSR in an organization. But however, it barely mentions personnel participation in the continuous improvement of processes, products or services, leaving existing circumscribed by social responsibility and health and safety activities. These mentions are listed in Table 38.2.

38.3 Conclusions

The CSR principles, models and standards cover several CSR issues on business activities. If we restrict our attention to those related to the personnel of the organization (and, more widely, the ones in the supply chain to which the organization belongs), it hardly appears in the models that we have reviewed.

Personnel participation in CI is given a more detailed treatment by other models or standards more traditionally linked to quality management and excellence, as is the case of the ISO 9004 standard and the EFQM Excellence Model. But however, as in the case of the CSR standards, development of personnel participation in the organization is not given detailed treatment in any of these.

The review allows us to conclude that personnel participation in CI is not sufficiently considered within the current CSR frame, probably because:

- it is regarded as too operative to include it in the CSR models and standards, that are too superficial with respect to the operative application of CSR practices:
- it is regarded as more a quality than a CSR practice, especially when taking into account that personnel participation is considered as one of the principles of quality management (ISO 2005);
- it is not quite as evolved as to form part of socially responsible practices considered as such by international consensus.

Probably the field of application of these CSR models and standards is too broad to deal with operational issues but, in our opinion, certain lineaments are missing, at least of the organizational, structural or strategic kind, that could help organizations to design and develop personnel participation programmes in CI.

We believe it appropriate for the bodies developing CSR standards to firmly incorporate personnel participation in CI in said models, given its strategic importance and potential contribution to business sustainability.

We believe it also necessary to develop standards and guides for structuring personnel participation in CI. There are not many companies implementing structured employee participation systems and, when they do so, many of them fail be- cause they apply a non-suitable structure and/or methodology. In the CSR standards reviewed, we have only found certain useful considerations for this in the AA1000 Stakeholder Engagement Standard (AA1000SES). Nor are ISO 9004 nor the EFQM Excellence Model of much help in this regard. A guide for the implantation of structured employee participation systems would be of great help for many organizations, especially the small and medium sized ones, with scarce in- house resources for developing these practices.

References

AccountAbility (2008a) AccountAbility principles standard (AA1000APS)
AccountAbility (2008b) Assurance standard (AA1000AS)
AccountAbility (2011) Stakeholder engagement standard (AA1000SES)
AccountAbility (2012) http://www.accountability.org/standards/aa1000aps.html. Accessed 15 March 2012
Boer H, Berger A, Chapman R, Gertsen F (eds) (2000) CI changes. From suggestion box to organisational learning. Continuous improvement in Europe and Australia. Ashgate, Aldershot
Bond TC (1999) The role of performance measurement in continuous improvement. Int J Oper Prod Manage 19(12):13–18
Forética (2012) http://www.foretica.org/conocimiento-rse/estandares/sge-21?lang=es. Accessed 15 March 2012
International Organization for Standardization (2005) ISO 9000—quality management systems—fundamentals and vocabulary, Geneva
International Organization for Standardization (2010) ISO 26000—Guidance on social responsibility, Geneva
Rapp C, Eklund J (2002) Sustainable development of improvement activities: the long-term operation of a suggestion scheme in a Swedish company. Total Qual Manag 13(7):945–969
Social AccountAbility International (2012) http://www.sa-intl.org, accessed on March 15, 2012
Terziovski M, Sohal AS (2000) The adoption of continuous improvement and innovation strategies in Australian manufacturing firms. Technovation 20(10):539–550

Chapter 39
A Performance Measurement Framework for Monitoring Supply Chain Sustainability

M. J. Verdecho, J. J. Alfaro-Saiz and R. Rodriguez–Rodriguez

39.1 Introduction

Collaboration is one strategy used by enterprises to compete and keep focused on their own core competencies. For that reason, many enterprises have engaged in collaborative relationships despite the fact that proper understanding of collaborative implications are often overlooked (Busi and Bititci 2006; Verdecho et al. 2009) causing collaborative relationships to fail. In order to gain understanding of collaborative contexts, many frameworks and models have been developed to conceptualise the drivers, barriers and effects of collaboration although there are still numerous issues to be solved (Busi and Bititci 2006).

One key aspect of collaborative relationships to be solved is their sustainability. Seuring and Müller (2008) define sustainable supply chain as 'the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social into account which are derived from customer and stakeholder requirements'. Therefore, in sustainable supply chains all three dimensions are to be fulfilled as well as customer and stakeholder requirements. There are various factors that push enterprises to accomplish supply chain sustainability such as legal demands/regulation, response to stake- holders, competitive advantage, customer demands, reputation loss, and environmental and social pressure groups. There is another key factor in the application of sustainable practices that is when a focal enterprise within a supply chain request to the rest of enterprises to meet environmental and social standards e.g. the implementation of these practices in the automotive sector. Despite the existence of success cases implementing sustainable practices, reality does not

M. J. Verdecho (✉) · J. J. Alfaro-Saiz · R. Rodriguez–Rodriguez
Research Centre on Production Management and Engineering (CIGIP).
Department of Business Organization, Universitat Politècnica de València,
Camino de Vera, s/n 46022 Valencia, Spain
e-mail: mverdecho@cigip.upv.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_39,

have to be avoided. Many enterprises have difficulties in the sustainable management of its own business even recognising the fact that its activity depends on its responsibility with its supply chain partners and stakeholders (Dyllick and Hockerts 2002). For that reason, it is important the design of tools that aid enterprises to develop and manage supply chain sustainability.

In addition, it is essential to note that supply chain sustainability should be derived from the strategy of the own supply chain. This implies that all the enterprises within the supply chain agree on common objectives and those objectives are pursued by all the enterprises in their operations. Otherwise, monitoring sustainability dimensions will be an isolated task lacking value to management. Then, it is necessary to establish mechanisms to deploy the supply chain strategy into operations as well as to monitoring the sustainability of the whole supply chain, which can be measured, and therefore, managed through performance measurement elements (objectives, performance indicators, etc.). Thus, it is needed for those enterprises to define and use a structured performance measurement framework that allows managing performance under various perspectives or dimensions. One of the most important performance frameworks developed in the academic literature and business applications is the Balanced Score Card (BSC) by Kaplan and Norton (1992).

Despite its importance, the BSC present some limitations. One limitation is the capability to prioritize, weight and consolidate data from performance elements (Yüksel and Dagdeviren 2010). In the BSC, once the objectives are defined and performance data gathered from their indicators, it would be useful to aggregate such data in order to obtain a global performance evaluation that will show whether the status of the supply chain is sustainable or not. This paper aims to fill this research gap.

In order to prioritize objectives, it is useful to define weights for the different objectives which can be stated as a multi-criteria problem involving different ac-tors. In the same vein, structuring and consolidating data may also be solved as a multi-criteria problem. Therefore, multi-criteria methods can contribute to the implementation of the BSC.

The purpose of this paper is to present a multi-criteria performance measurement framework for monitoring supply chain sustainability considering the deployment of the strategy from the strategic level to the operations level and allow- ing an efficient implementation of its performance measurement elements by introducing an aggregation mechanism that reflects the sustainability status of the supply chain. With this tool, management of the different enterprises of the supply chain will obtain an overall prioritisation of their elements so that decision makers can focus on those elements more relevant for their sustainability and competitiveness.

39.2 Background

Supply chain sustainability is at an initial phase of development (Ageron et al. 2011). This is probably one of reasons why there is few literature in this field, the vast majority published in the recent years. Some of these works have exposed frameworks that aid to conceptualise and classify supply chain sustainability literature such as the works by Seuring and Müller (2008) and Carter and Rogers (2008). Other works present models for evaluating some aspects of supply chain sustainability such as supplier selection (Bai and Sarkis 2010) or the selection of a supply chain configuration (Sarkis 2003). In fact, most of these works only consider economic and environmental sustainability and the social dimension has barely been considered (Seuring and Müler 2008).

Regarding the main focus of this paper, few works deal with the development of performance measurement frameworks for supply chain sustainability. In fact, there are several key characteristics that these frameworks need to fulfil in order to achieve an efficient supply chain sustainability management. First, the performance elements should be derived from the strategy of the supply chain so that the tool supports management of the supply chain enterprises towards the achievement of common objectives. Second, it should provide a methodology that aids to define the necessary steps to be followed to achieve an adequate implementation. Third, it must provide a global performance evaluation that will show whether the status of the supply chain is sustainable or not. These three key characteristics are the basis for analyzing the few performance measurement frameworks for supply chain sustainability (only four works) encountered in the literature as follows.

Erol et al. (2011) presents a fuzzy multi-criteria framework for measuring sustainability performance of a supply chain. Büyüközkan and Berkol (2011) propose a method to design a sustainable supply chain using an integrated analytic network process and goal programming approach in quality function deployment. Hassini et al. (2012) present a performance framework for sustainable supply chain management. However, these frameworks do not consider the strategy of the supply chain or include an aggregation method to provide a global analysis of supply chain sustainability.

There is only one work, Cetinkaya et al. (2011), that considers the deployment of the strategy of the supply chain into operations. The authors expose a performance measurement system based on the BSC for managing supply chain sustainability. In this case, the framework considers the strategy of the supply chain but lacks of mechanisms to prioritize and weight the objectives defined as well as to evaluate the global status of supply chain sustainability.

The purpose of the next section is to introduce a multi-criteria performance measurement framework that meets all three key characteristics mentioned above.

39.3 The Multi-Criteria Performance Measurement Framework for Monitoring Supply Chain Sustainability

In Verdecho et al. (2010a), the COL-PMS framework for managing performance within collaborative contexts is presented. The COL-PMS framework is an integrated and solid PMS structure based on the BSC for inter-organizational relationships composed by five perspectives (financial, customer, processes, innovation and learning and collaboration perspectives), the first four perspectives are the original ones of the BSC and the fifth perspective is oriented to manage the collaboration aspects (coordination, trust, information sharing, etc.). However, its structure lacks of performance elements to monitor two important dimensions of sustainability: environmental and social dimensions. Thus, the starting point of our work has been to extend the COL-PMS framework to introduce these two dimensions. Then, the framework has been complemented with a methodology that aids to implement the performance measurement framework by using the multi-criteria method the Analytic Hierarchy Process (AHP). AHP, developed by Saaty (1980), aims at integrating different measures into a single assessment for ranking decision alternatives which is the case of our problem. AHP has been used for many applications involving performance measurement criteria such as selecting a supplier (Masella and Ragone 2000; Verdecho et al. 2010b), selecting performance indicators for supply chain management (Bhagwat and Sharma 2007), and selecting ERP systems in textile industry (Cebeci 2009).

The methodology is composed of seven phases. In the phase 1, the performance elements of the performance measurement framework are defined in seven perspectives (financial, customer, process, innovation and learning, collaboration, environmental and social perspectives).

In the phase 2, the AHP method is applied to build a model. The AHP method structures the decision problem in a hierarchy of levels. These levels are linked by unidirectional dependence relationships. In the upper level of the hierarchy, it is defined the ultimate goal of the decision problem. Then, the criteria that contribute to achieve the goal stand in the second level. Then, various intermediate levels may be modelled to represent different levels of sub-criteria. Finally, in the last level, the decision alternatives are established. The AHP method provides relative weights to each element within a level depending on its contribution to an element linked to it that is located on the immediate upper level. In our case, as we use the AHP model to obtain the weights of the performance objectives, we will have three levels (see Fig. 39.1): vision (supply chain sustainability), perspectives (criteria) and, finally, performance objectives (alternatives).

In the phase 3, following the application of AHP, pairwise comparisons are made within each level using the fundamental scale of Saaty (1980), and the local priorities of the compared elements (priority vector) are calculated. Then, the final weights for the alternatives are calculated (phase 4). For that purpose, priorities of

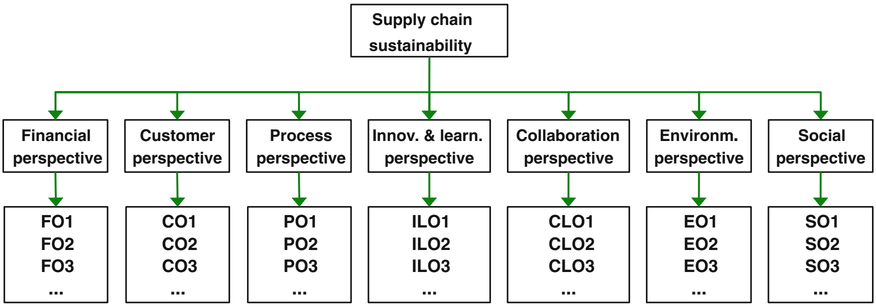


Fig. 39.1 BSC-AHP performance measurement framework for supply chain sustainability

objectives are combined together with the sets of priorities of the performance perspectives.

Then, in phase 5, it is performed a sensitive analysis to check how changes in the local weights of one of the perspectives or objectives affect the final priorities previously obtained. The purpose of this phase is to verify that the solution obtained is robust enough. In case that the solution is not robust, it is needed to go back into the phase 3 to analyze the pairwise comparison matrices obtained.

In phase 6, the data regarding the performance indicators is collected, according to the frequency stated in performance measurement framework. Finally, phase 7, it is obtained the overall performance evaluation by multiplying the priority of every performance objective (given by the normalized priority) and the value reached in its corresponding performance indicator. This overall performance evaluation has to be contrasted with a value defined as goal that will represent the degree of sustainability within the supply chain to be reached (defined as a percentage of achievement).

39.4 Case Study

The performance measurement framework has been applied to a supply chain belonging to the automotive sector which is composed raw material suppliers, design centres and manufacturing plants working for main OEMs. It has to be noted that this supply chain had already implemented a performance measurement framework so that the development of this approach was easier as the partners had performed a joint definition of a performance measurement framework.

The first phase of the methodology consists of the definition of the performance elements for the seven perspectives. This is a very important task as managing directors of the different enterprises have to reach an agreement on the strategic aspects of the relationship. When enterprises come with different backgrounds, they have to define a common business vision, in this case, regarding the sustainability dimensions. Table 39.1 shows the performance elements (objectives

Table 39.1 Performance elements of the automotive supply chain

Perspect	Objectives	KPIs
Financial	FO1 Maintain sales	KPI1 = sales (monthly)
	FO2 Increase high quality product mar- gins by 5 %	KPI2 = average of high quality products margin variation (monthly)
	FO3 Increase the capital invested by shareholders 10 %	KPI3 = capital invested by shareholder (semester)
	FO4 Increase the number of new investors by 15 %	KPI4 = number of investors (quarterly)
Environmental	EO1 Reduce waste by 8 %	KPI5 = waste weight (monthly)
	EO2 Reduce energy consumption by 3 %	KPI6 = energy consumption (monthly)
	EO3 Increase recycling materials by 5 %	KPI7 = recycled materials weight(monthly)
	EO4 Increase number of ISO 14000 cer-tifications by 20 %	KPI8 = ISO 14000 new certifications
Social	SO1 Increase annual training by 20 %	KPI9 = number of training hours (semester)
	SO2 Reduce customer complaints by 25 %	KPI10 = number of customer complaints (monthly)
	SO3 Increase stakeholder involvement decision-making by 15 %	KPI 11 = number of meetings with stake-holders (quarterly)
	SO4 Increase the number of personnel career development programs by 10 %	KPI12 = personnel career programs (semester)

and KPIs) defined for the supply chain for the financial, environmental and social perspectives. It consists of twelve objectives and KPIs.

These KPIs have been defined by the enterprises based on the objectives that they want to reach. It took three meetings of 1.5 h, what seems reasonable, to complete the list of objectives and KPIs for the seven perspectives (define the new objectives and KPIs for the new perspectives and check consistency with the objectives and KPIs of the existing performance measurement framework and perform some adjustments).

In the phase 4, the weights of the objectives are obtained. Results showed that the most important objectives representing 65 % of the total weight were: FO1 maintain sales (with normalized weight of 0.14), FO3 Increase the capital invested by shareholders (0.11), CO2 Increase market share (0.08), ILO1 Increase innovation capability (0.08), SO2 Reduce customer complaints (0.07), EO2 Reduce energy consumption (0.06), PO1 Decrease product development lead-time (0.06) and CL02 Increase coordination (0.05). It can be observed that the critical objectives belong to all performance perspectives but the importance of the perspectives differ, being the financial perspective the most relevant followed by the customer and the innovation and learning perspectives.

In the last phase it is obtained the final results. The analysis showed that performance was mainly achieved by some of the most relevant objectives (those objectives with highest weight). However, financial objectives, among others, were not accomplished in the desired level (accomplished around 45 %) and decision makers have to analyze them further. For those objectives that have not reached the expected results, actions plans are to be developed which allow reassessing the current targets. In general, performance achievement was only reached at the 70 % what was under the initial expectations (75 %). However, results showed that performance measurement implementation has provided performance knowledge to the supply chain as well as a tool for monitoring sustainability performance.

39.5 Conclusions and Research Implications

In the recent years, few works have dealt with the development of performance measurement frameworks for supply chain sustainability but they lack of mechanism to weight and consolidate performance data into a global evaluation that allows deciding if the supply chain is achieving its sustainability objectives up to a proper degree. This paper has introduced a performance measurement framework that fills this research gap. Also, it has described a case study in an automotive supply chain providing the main insights in the application of the approach. Further research work will be developed in three main lines: (a) validate this performance measurement framework in supply chains of different characteristics and other sectors, (b) use other performance structures instead of BSC and other multicriteria methods instead of AHP and (c) deploy further the connection between the performance measurement framework for the supply chain and the individual enterprises performance measurement framework.

Acknowledgments This work has been developed within the framework of two research projects titled “Exploration of the hidden information of the performance indicators through its cause-effect relationships in an inter-organizational context” (PAID- 06-11-1992) funded by the Polytechnic University of Valencia and “Potenciación de la Competitividad del Tejido Empresarial Español a través de la Logística” funded by the Spanish Ministry of Education and Science (PSE-370500-2007-1).

References

Ageron B, Gunasekaran A, Spalanzani A (2011) Sustainable supply management: an empirical study. Int J Prod Econ (in press)

Bai C, Sarkis J (2010) Integrating sustainability into supplier selection with grey system and rough set methodologies. Int. J. Prod Econ 124:252–264

Bhagwat R, Sharma MK (2007) Performance measurement of supply chain management using the analytical hierarchy process. Prod Planning Control 18(8):666–680

Busi M, Bititci US (2006) Collaborative performance management: present gaps and future research Int J of Prod Perform Manage, 55(1): 7–25

Büyüközkan G, Berkol C (2011) Designing a sustainable supply chain using an integrated analytic network process and goal programming approach in quality function deployment. Expert Syst Appl 38:13731–13748

Carter CR, Rogers DS (2008) A framework of sustainable supply chain management: moving toward new theory. Int J Phys Distrib Logistics Manage 38(5):360–387

Cebeci U (2009) Fuzzy AHP-based decision support system for selecting ERP systems in textile industry by using balanced scorecard. Expert Syst Appl 36:8900–8909

Cetinkaya B, Cuthbertson R, Graham E, Klaas-Wissing.et al. (2011) Sustainable supply chain management: practical ideas for moving towards best practice, Springer

Dyllick T, Hockerts K (2002) Beyond the business case for corporate sustainability. Bus Strategy Environ 11:130–141

Erol I, Sencer S, Sari R (2011) A new fuzzy multi-criteria framework for measuring sustainability performance of a supply chain. Ecol Econ 70(6):1088–1100

Hassini E, Surti C, Searcy C (2012). A literature review and a case study of sustainable supply chains with a focus on metrics Int J Prod Econ (in press)

Masella C, Rangone A (2000) A contingent approach to the design of vendor selection systems for different types of co-operative customer/supplier relationships. Int J of Oper Prod Mngm 20(1):70–84

Kaplan RS, Norton, DP (1992) The balanced scorecard—measures that drive performance. Harvard Bus Rev 70(1): 71–79

Saaty TL (1980) The analytic hierarchy process. McGraw-Hill, New York

Sarkis J (2003) A strategic decision framework for green supply chain management. J Cleaner Prod 11:397–409

Seuring S, Müller M (2008) From a literature review to a conceptual framework for sustainable supply chain management. J Cleaner Prod, 16: 1699–1710

Verdecho, MJ, Alfaro JJ, Rodriguez–Rodriguez R (2010a) COL-PMS: a collaborative performance measurement system. BASYS 2010, IFIP AICT, 322, pp 56–67. Springer, Heidelberg

Verdecho MJ, Alfaro JJ, Rodriguez–Rodriguez R (2009) Foundations for collaborative performance measurement. Prod Plann Control 20(3):193–205

Verdecho MJ, Alfaro JJ, Rodriguez–Rodriguez R (2010b) A multi-criteria approach to select suppliers based on performance BASYS 2010, IFIP AICT vol. 322, pp 47–55 Springer, Heidelberg

Yuksel I, Dagdeviren M (2010) Using the fuzzy analytic network process (ANP) for balanced score-card (BSC): a case study for a manufacturing firm. Expert Syst with Appl 37:1270–1278

Part VI
Papers Prize–Award

Chapter 40
A Methodology to Share Profits and Costs in Non-hierarchical Networks

Beatriz Andrés and R. Poler

40.1 Introduction

The importance of collaboration has increased in supply networks; thus, the number of so called non-hierarchical manufacturing networks (NHN) has also increased (Poler 2010). NHN are characterised by equally powered partners and decentralised decision making (DDM). In NHN all the partners are involved in the business processes management in a collaborative way. NHN require close collaboration, extensive exchange of information and changes over the behavior of the networked partners.

Andrés and Poler (2011) identify the major needs to promote collaboration in non-hierarchical networks (Table 40.1).

Amongst the collaborative problems this paper focuses on share profits and costs problem. In light of this, a methodology for sharing costs and profits in NHN is proposed aiming to fill the gap of designing an effective methodology to ensure the equitable sharing among networked partners for achieving the needed collaboration and trust.

B. Andrés (✉) · R. Poler
Research Centre on Production Management and Engineering (CIGIP), Universitat Politècnica de València (UPV), Plaza Ferrándiz y Carbonell, 2, 03801 Alcoy (Alicante), Spain
e-mail: beaanna@cigip.upv.es

R. Poler
e-mail: rpoler@cigip.upv.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_40, © Springer-Verlag London 2014

Table 40.1 Relevant problems for collaborative business processes according to the strategic, tactical and operational decision making levels (S/T/O) (Andrés and Poler 2011)

Level	Strategic	Tactical	Operational
Relevant collaborative problems to provide solutions	Decision system design	Knowledge management	Inventory management
	Partners selection	Uncertainty management	Process connection
	Strategy alignment	Negotiation Contracts	
	Partners coordination	Share profits and costs	
	Product design	Coordination mechanisms management	
	Coordination mechanisms design		

40.2 Share Costs and Profits Problem

Amongst all the problems with inefficient solutions, the *share costs and profits* problem, classified at the tactical decision level, is selected (Table 40.1). The chosen problem has a significant importance for establishing collaborative processes with partners of the same network. Next section provides a solution to solve this problem.

The contribution in any of the three solution categories (models, guidelines and tools) is a challenge. The literature review provides models and guidelines for addressing the share costs and profits problem (Table 40.2). The research carried out shows that the guidelines do not successfully adapt to the NHN context. Furthermore, there is a lack of tools to deal with the share costs and profits problem in networks characterised by the DDM.

The found solutions have a common gap that means the provided solutions do not address the problem in the decentralised decision making context. Concluding, there is an absence of a methodology that enables networked SMEs to share costs and profits within the collaborative non-hierarchical partners.

40.3 Proposed Solution Definition: SP-NHN Methodology

In this section a methodology that enables SMEs to manage the sharing of costs and profits, when collaborative relationships are established, is proposed. The purpose of this section is to develop the *Share Profits in Non-hierarchical Networks* (SP-NHN) methodology. The proposed approach assumes that the relations between participating companies are non-hierarchical and the decision making process is decentralised. The proposed approach defines 7 main phases for the methodology successful implementation at non-hierarchical networks of SMEs. Figure 40.1a

Table 40.2 Models and guidelines to overcome the sharing costs and profits problem

Author	Main considerations and solutions
Goyal and Gupta (1989)	The arrangement to share costs can be achieved by the vendor through giving the buyer a price quantity discount and enticing him to buy larger quantities. Integrated models are classified in: (1) Models which deal with joining economic lot sizing policies (2) Models which deal with inventory coordination by simultaneously determining the order quantity of the buyer and vendor (3) Models which deal with integrated problems but do not determine simultaneously the order quantity of the buyer and vendor (4) Models which deal with buyer-vendor coordination through marketing considerations
Chen et al. (2003)	A multiproduct, multistage, and multiperiod production and distribution planning model to achieve multiple objectives such as maximizing the profit of each network participant and ensuring a fair profit distribution. The model is formulated as a multiobjective mixed-integer non-linear programming (MOMINLP) problem. The fuzzy-set theory is used to attain a compromise solution among all participant companies of the supply chain
Caldentey and Wein (2003)	Three solutions provided: S1: Nash equilibrium S2: Contracts based on transfer payments between the two players that coordinate the system. Each player transfers a fixed fra ction of its own cost to the other player S3: Stackelberg games, where one agent has all the bargaining power
(Giannoccaro and Pontrandolfo 2004)	SC contract model, to coordinate the SC, based on the revenue sharing mechanism. This model allows the system efficiency and improves the SC actors profits, by tuning the contract parameters.
Corbett et al. (2005)	S1: Shared-savings contracts that typically combine a fixed service fee with a variable component based on consumption volume S2: Double moral hazard framework, in which both parties decide how much effort to exert by trading off the cost of their effort against the benefits that they will obtain from reduced consumption
Gupta and Weerawat (2006)	S1: Fixed-markup contract S2: Simple revenue-sharing contract: Under a simple revenue-sharing contract, M chooses a value of revenue-fraction and S responds by picking the target inventory level S3: Two-part revenue-sharing contract: consider now the contract in which M offers different revenue-fractions depending on the choice of target inventory level by S
Sarmah et al. (2006)	Surplus dynamic division among the decision networked members

(continued)

Table 40.2 (continued)

Author	Main considerations and solutions
Audy et al. (2010)	S1: Financial flow between the business units. The financial flow is based on a predefined incentive rule such as pricing agreements or quantity discount S2: Sharing principle based on an economic model (i.e. cost allocation method) such as the Shapley Value, the nucleolus and the separable and non-separable costs. Such economic models, generally based on cooperative game theory, allocate the total cost of the common-solution among the partners. S3: companies previously agree with the sharing principle behind the Equal Profit Method (from Frisk et al. 2010), an economic model that aims to find a stable allocation such that the maximum difference in relative savings between all pairs of two collaborating companies is minimized. In a benefit sharing that the companies could agree on, a new constraint is added to optimize the problem. The new constraint states that each pair of companies must have the same relative savings S4: The cost fixing takes into account the incurred cost to do the activity and the revenue associated with the activity. The benefit sharing is addressed with the financial flow between each company and the used resources of the other company
Jähn (2010)	An algorithm calculates the profits and incentive payments within the networked partners. Assuring a minimal profit for each enterprise

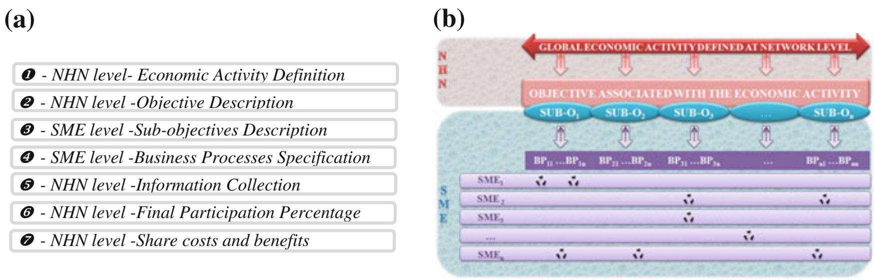


Fig. 40.1 **a** 7 Phases. **b** Architecture of the SP-NHN methodology

shows the 7 phases that compose the *SP-NHN* methodology. Furthermore, an architecture associated with the methodology is modeled (Fig. 40.1b).

A set of tools must be considered to follow the stages defined by the proposed methodology and architecture. Therefore, the methodology must be complemented by an information architecture designed for SMEs to collect process and analyse the used information. The description of the phases is presented next.

Phase 1 *Economic Activity Definition*. The NHN global strategy, mission and vision are defined at the economic activity level. The SMEs managers of the network come together to agree the economic activity to be performed. The network managers name the finance and communication managers.

Phase 2 *Objective Description*. The global economic activity objective is described. The SMEs managers meet on a second round of meetings to define the global goal associated with the economic activity described in the previous phase.

Phase 3 *Sub-objectives Description*. The global objective is projected at the local level (SMEs). The network objective consists of the SMEs sub-objectives. The sub-objectives are defined for each SME according to their resources and capabilities. The sub-objectives are defined to achieve the global objective.

Phase 4 *Business Processes Specification*. Each SME develops the business processes in order to achieve the sub-objectives. The business processes generate data about costs, resources, investments and generated assets. Production, quality and finance departments of each SME define the necessary business processes to achieve the sub-objectives defined in phase 3.

Phase 5 *Information Collection*. Business processes provide a series of data that will help to obtain the final participation ratio of NHN partners. The information to gather is:

- *Resources* used by the SMEs to implement the process.
- *Investments* made by the SMEs to achieve the sub-objectives.
- *Costs* incurred in the process carried out by the SMEs to achieve the sub-objectives.
- *Generated Assets* for each networked NHN.
- *Participation Percentage* required for each networked partner.

The information architecture proposed by Alfaro et al. (2010) can be used for exchange the SMEs information. Each SME provides the data required to feed the network level. Then, the requested information is transformed, stored and processed in a global meta-repository. The *bus* of exchange of global information allows the information sharing from different SMEs repositories towards a global meta-repository. The information architecture must be used in parallel with the methodology.

A worker carries out the local repository tasks such as data collection, storage and transaction. The stored data in the local repository is transferred to the global meta-repository where the *BUS manager* performs the harvesting, processing, storage and analysis tasks.

Table 40.3 Degree of coverage of each sub-objective relative to the global objective

○	Sub-objective$_j$ does not cover the global objective
◔	Sub-objective$_j$ covers between 1 and 25 % of the global objective
◑	Sub-objective$_j$ covers between 26 and 50 % of the global objective
◕	Sub-objective$_j$ covers between 51 and 75 % of the global objective
●	Sub-objective$_j$ covers 100 % of the global objective

Phase 6 *Final Participation Percentage*. This phase determines the SME's final participation in each business process to achieve the global objective. The final participation percentage is obtained through the data collected in the global meta-repository. In this case we take into account (1) the degree of coverage of each sub-objective relative to the global objective and (2) the degree of participation of the business process performed by the SMEs to achieve the global objective.

The global objective is defined from the economic activity. To entirely complete the global objective the sub-objectives are needed. Thus, each sub-objective partially covers the defined global objective.

To calculate the percentage of participation of each SME, the degree of coverage of each sub-objective relative to the global goal is first defined (Table 40.3). This variable will determine the importance of each sub-objective to reach the global one.

Afterwards, we define the degree of participation of the business process performed by the SMEs to achieve the global objective (Table 40.4). Thus, a scale of SMEs participation degree is defined, which will determine the degree of SMEs participation to obtain the sub-objective. We have to take into account that each sub-objective is achieved by one or more business process (BP).

Then all the degrees of participation by each SME for each sub-objective are added up: $\sum$ *Degree of Participation SME$_i$ in BPk.*

Therefore, the data concerning to the (1) *degree of coverage of each sub-objective relative to the global objective*—Table 40.3—and the (2) *degree of*

Table 40.4 Degree of participation of the business process performed by the SMEs

	The SME$_i$ does not participate in the business process k for obtaining the sub-objective$_j$
	The SME$_i$ participate between 1 and 25 % in the business process k for obtaining the sub-objective$_j$
	The SME$_i$ participate between 26 and 50 % in the business process k for obtaining the sub-objective$_j$
	The SME$_i$ participate between 51 and 75 % in the business process k for obtaining the sub-objective$_j$
	The SME$_i$ participates 100 % in the business process k for obtaining the sub-objective$_j$

participation of each SME—Table 40.4—allow to calculate the *final participation rate* of each SME, by Eq. 40.1:

$$\begin{aligned} Final\ Participation\ Rate = \sum_{Sub-Objective_j} \Big(Degree\ of\ Coverage\ SO_j \\ * \sum Degree\ \ of\ Participation\ SME_i\ in\ BP_k \Big) \forall SME_I \end{aligned} \tag{40.1}$$

The global meta-repository calculates the final participation rate for each company taking into account the resources used to carry out the business processes. The *bus manager* communicates the SMEs managers the final participation rate result.

Phase 7 *Share costs and profits*. The distribution of costs and profits is carried out based on the collected information (*phase 5*) and the calculated final participation percentage (*phase 6*). The more resources, investments and costs in each SME, the more profits proportion will be reaped. The NHN finance manager performs the profits distribution among the networked SMEs.

The share profits and costs methodology is based on equitable distribution. The Eq. (40.2) provides the percentage of each SME respect to the overall cost of the activity.

$$\begin{aligned} \%\, SME_i\ cost = \sum_{sub-Objective_j} \frac{SME_i\ cost}{Sub-Objective_j Total\ Cost} \\ \times\ Degree\ of\ coverage\ of\ each\ Sub-Objective_j \end{aligned} \tag{40.2}$$

The cost and profit sharing are done through the average of the *Final Participation rate of each SME* (Eq. 40.1) and *% SME cost* (Eq. 40.2) following Eq. (40.3).

$$Share\ costs\ in\ SME_i = \frac{Final\ Participation\ Rate\ of\ SME_i + \%\ cost}{2} \tag{40.3}$$

For better understanding we propose an example. Consider a NHN with 3 SMEs.

Taking into account the defined parameters (Table 40.5) we proceed to calculate the participation rate of each SME according the Eq. (40.1).

Afterwards we calculate the SME percentage cost according the Eq. (40.2).

With the *final participation rate of each SME* (Table 40.6) and the *% SME cost* (Table 40.7) the total percentage of participation is calculated. Based on the total percentage of participation we obtain the final percentage to allocate the costs or profits, using Eq. 40.3 (Table 40.8).

Thus, $\mathbf{SME_1}$ accounts for SC_1 % of the costs/profits, $\mathbf{SME_2}$ accounts for SC_2 % of the costs/profits and $\mathbf{SME_3}$ accounts for SC_3 % of the costs/profits.

Table 40.5 Nomenclature table

Sets	
{i}	set of SMEs
{j}	set of sub-objectives (SO)
{*k*}	*set of business processes* (*BP*)
Parameters	
α	degree of coverage SO_j relative to the global objective (○,◔,◑,◕,●)
β_{ijk}	degree of participation of SME_i to reach the SO_j in BP_k ()
C_{ij}	SME_i cost to reach the SO_j
TC_j	Total cost to reach the SO_j
R_i	Final participation rate of SME_i
RIC_i	Resources, investment and cost participation degree of SME_i
SCi	Final percentage cost to share among SME_i

Table 40.6 Participation rate of each SME (example)

	SO_1	SO_2	SO_3	Equation 1	Participatin rate
SME_1	β_{11}	β_{12}	β_{13}	$\alpha_1 \times \beta_{11} + \alpha_2 \times \beta_{12} + \alpha_3 \times \beta_{13}$	R_1
SME_2	β_{21}	β_{22}	β_{23}	$\alpha_1 \times \beta_{21} + \alpha_2 \times \beta_{22} + \alpha_3 \times \beta_{23}$	R_2
SME_3	β_{31}	β_{32}	β_{33}	$\alpha_1 \times \beta_{31} + \alpha_2 \times \beta_{32} + \alpha_3 \times \beta_{33}$	R_3

Table 40.7 SME percentage cost (example)

	SO_1	SO_2	SO_3	Equation 2	Resources/investment/cost
SME_1	C_{11}	C_{12}	C_{13}	$\frac{C_{11}}{TC_1} \times \alpha_1 + \frac{C_{12}}{TC_2} \times \alpha_2 + \frac{C_{13}}{TC_3} \times \alpha_3$	RIC_1
SME_2	C_{21}	C_{22}	C_{23}	$\frac{C_{21}}{TC_1} \times \alpha_1 + \frac{C_{22}}{TC_2} \times \alpha_2 + \frac{C_{23}}{TC_3} \times \alpha_3$	RIC_2
SME_3	C_{31}	C_{32}	C_{33}	$\frac{C_{31}}{TC_1} \times \alpha_1 + \frac{C_{32}}{TC_2} \times \alpha_2 + \frac{C_{33}}{TC_3} \times \alpha_3$	RIC_3
Total cost SO_j	TC_1	TC_2	TC_3		

Table 40.8 Total percentage of participation SME_i (example)

SME_i	Final participation rate	% Resources/investment/cost	Share costs in SMEs
SME_1	R_1	RIC_1	$SC_1 = \frac{R_1 + RIC_1}{2}$
SME_2	R_2	RIC_2	$SC_2 = \frac{R_2 + RIC_2}{2}$
SME_3	R_3	RIC_3	$SC_3 = \frac{R_3 + RIC_3}{2}$

40.4 Conclusions and Further Research

Amongst the relevant problems that do not have satisfactory solutions in NHN context (Table 40.1), this paper begins a series of solution proposals that will enable us to establish a collaborative framework focused on NHN.

Particularly, the paper addresses the share costs and profits problem due to this problem has not been discussed in the literature from a decentralised view.

To deal with the problem a solution based on a *SP-NHN methodology* is proposed. *SP-NHN* is able to establish the participation percentage for allocating the profits and costs of the global economic activity conducted by the NHN.

The future research lines are focused on building a "Collaborative Framework for Non-hierarchical Manufacturing Networks" that will focus with problems which current solutions do not provide satisfactory degrees of coverage in the NHN perspective. The expected contribution of the future dissertation research is to develop a framework that provides models, guidelines and tools for supporting collaborative processes, specifically in the non-hierarchical context (NHN). The main aim of the collaborative framework is to achieve a better understanding of how SMEs deal with collaborative problems in NHN.

References

Alfaro JJ, Rodríguez R, OrtizA, Verdecho MJ (2010) An information architecture for a performance management framework by collaborating SMEs. Comput Ind 61(7):676–685

Andrés B, Poler R (2011) Análisis de los Procesos Colaborativos en Redes de Empresas No-Jerárquicas. XV Congreso de Ingeniería de Organización. Cartagena

Audy JF, D'Amours S, Lehoux N, Rönnqvist M (2010) Generic mechanisms for coordinating operations and sharing financial benefits in collaborative logistics. In: Camarinha-Matos LM, Boucher X, Afsarmanesh H (eds) Collaborative networks for a sustainable world (11th IFIP WG 5.5 working conference on virtual enterprises, PRO-VE 2010 ed, pp 537–544) Springer, Etienne, France, 11–13 October 2010

Caldentey R, Wein LM (2003) Analysis of a decentralized production-inventory system. Manuf Serv Oper Manage 5(1):1

Chen C, Wang B, Lee W (2003) Multiobjective optimization for a multienterprise supply chain network. Ind Eng Chem Res 42:1879–1889

Corbett CJ, DeCroix GA, Ha AY (2005) Optimal shared-savings contracts in supply chains: linear contracts and double moral hazard. Eur J Oper Res 163(3):653–667

Giannoccaro I, Pontrandolfo P (2004) Supply chain coordination by revenue sharing contracts. Int J Prod Econ 89(2):131–139

Goyal SK, Gupta YP (1989) Integrated inventory models: the buyer-vendor coordination. Eur J Oper Res 41:261–269

Gupta D, Weerawat W (2006) Supplier–manufacturer coordination in capacitated two-stage supply chains. Eur J Oper Res 175(1):67–89

Jähn H (2010) The application of incentive mechanisms for the participation of enterprises in collaborative networks from an economic perspective. In: Camarinha-Matos LM, Boucher X, Afsarmanesh H (eds) Collaborative networks for a sustainable world (11th IFIP WG 5.5 working conference on virtual enterprises, PRO-VE 2010 ed pp 773–780) Springer, Etienne, France, 11–13 October 2010

Poler R (2010) Intelligent non-hierarchical manufacturing networks (iNet-IMS). Intelligent manufacturing systems. Obtenido de http://www.ims.org/sites/default/files/iNet-IMS%20MTP%20Initiative%202009%20v1.3.doc

Sarmah SP, Acharya D, Goyal SK (2006) Buyer vendor coordination models in supply chain management. Eur J Oper Res 175(1):1–15

Frisk M, Jornsten K, Göthe-Lundgren M, Rönnqvist M (2010) Cost allocation in collaborative forest transportation. Eur J Oper Res 205(2): 448–458

Chapter 41
Fill Rate in a Periodic Review Base Stock System Under Discrete Distributed Demand for the Backordering Case

E. Babiloni, E. Guijarro, M. Cardós and S. Estellés

41.1 Introduction and Literature Review

The traditional problem of the periodic review, base stock (R, S) system is usually on the determination of the base stock, S, such that total costs are minimized or some target customer service level is fulfilled. Even if the cost criterion is used for that purpose, the service level is usually included by imposing penalty costs on shortages (van der Heijden 2000) or by using it to compute the base stock in order to minimize holding costs of the system (Babiloni et al. 2011). Therefore accurate expressions to estimate customer service levels are required. Appropriate service indicators are the cycle service level and the fill rate, being the latter the most used in practice (van der Heijden 2000). This paper focuses on the exact estimation of the fill rate in (R, S) systems. Furthermore, when managing inventories it is required to know how to proceed when an item is out of stock and a customer order arrives. There are two extreme cases: the backordering case (= any unfulfilled demand is backordered and filled as soon as possible); and the lost sales case (= any unfulfilled demand is lost). This paper focuses on the backordering case.

The fill rate is defined as the fraction of demand that is immediately fulfilled by the on hand stock. A common approach to estimate it, consists on computing the number of units instead of computing directly the fulfilled demand per replenishment cycle. This approach, known in the related literature as the traditional approximation and denoted by β_{Trad} further on, consists of calculating the complement of the quotient between the expected unfulfilled demand per replenishment cycle (also known as expected shortage) and the total expected demand per replenishment cycle as follows:

E. Babiloni (✉) · E. Guijarro · M. Cardós · S. Estellés
Departamento de Organización de Empresas, Universitat Politècnica de València, Camí de Vera, s/n, 46022 Valencia, Spain
e-mail: mabagri@doe.upv.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_41,

$$\beta_{Trad} = 1 - \frac{E(unfulfilled\ demand\ per\ replenishment\ cycle)}{E(total\ demand\ per\ replenishment\ cycle)} \quad (41.1)$$

One limitation of the available methods devoted to estimating β_{Trad} in the (R, S) system for the backordering case is that they estimate it only for specific demand conditions. In this sense, Hadley and Whitin (1963), Silver and Peterson (1985), Johnson et al. (1995), Silver and Bischak (2011) suggest methods to estimate it when demand is normally distributed whereas Teunter (2009), Sobel (2004), Zhang and Zhang (2007) pose them when demand follows any continuous distribution. When demand is discrete, only (Hadley and Whitin 1963) suggest a method to estimate β_{Trad} for Poisson demands but for the rest of our knowledge, no methods are available to estimate it when demand follows any discrete distribution function.

Another approach to compute the fill rate consists of estimating directly the fraction of the fulfilled demand per replenishment cycle instead of determining the expected shortage, as follows:

$$\beta = E\left(\frac{unfulfilled\ demand\ per\ replenishment\ cycle}{total\ demand\ per\ replenishment\ cycle}\right) \quad (41.2)$$

Guijarro et al. (2012) show that expression (41.1) and expression (41.2) are not equivalent and propose methods to estimate both for any discrete demand pattern when inventory is managed following the lost sales case principle. However, there is not available any method to estimate β_{Trad} and β when demand is modeled by any discrete distribution and the inventory is managed following the backordering case, i.e. when unfulfilled demand is backlogged to the following cycle. This paper fulfils this research gap and suggests two new and exact methods to estimate both expressions (Sect. 41.3). Furthermore, we present and discuss some illustrative examples of the performance of both versus a simulated fill rate and over different demand patterns (Sect. 41.4). The discussion and summary of this work are summarized in Sect. 41.5.

41.2 Basic Notation and Assumptions

The traditional periodic review, base stock (R, S) system places replenishment orders every R units of time of sufficient magnitude to raise the inventory position to the base stock S. The replenishment order is received L periods after being launched. Figure 41.1 shows an example of the evolution of the on hand stock (= stock that is physically on shelf), the net stock (= on hand stock − backorders) and the inventory position (= on hand stock + stock on order − backorders) for the backordering case.

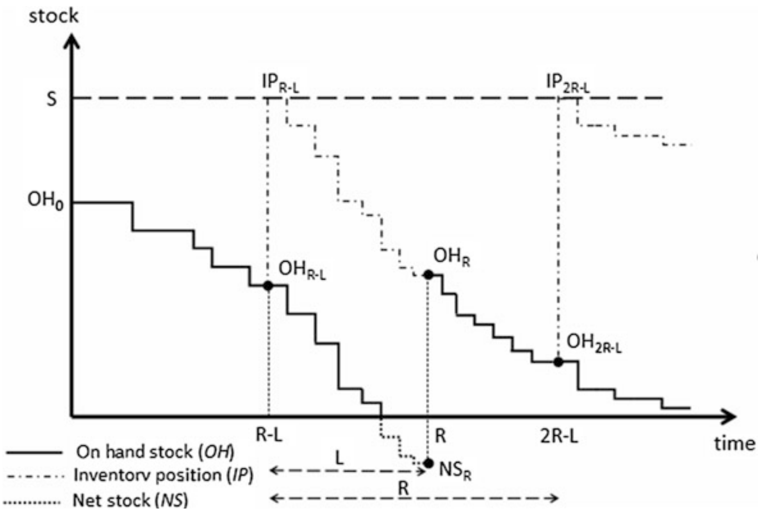


Fig. 41.1 Example of the evolution of a (*R*, *S*) system (backordering case)

Notation is as follows:

S	Base stock (units),
R	Review period corresponding to the time between two consecutive reviews and replenishment cycle corresponding to the time between two consecutive deliveries (time units),
L	Lead time for the replenishment order (time units),
OH_t	On hand stock at time t (units),
IP_t	Inventory position at time t (units),
NS_t	Net stock at time t (units),
D_t	Total demand during t consecutive periods (units),
$f_t(\cdot)$	Probability mass function of D_t,
$F_t(\cdot)$	Cumulative distribution function of D_t,

The rest of the paper assumes that: (1) time is discrete and is organized in a numerable and infinite succession of equi-spaced instants; (2) the lead time, L, is constant; (3) the replenishment order is added to the inventory at the end of the period in which it is received, hence these products are available for the next period; (4) demand during a period is fulfilled with the on hand stock at the beginning of the period; and (5) demand process is discrete, stationary and i.i.d.

41.3 Estimation of the Fill Rate in a Discrete Demand Context

41.3.1 Derivation of an Exact Method to Compute β_{Trad}

The traditional approximation of the fill rate computes the complement of the ratio between the expected unfulfilled demand (expected shortage) and the expected demand per replenishment cycle as shown in expression (41.1). The expected demand can be straightforwardly computed so all that is left to compute is the expected unfulfilled demand per replenishment cycle. Then, if at the beginning of the cycle there is not stock on shelf to satisfy any demand, the net stock at this time is zero or negative ($NS_O \leq 0$) and therefore the expected shortage is equal to the expected demand during the replenishment cycle. Hence, the β_{Trad} is equal to zero.

On the other hand if the net stock at the beginning of the cycle is positive ($NS_O > 0$), the shortage is equal to the difference between the NS_O and the amount of demand that exceed NS_O during that cycle. By definition, the net stock when positive can be from 1 to S, and hence:

$$E\,(\text{unfulfilled demand per replenishment cycle}) = \sum_{NS_0=1}^{S} P(NS_0)\cdot \sum_{D_R=NS_0-1}^{\infty} (D_R - NS_0)P(D_R) \tag{41.3}$$

Since the net stock is equivalent to the inventory position minus the on order stock, the net stock balance at the beginning of the cycle is $NS_0 = S - D_L$ Then

$$P(NS_0) = P(D_L = S - NS_0) = f_L(S - NS_0).$$

Therefore, β_{Trad} when demand follows any discrete distribution function can be estimated with the following expression:

$$\beta_{Trad} = 1 - \frac{\sum_{NS_0=1}^{S} f_L(S = NS_0)\cdot \sum_{D_R=NS_0+1}^{\infty} (D_R - NS_0) f_R(D_R)}{\sum_{D_R=1}^{\infty} D_R \cdot f_R(D_R)} \tag{41.4}$$

41.3.2 Derivation of an Exact Method to Compute β

The fill rate is defined as the fraction of demand that is immediately fulfilled from shelf and therefore, cycles that do not show any demand should not be taken into account. According to (Guijarro et al. 2012) to derive an exact method to compute the fill rate over different demand patterns including intermittent demand, is necessary to include explicitly the condition of having positive demand during the cycle. Note that from a practical point of view, it is useless to consider a service metric when there is no demand to be served. Then, positive demand during a cycle can be: (1) lower or equal than the net stock at the beginning of this cycle, i.e. $D_R \leq NS_O$, and therefore the fill rate will be equal to 1; or (2) greater than the net stock, i.e. $D_R > NS_O$, and therefore the fill rate will be the fraction of that demand which is satisfied by the on hand stock at the beginning of this cycle. Hence

$$\beta(NS_0) = P(D_R \leq NS_0 | D_R > 0) + \sum_{D_R = NS_0 + 1}^{\infty} \frac{NS_0}{D_R} \cdot P(D_R | D_R > 0) \tag{41.5}$$

where the first term indicates (1) and the second term indicates (2). Rewriting expression (41.5) through the probability mass and cumulative distribution functions of demand, $f_t(\cdot)$ and $F_t(\cdot)$, respectively, results in

$$\beta(NS_0) = \frac{F_R(NS_0 - F_R(0))}{1 - F_R(0)} + \sum_{D_R = NS_0 + 1}^{\infty} \frac{NS_0}{D_R} \cdot \frac{f_R(D_R)}{1 - F_R(0)} \tag{41.6}$$

Therefore, by applying expression (41.6) to every positive net stock level at the beginning of the period, the method to estimate β when demand follows any discrete distribution function results as follows:

$$\beta = \sum_{NS_0 = 1}^{S} f_L(S - NS_0) \cdot \left\{ \frac{F_R(NS_0 - F_R(0))}{1 - F_R(0)} + \sum_{D_R = NS_0 + 1}^{\infty} \frac{NS_0}{D_R} \cdot \frac{f_R(D_R)}{1 - F_R(0)} \right\} \tag{41.7}$$

41.4 Illustrative Examples

This section illustrates the performance of expression (41.4) and (41.5) (β_{Trad} and β respectively) against the simulated fill rate, β_{Sim}, which is computed as the average fraction of the fulfilled demand in every replenishment cycle when considering 20,000 consecutive periods (T = 20,000) as in expression (41.8). Data used for the simulation is presented in Table 41.1 which encompasses 180 different cases.

$$\beta_{Sim} = \frac{1}{T} \sum_{t=1}^{T} \frac{fulfilled\ demand_t}{total\ demand_t} \tag{41.8}$$

Demand is simulated by using the negative binomial since it is able to fulfill the smooth, intermittent, erratic and lumpy categories suggested by (Syntetos et al. 2005) as shown in Fig. 41.2.

Figure 41.3 shows the comparison between β_{Trad}, β and β_{Sim} for the Table 41.1 cases. In it, we see that β_{Trad} tends to underestimate the simulated fill rate and therefore the traditional approximation seems to be biased. (Johnson et al. 1995)

Table 41.1 Set of data (180 cases)

Lead time	L = 1, 3, 5
Review period	R = 1, 3, 5
Order up to level	S = 1, 3, 5, 7, 10
Demand pattern negative binomial (r,θ)	Smooth (4, 0.7); intermittent (1.25, 0.9); erratic (1.5, 0.3); lumpy (0.75, 0.25)

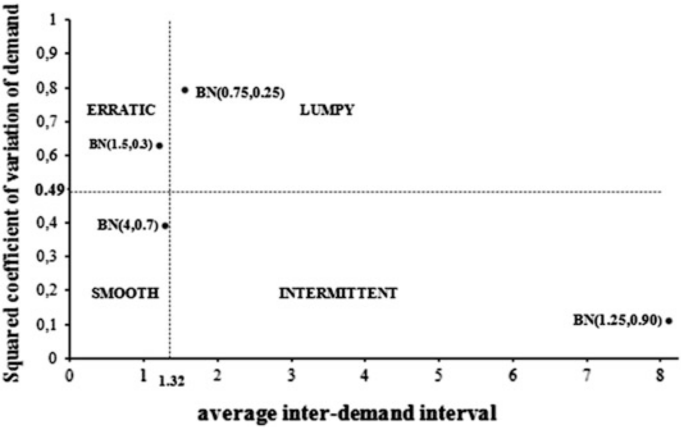


Fig. 41.2 Demand patterns used in the simulation according to the categorization of demand suggested by (Syntetos et al. 2005)

pointed out similar results when demand is normally distributed, whereas (Guijarro et al. 2012) when demand is Poisson distributed for the lost sales case. The expression (41.4) leads to the exact value of the traditional approximation. Therefore deviations as Fig. 41.3a shows, arise from estimating the fill rate using the traditional approach (expression (41.1)) and not from how it is calculated. Regarding the performance of β, Fig 41.3b shows that neither bias nor significant deviations appear on it for any of the 180 cases and therefore β compute accurately the fill rate over different discrete demand patterns.

41.5 Discussion and Summary

The traditional approach of the fill rate, β_{Trad}, computes it by estimating the ratio between the expected unfulfilled demand and the total expected demand per replenishment cycle through computing the expected shortage per replenishment cycle. Section 41.3.1 presents an exact method to compute β_{Trad} for any discrete demand distribution and for the backordering case. However, Fig. 41.3a shows that β_{Trad} tends to underestimate the simulated fill rate. An important consequence

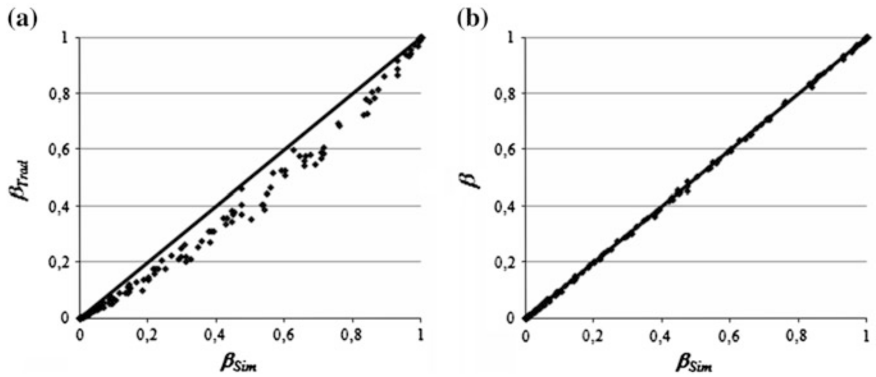


Fig. 41.3 β_{Trad} and β versus β_{Sim} for the cases from Table 41.1

of the underestimation behavior is found when using a target fill rate to determine the order up to level of the inventory policy. Figure 41.4 shows the evolution of β_{Trad}, β_{Sim}, and the exact estimation of the fill rate that is derived in Sect. 41.3.2, β, when increasing the base stock for a smooth demand modeled by a Negative binomial with $r = 4$ and $\theta = 0.7$. In this case, if a target fill rate is set to 0.60, β_{Trad} leads to $S = 5$ whereas in fact just $S = 3$ is necessary to reach the target. In this example, using β_{Trad} to determine order up to level leads to an unnecessary increase in the average stock level and thus total costs of the system. This inefficiency is especially relevant in industries in which the unit cost of the item is high and/or storage space is limited. Therefore, managers should be aware of the risk of using the traditional approximation to set the order up to level.

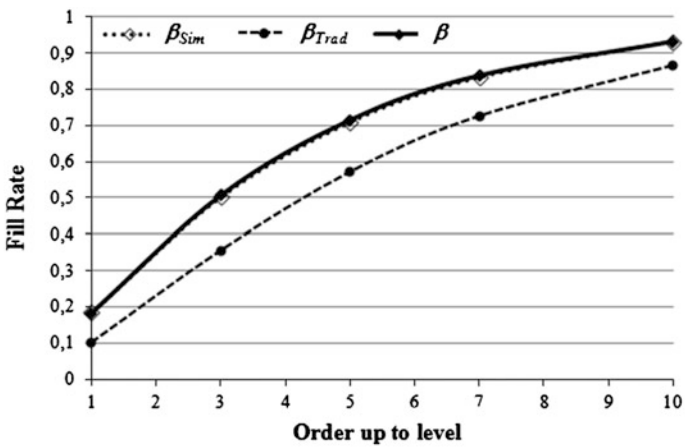


Fig. 41.4 Comparison between β_{Trad}, β and β_{Sim} with Negative binomial demand with $r = 4$ and $\theta = 0.7$ (smooth), $R = 1$ and $L = 1$

The method derived in Sect. 41.3.2, β, computes the fill rate directly as well as the expected fulfilled demand per replenishment cycle for the backordering case. This method presents the following advantages: (1) simulation results show their accuracy over different demand patterns; (2) outperforms the traditional approach and therefore the above mentioned risks of using β_{Trad}; (3) avoids the distortion caused in the metric by the cycles with no demand and therefore it can be used even if the probability of no demand during the cycle cannot be neglected; (4) applies for any discrete demand distribution.

References

Babiloni E, Cardos M, Guijarro E (2011) On the exact calculation of the mean stock level in the base stock periodic review policy. J Ind Eng Manage 4:194–205

Guijarro E, Cardós M, Babiloni E (2012) On the exact calculation of the fill rate in a periodic review inventory policy under discrete demand patterns. Eur J Oper Res 218:442–447

Hadley G, Whitin T (1963) Analysis of Inventory Systems. Prentice-Hall, Englewood Cliffs

Johnson ME, Lee HL, Davis T, Hall R (1995) Expressions for item fill rates in periodic inventory systems. Nav Res Logist 42:57–80

Silver EA, Peterson R (1985) Decisions system for inventory management and production planning. John Wiley & Sons, New York

Silver EA, Bischak DP (2011) The exact fill rate in a periodic review base stock system under normally distributed demand. Omega-int J Manage S 39:346–349

Sobel MJ (2004) Fill rates of single-stage and multistage supply systems. Manuf Serv Oper Manage 6:41–52

Syntetos AA, Boylan JE, Croston JD (2005) On the categorization of demand patterns. J Opl Res Soc 56:495–503

Teunter RH (2009) Note on the fill rate of single-stage general periodic review inventory systems. Oper Res Lett 37:67–68

van der Heijden MC (2000) Near cost-optimal inventory control policies for divergent networks under fill rate constraints. Int J Prod Econ 63:161–179

Zhang J, Zhang J (2007) Fill rate of single-stage general periodic review inventory systems. Oper Res Lett 35:503–509

Chapter 42
A Proposed Collaborative Network Enterprise Model in the Fruit-and-Vegetable Sector Using Maturity Models

Maria Alonso-Manzanedo, M. Victoria De-la-Fuente-Aragon and Lorenzo Ros-McDonnell

42.1 Introduction

Within the last thirty years the Fruit-and-Vegetable sector has become the first Spanish agricultural sector in terms of production value. Spain is the first European producer of fresh fruit and vegetables and the first European exporter of these products.

In an ever-increasing globalized market, with competition from producers and distributors from other regions within and outside of the European Union, companies are compelled to a continuous innovative effort to adopt and adapt new measures to add value to the sector, making it possible to respond to consumers' demands and to face fierce foreign competition.

The importance of focusing on those aspects which enable producers to have an advantageous position over their competitors gives rise to the need for an evaluation of the performance of the Fruit-and-Vegetable companies, both as individual actors and within their own collaborative activities. To do so, maturity models are proposed to evaluate, by means of objective measuring, the current state of the company's individual and collaborative processes. Implementation of these models will help to improve the logistic network's performance.

This paper is organized as follows: Sect. 42.2 presents a review of the existing literature on inter-company collaborative networks and maturity models; Sect. 42.3 exhibits the theoretical framework used to develop a research project to create a logistic network model for the Fruit-and-Vegetable sector, from the point of view of key processes. After outlining the conclusions, the paper is concluded by suggesting directions for future research.

M. Alonso-Manzanedo · M. Victoria De-la-Fuente-Aragon (✉) · L. Ros-McDonnell
Grupo Gestión e Ingeniería de Organización (GIO). ETSII, Campus Muralla del Mar, C/Dr. Fleming s/n, 30202 Cartagena, Spain
e-mail: marivi.fuente@upct.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_42,

42.2 A Review of the Literature

42.2.1 Key Features of the Cold Chain

Within the concept of supply chain, the Cold Supply Chain stands out as a singularity. Due to the very nature of the products being processed, handled, transported and marketed, the management of this kind of chain is affected by a number of peculiar aspects. The integrity of these products must be preserved at all times during the phases of loading, transport, unloading, handling and storage, and the responsibility reaches as far as the retail selling point. To assure quality, food safety and shelf life of perishable produce, temperature control is essential all along this chain (Moureh et al. 2009).

The principles and general provisions on food legislation laid down by Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 seek to guarantee food safety and to protect consumers' interests. To this goal, it is necessary to know and register all actions taken on a product from the start to the end of its supply chain. This is known as *Product Traceability*.

Traceability is about systematically linking information flows with physical flows of goods in a way that information on any specific batch or group of products can be recalled at any given time. Therefore, integrating information systems along the cold chain is crucial to achieve optimum levels of traceability and for comprehensive process management (Somers and Nelson 2003), as well as for inter-operativeness of key processes in the supply chain.

Small and medium-sized companies with limited resources need to join forces, through collaboration, to adapt to ever-changing conditions in today's turbulent, competitive markets. They must improve significantly their abilities by means of new business models, strategies, governance rules, processes and technology (Camarinha-Matos et al. 2009).

Alliances and collaboration among members of the supply chain lead to an improved performance of the logistic network, increased inventory turnover, higher income, cost reduction, product availability and added value (Fawcett et al. 2008); all of which translates into competitive advantage against competitors (Dacin et al. 1997; Wheelen and Hungar 2000). For manufacturing companies sharing abilities and resources, collaboration is a key asset to obtain a quick response to market demands (Camarinha-Matos et al. 2009).

To build these collaborative links, member companies must be willing to invest in personnel and resources, even if other companies may benefit directly from their investment. They must also be prepared to share knowledge, either explicit or implicit, with other companies, even if these collaborators could be regarded as competitors (Dyer 2000). Elmuti and Kathawala (2001) pointed out that trust is the hardest and the most important factor for the success of this kind of collaboration, since it is the people who trust each other, not the companies.

A collaborative network or collaborative supply chain is the optimum, most advanced level of collaborative relationship to be found among companies. These companies start by exchanging information. At any given stage, they decide to align some of their processes to achieve shared targets. Gradually, confidence is built among people, and in time this results in stronger collaborative relationships among companies, where efforts are pooled seeking common goals by sharing not only information, but also resources, risks, profit and loss (Camarinha-Matos and Afsarmanesh 2008).

42.2.2 The Evolution of Maturity Models

Maturity models are management tools. They are used to evaluate by means of objective measuring the current state of the company, depending on the views of each model. Its implementation will help to improve the company's internal and external processes. Possible improvements suggested by maturity models are arranged in steps in accordance with each level of maturity, the objective being an evolutionary improvement in processes.

The concept of *maturity* has become popular with the development of the Capability Maturity Model (CMM) proposed by Software Engineering Institute (SEI 1995).

The concept of *maturity processes* has been developed and tested in software development processes (Harter et al. 2000), in project management processes (Ibbs and Kwak 2000), and in business processes (Fisher 2004; Lee et al. 2007; McCormack 2007; Vom Brocke and Rosemann 2010). Particular to the latter are those models specifically developed for supply chains (Lockamy and McCormack 2004, Daozhi et al. 2006).

Business Process Maturity stems from the idea that all processes have a life cycle, or stages of development, which are clearly definable, measurable and manageable in time. This evolves into the concept of *maturity levels*. Among all the Business Process Maturity Models (BPMM) found in literature, we pledge to the model proposed by McCormack and Johnson (2001), McCormack (2007), which analyzes the maturity of the company's processes from the following perspectives: definition of activities and processes documentation; job structuring; process management and measuring; management structure and process focusing.

The Supply Chain Maturity Model (SCMM) of Lockamy and McCormack (2004) expands the previously mentioned BPMM model to gauge the level of managerial integration, collaboration and trust currently existing among the members of the supply chain. The frame of reference used for the development and measuring of processes performance is the SCOR model. Five key processes are analyzed from the perspectives of McCormack's (2007) BPMM: *plan, source, make, deliver and return.*

None of the current models found in the literature can be used for measuring the maturity of collaborative networks, since they need to measure not only the factors necessary to evaluate processes or supply chains but also all the factors regarded in

Table 42.1 Relevant factors in collaborative relationships [adapted from Verdecho et al. (2012)]

Factors	
Strategic factors	Joint vision, design of the inter-enterprise network, equity, top management support
Business process and infrastructure factors	Process alignment, IS/ICTs interoperability, complementary skills, coordination between activities
Organizational structure factors	Collaboration leadership, compatibility of management styles, joint decision-making, multidisciplinary teams
Cultural factors	Trust, commitment, cooperation, information shared, conflict resolution management

the literature as relevant for collaboration relationships (Verdecho et al. 2012), as shown in Table 42.1.

42.3 Proposed Research

A Fruit-and-Vegetable logistic network is composed of the following:

- Producers: farmers or agrarian associations dedicated to the production of fruits and vegetables, as well as to the packing operations necessary for subsequent marketing of their products.
- Marketers: companies exporting these products and coordinating sales campaigns.
- Hauliers: companies committed to national and/or international transport of perishable goods.
- Distributors: acting as a customer in the collaborative network, these are mainly logistical platforms and large food chains.

The business model will be developed for a collaborative network of the Fruit and Vegetable sector by taking the SCOR model as a reference. The reason for choosing this model is the fact that it is easily extensible to any type of company, chain or network, besides being a model of reference thoroughly accepted by the academics. The processes of the network can be broken down on the basis of the five key processes proposed by the SCOR model (Poluha 2010) (Fig. 42.1).

Once the network's managerial model has been proposed it will be validated by using a repository of maturity models whose parameterization has been designed to analyze the singularities and the relevant factors of the processes of a collaborative network. The views used for the validation of the company model are:

- Functions: activities and documentation of each process will be analyzed (Fisher 2004; Lee et al. 2007; McCormack 2007).
- Assets: tangible and human resources will be analyzed (Fisher 2004; Daozhi et al. 2006; Vom Brocke and Rosemann 2010)

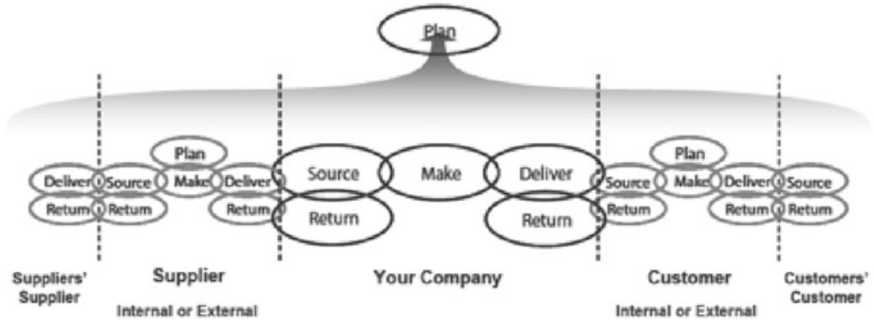


Fig. 42.1 Key processes of the SCOR model, (Poluha 2010)

- Management systems and IT systems: their degree of inter-connectability will be measured (Fisher 2004; McCormack 2007; Vom Brocke and Rosemann 2010).
- Costs: processes costs and supply chain management cost will be measured (Lockamy and McCormack 2004; Daozhi et al. 2006).
- Process structure: work teams integration, alliances, partnerships and contracts among members of the supply chain will be analyzed (Lee et al. 2007; McCormack 2007).
- Strategy: The decision-making process and strategy alignment will be analyzed (Fisher 2004; Vom Brocke and Rosemann 2010).
- Culture: the organizational culture will be analyzed (Fisher 2004; Vom Brocke and Rosemann 2010).

The maturity levels proposed (from the selected views) have been obtained after adapting the maturity levels of the models proposed by Fisher (2004), Lockamy and McCormack (2004); McCormack (2007), Pache and Spalanzani (2007), and Camarinha-Matos and Afsarmanesh (2008). These levels of maturity are:

- *LEVEL 1. Ad hoc*: The processes of the members of the supply chain are unstructured and directed towards the interests of their own organizations. They do not set objectives and are not capable of determining the results of the processes. For these reasons, the management costs of the supply chain are very high.
- *LEVEL 2. Defined*: The key processes of the network are defined and documented. Relationships consisting of mere information exchanges begin to appear among some members of the network, suppliers and customers. Monitoring tools start to be used for key processes.
- *LEVEL 3. Linked*: The management of the supply chain or network is a strategic function. Process managers define, develop and maintain the key processes. There is feedback between the key processes of the members (sharing objectives) and the measuring systems. Information is shared among the members. Partnership contracts exist among the members of the network. The network's management costs begin to decrease as customer satisfaction levels increase.

- *LEVEL 4. Integrated*: The members of the net collaborate at process level. Functions are organized and jobs are dimensioned under the guidelines of the SCM. Planning and forecasting tasks are performed jointly by the members of the network. The processes teams are responsible for the processes from start to end. Not only is information shared, but also resources for the attainment of compatible objectives. Contracts start to spread to all the members of the network. The costs of SCM decrease considerably and customers' satisfaction becomes a competitive advantage.
- *LEVEL 5. Extended*: There is reciprocal trust and mutual dependence among the members of the network, key variables for collaboration. Information, resources and responsibilities for the attainment of common objectives and generation of added value are shared, as well as risks, profits and losses.

Within these levels of maturity, the principles that should be implemented at each level in order to reach some superior results are described. The transition from one maturity level to another requires that several members of the network carry out organizational changes; changes in terms of cooperation modes, with processes interrelated or performance indicators adapted to the relationship patterns among the members. The scope of each one of these maturity levels upgrades the capacity of the processes of the supply network (Fig. 42.2).

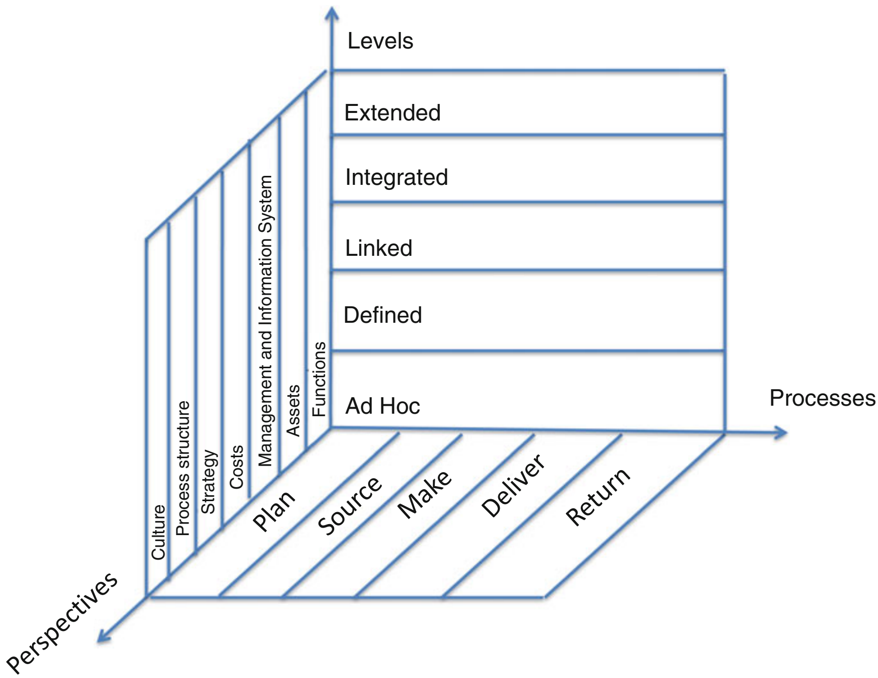


Fig. 42.2 Proposed maturity model

Based on the results obtained with the validation of the model, best practices will be proposed for the improvement of the collaborative network's performance.

42.4 Conclusions

Several methods exist for modelling business processes, depending on the various scenarios or organization views intended to be represented. In our research project we intend to develop a logistic network model for the Fruit and Vegetable sector based on maturity models.

The maturity models approach will allow evaluating in an objective way the state of the company and the network from the views determined by each of the selected models, the purpose of which is to establish the existing levels of integration and collaboration within the studied network, and to be able to obtain evolutionary improvements in the network's collaborative processes.

References

Camarinha-Matos LM, Afsarmanesh H (2008) Collaborative networks—reference modelling. Springer, New York

Camarinha-Matos LM, Afsarmanesh H, Galeano N, Molina A (2009) Collaborative networked organizations concepts and practice in manufacturing enterprises. Comput Ind Eng 57:46–60

Dacin MT, Hitt MA, Levitas E (1997) Selecting partners for successful international alliances: examination of US and Korean firms. J World Bus 32(1):3–16

Daozhi Z, Liang Z, Xin L, Jianyong S (2006) A new supply chain maturity model with 3-dimension perspective. Int Technol and Innov Conf 1732–1737

Dyer JH (2000) Collaborative Advantage: winning through extended enterprise supplier networks. Oxford University Press

Elmuti D, Kathawala Y (2001) An overview of strategic alliances. Manag Decis 39(3):205–217

Fawcett SE, Magnan GM, McCarter MW (2008) Benefits, barriers, and bridges to effective supply chain management. Supply Chain Manage: Int J 13(1):35–48

Fisher DM (2004) The business process maturity model. A practical approach for identifying opportunities for optimization. http://www.bptrends.com/resources_publications.cfm. Accessed Sept 2005

Harter DE, Krishnan MS, Slaughter SA (2000) Effects of process maturity on quality, cycle time and effort in software product development. Manage Sci 46(4):451–466

Ibbs CW, Kwak YH (2000) Assessing project management maturity. Project Manage J 31(1):32–43

Lee J, Lee D, Kang S (2007) An overview of the business process maturity model (BPMM). Springer, Berlin

Lockamy A III, McCormack K (2004) The development of a supply chain management process maturity model using the concepts of business process orientation. Supply Chain Manage: Int J 9(4):272–278

McCormack K (2007) Business process maturity: theory and application. DRK Research, Raleigh, NC

McCormack K, Johnson W (2001) Business process orientation: gaining the E-business competitive advantage. St Lucie Press, Delray Beach, FL

Moureh J, Tapsob S, Derens E, Flick D (2009) Air velocity characteristics within vented pallets loaded in a refrigerated vehicle with and without air ducts. Int J Refrig 32:220–234

Pache G, Spalanzani A (2007) La gestion des chaînes logistiques multi-acteurs: perspectives stratégiques. Ed. PUG

Poluha RG (2010) Application of the SCOR Model in Supply Chain Management. Cambria Press, Supply Chain Council, Inc Cypress, TX

SEI (1995). http://www.sei.cmu.edu

Somers TM, Nelson KG (2003) The impact of strategy and integration mechanisms on enterprise system value: empirical evidence from manufacturing firms. Eur J Oper Res 146:315–338

Verdecho MJ, Alfaro JJ, Rodriguez R, Ortiz A (2012) The analytic network process for managing inter-enterprise collaboration: a case study in a collaborative enterprise network. Expert Syst Appl 39:626–637

Vom Brocke J, Rosemann M (2010) Handbook in business process management 2. Springer

Wheelen TL, Hungar DJ (2000) Strategic management and business policy: entering 21st century global society. Prentice Hall, London

Chapter 43
Incorporating Small-Scale Farmers into Sustainable Supply Chains: A Case Study

Inma Borrella, Ruth Carrasco-Gallego, Carlos Mataix and Ramón Fisac

43.1 Introduction

Increased globalization and outsourcing are leading industries to compete at a supply chain level rather than holding out a traditional inter-firm competition (Seuring and Muller 2008; Andersen and Skjoett-Larsen 2009). In this context, a better informed society is increasingly demanding sustainability requirements to be incorporated in business decision making (Seuring et al. 2008). Different stakeholder groups, such as governments, workers, customers, non-governmental organizations and even shareholders, are exerting pressure to compel companies to act more responsibly towards the society and the environment. A responsible behavior is not only demanded within the firm's field of action but also along its entire supply chain (Lee and Kim 2009).

In the last few years, some companies with experience in the implementation of sustainability programs along their supply chains are exploring innovative ways to achieve social sustainability. One mechanism is to analyze how supply chains can contribute to poverty alleviation in developing countries. To give an example, Natura—a Brazilian cosmetics firm—has integrated indigenous communities as suppliers of innovative natural ingredients (Natura 2012).

This paper aims to enlighten through a case study how to articulate the incorporation of low-income producers into supply chains. It will be structured as follows: in Sect. 43.2, we present the results of a literature review focused on the social sustainability of supply chains and on how supply chain strategies can contribute to poverty alleviation. In Sect. 43.3, we introduce the case study

I. Borrella (✉) · R. Carrasco-Gallego · C. Mataix · R. Fisac
Grupo de Investigación en Organizaciones Sostenibles (GIOS), Escuela Técnica Superior de Ingeniería Industrial (Technical University of Madrid), C/ José Gutiérrez Abascal, 28006 Madrid, Spain
e-mail: inma.borrella@upm.es

J. C. Prado-Prado and J. García-Arca (eds.), *Annals of Industrial Engineering 2012*,
DOI: 10.1007/978-1-4471-5349-8_43,

research methodology adapted to this particular research work. Next, in Sect. 43.4, the results of the case study itself are related. Finally, concluding remarks and future research propositions form Sect. 43.5, the last section of this paper.

43.2 Literature Review

43.2.1 Social Sustainability in Supply Chains

Sustainability is constituted by three dimensions: economical sustainability, environmental sustainability and social sustainability (Elkington 1998). Research on supply chain sustainability has mainly focused on environmental issues, while the social aspects have remained largely unexplored. In previous stages of this research work, we conducted a review to determine to what extent social sustainability issues have been dealt with in supply chain literature (Borrella et al. 2012). Our study included the analysis of the last five special issues on sustainable supply chain management, published between 2007 and 2009 (International Journal of Production Economics 111 (2), International Journal of Production Research 45 (18–19), Journal of Operations Management 25 (6), Journal of Cleaner Production 16 (15), Supply Chain Management: An International Journal 14 (2)). In our analysis we found out that only 17 papers—out of a total of 71—made some kind of reference to social issues. From those 17, only 8 were directly centered in the so-called social issues of the supply chain. These papers were mainly focused on the implementation of Corporate Social Responsibility principles along the supply chain through standards and codes of conduct. Social issues in these papers were principally identified with the improvement of working conditions.

There is a call from the academic community to deepen the research on the social dimension of sustainability of supply chains (Carter and Rogers 2008; Seuring et al. 2008). This reveals that it is a field with a great potential for contributions from the academic point of view. Some concepts relating social sustainability and supply chains are currently emerging, such as: corporate social responsibility in supply chains (Pedersen 2009; Maloni and Brown 2006; Andersen and Skjoett-Larsen 2009), shared value (Porter and Kramer 2011), base or bottom of the pyramid business (Prahalad 2005; London and Hart 2004), societal lifecycle analysis (Matos and Hall 2007; Hutchins and Sutherland 2008; Hunkeler 2006), social footprint (Mcelroy et al. 2008) or poverty footprint (Clay 2005). This shows the increasing importance given to social sustainability issues by scholars, but it also underlines that the research on the area has been scattered and fragmented.

43.2.2 Alleviating Poverty Through BoP Strategies

Innovative strategies to fight poverty are being created at the interface between sustainable supply chain management, business strategy and international development spheres of knowledge. Both practitioners and academics are reaching common ground in the emerging social sustainability arena.

The majority of research in the BoP domain has focused on the way of serving consumers, and the capabilities ventures must develop to be successful in these mostly informal economies. Nonetheless some authors object this approach arguing that: (1) usually profitable BoP products are not socially beneficial and vice versa (Garrette and Karnani 2010); (2) the BoP market as defined by Prahalad includes the growing middle-class in developing countries, not only the poor (Jaiswal 2008); (3) the best way to fight poverty is focusing on the poor as producers, not as consumers (Karnani 2005); (4) very few companies are qualified to compete at the BoP market (Karamchandani et al. 2011).

43.3 Research Objectives and Methodology

The aim of this paper is to provide some insights into the following research question: "How could impoverished small-scale producers be effectively incorporated into supply chains?". To the best of our knowledge, very few studies on this subject have been developed from the supply chain domain. The only work we found in direct relation to this research line is the paper from Hall and Matos (2010).

The study presented here emerges from an ongoing research on social impacts of sustainable supply chains. The field of knowledge raised by this paper is not mature yet and very little empirical research has been done. This is the reason why using a case study approach was considered suitable. The objective of the case study is to understand the dynamics present in a particular setting: the participation on equal terms of impoverished Senegalese farmers in local vegetable supply chains. The unit of analysis of this case study is the Senegalese horticulture local supply chain: all the actors and functions that enable to move agricultural products from the fields to the local markets. An initiative of Manobi, a Senegalese firm whose activities aim to streamline the link between small-scale producers and local markets, motivated the research.

This case study was selected for theoretical and not statistical reasons. Enterprises dedicated to offer services that foster the integration of the poor as producers in supply chains are rare, so this case study is peculiar enough to be considered an "extreme situation" in which the process of interest is transparently observable (Eisenhardt 1989; Yin 2009).

Case study research is a theory-building approach deeply embedded in rich empirical data coming from a variety of data sources (Eisenhardt and Graebner 2007). Different data sources and methods were used in this research: documentation, archival records, interviews, direct observation and participant observation.

Two researches travelled to Senegal and stayed there for one month for data collection. We were involved in Manobi's activities related to the provision of services to farmers, carrying out a participant observation research.

During this stay, the researchers made nine visits to different local markets—both urban and rural—located either in Dakar or in villages of the Niayes region. During those visits, direct observation was applied, as well as interviews to various participants in the horticultural supply chain. A guided interview approach was followed, for the purpose of collecting the same general areas of information from each interviewee while allowing a certain degree of freedom and adaptability. Farmers attending the market, middlemen, market brokers, wholesalers, retailers and consumers were inquired. Semi-structured interviews were also carried out: one to Manobi's director and two to Manobi's responsible for the horticultural business area—one at the beginning of the stay and another before leaving. Additionally, three focus groups were organized: farmers cooperative of Kayar, farmers cooperative of Mboro and a group of independent farmers from the village of Darou Salam Thioune.

Internal documentation provided by Manobi was examined and its market prices database was analyzed, in order to find out what percentage of the final value was generally captured by each agent of the supply chain.

Impoverished farmers, and other actors in the supply chain who took part in the study, were selected by the researchers in order to ensure that representative samples of both clients and not clients of Manobi were included.

Validation of confidence of findings was addressed by using triangulation (Eisenhardt 1989; Lewis 1998). Multiple perspectives were also provided due to the participation of two researchers on this study, which generally reduces bias and provides complementary insights, enhancing the confidence on the findings. (Table 43.1).

The results obtained from this field work are presented in the following section.

Table 43.1 Sources of information and data collection methods used in this study (own development)

Data collection methods	Sources of information					
	Manobi	Farmers	Middlemen	Market brokers	Wholesalers	Retailers
Documents	*					
Archival records	*					
Interviews	*	*	*	*	*	*
Direct observation		*	*	*	*	*
Participant observation	*					

43.4 The Manobi Case: Integrating Impoverished Farmers in Senegalese Horticulture Supply Chains

43.4.1 Context

The horticulture sector in Senegal was responsible of the 17 % of the GDP in 2010 (World Bank 2012) and it is estimated that it provides work to a 35 % of the population. Small-scale farmers are responsible for most of the horticultural production in the country. This sector is quite disorganized, characterized by highly fluctuating prices, great vulnerability to imported products, inefficient links between the farming fields and the main local markets, complicated and expensive logistics and poor infrastructures. Many actors play different roles in the chain, but the structure is unclear and the coordination, weak, leading to a low efficiency of commercial transactions.

Manobi is a French Senegalese medium-sized company located in Dakar, the capital of Senegal. It is the first Senegalese operator of added-value services through mobile phone applications. Most of its services seek to facilitate professional activities in the primary sector: agriculture, fishing and poultry. Its client portfolio includes from big multinational companies to small-scale farmers. Manobi's purpose is to help professionals to improve their management abilities, reduce their operating costs and develop their business competitiveness.

43.4.2 Hindering Factors for the Incorporation of Small-Scale Farmers into Supply Chains

As a result of the field research carried out with Manobi, we identified a number of hindering factors that inhibit the incorporation of small-scale farmers in the Senegalese horticulture supply chain in equitable conditions. We have structured those barriers in four categories: information, production, credit and payment, and organization (Table 43.2).

All these difficulties have repercussions on the whole supply chain performance, but the biggest impacts fall on the weakest participants in the supply chain: the impoverished farmers. Their negotiating position is undermined and they become more vulnerable with regard to other supply chain agents.

Table 43.2 Main barriers faced by small-scale farmers in the Senegalese horticulture sector (own development)

Information	Uncertain price fluctuation
	Information distortion and lack of transparency
	Fast expiration of the information validity
Production	Low product quality
	Low efficiency of production
	Lack of conservation infrastructure
Finances	Cash-flow problems
	Payment inconsistency
	Difficult access to credit
Organization	Geographical dispersion of farmers
	Weak cooperative movement
	Scarce contractual relationships

43.4.3 ICT Solutions to Connect Farmers and Markets more Efficiently

Manobi was worried about the low percentage of the product final value that was captured by the farmers. From Manobi's point of view, growers were the ones supporting the highest risks and constraints—non-payment, crop failure, input procurement—and the lowest benefits. After doing some research, Manobi got to the following conclusion: the limited bargaining power of farmers was due to a lack of access to reliable current information on market prices.

In 2003, Manobi set out an information service consisting of a database fed daily by market pollsters and a diffusion mechanism through mobile phone technology. The aim of this service was to provide almost instantly objective up-to-date information about horticultural product prices in the main local markets.

Target customers for this service were impoverished farmers living in rural areas. Therefore, it was designed as a low-cost service, which could be activated under request—sending a text message. A little initial investment was required to receive the "start service pack", which included a cell-phone and some phone credit.

43.4.4 Results

The service was very successful. The platform reached 60.000 associated clients. Not only farmers were interested in Manobi's service, but also traders and middlemen, who could optimize their journeys and choose more efficiently the most profitable market to sell their products thanks to a better access to information.

Farmers improved their bargaining power but their income did not remarkably increase. The access to information made the system more transparent, but the existence of other deep structural problems, such as poor infrastructures—lack of proper warehouses, bad road links—or cash-flow problems, compel farmers to sell their products at a still low price to the middleman.

The service success lasted for a while, but after some years the number of active clients plummeted. We consider that this drop of demand was caused by the fast expansion of cell-phone access in Senegal. The penetration was of only 8 % when Manobi began offering its services in 2003, quickly growing to 27 % in 2006 and reaching 67 % in the year 2010 (World Bank 2012). In 2003, the lack of access to reliable up-to-date information was a big problem; but as the mobile phone sector grew, this difficulty disappeared. People working at the market became the main market information providers.

43.5 Conclusion and Further Research

Incorporating impoverished farmers into supply chains is a challenge. Supply chains in developing countries have a lot of failures, and the consequences of any malfunction affect more intensely the weakest agents. In this paper we have contributed to the literature on socially sustainable supply chains by presenting a case study that enlightens some of those challenges. Within the Manobi case, we have identified and classified the most important problems faced by small-scale farmers in the Senegalese horticultural supply chain. Manobi addressed one of those problems—information asymmetry—by providing a cheap information service through cell-phones. However, results were not as good as expected. A holistic approach is needed to address the constraints faced by smallholder farmers. Fair and transparent trading conditions should be guaranteed, as well as the production techniques and infrastructures improved, the architecture of the system strengthened and the access to credit and financial services facilitated.

Further research could deepen in the understanding of the barriers faced by impoverished communities to become solid empowered suppliers, explore the ways to overcome these difficulties, or research how to improve the performance of poor-inclusive supply chains.

References

Andersen M, Skjoett-Larsen T (2009) Corporate social responsibility in global supply chains. Supply Chain Manage: Int J 14(2):75–86

Borrella I, Carrasco-Gallego R, Moreno J, Mataix C (2012) Social issues in sustainable supply chain networks: state of the art and further research directions. In: 2012 Industrial Engineering Research Conference (IERC). (Accepted Mar 2012)

Carter CR, Rogers DS (2008) A framework of sustainable supply chain management: moving toward new theory. Int J Phys Distrib Logistics Manage 38(5):360–387

Clay JW (2005) Exploring the links between international business and poverty reduction: a case study of Unilever in Indonesia. Oxfam GB, Novib Oxfam Netherlands and Unilever

Eisenhardt KM (1989) Building theories from case study research. Acad Manag Rev 14(4):532–550
Eisenhardt KM, Graebner ME (2007) Theory building from cases: opportunities and challenges. Acad Manag J 50(1):25–32
Elkington J (1998) Cannibals with forks: The triple bottom line of sustainability. New Society Publishers, Gabriola Island
Garrette B, Karnani A (2010) Challenges in marketing socially useful goods to the poor. California Management Review
Hall J, Matos S (2010) Incorporating impoverished communities in sustainable supply chains. Int J Phys Distrib Logistics Manage 40(1/2):124–147
Hunkeler D (2006) Societal LCA methodology and case study. Int J Life Cycle Assesment 11(6):371–382
Hutchins MJ, Sutherland JW (2008) An exploration of measures of social sustainability and their application to supply chain decisions. J Cleaner Prod 16(15):1688–1698
Jaiswal A (2008) The fortune at the bottom or the middle of the pyramid? Innov: Technol, Governance, Globalization
Karamchandani A, Kubzansky M, Lalwani N (2011) Is the bottom of the pyramid really for you? Harvard Bus Rev
Karnani A (2005) Misfortune at the bottom of the pyramid. Greener Manage Int 51:99
Lee K-H, Kim J-W (2009) Current status of CSR in the realm of supply management: the case of the Korean electronics industry. Supply Chain Manage: Int J 14(2):138–148
Lewis M (1998) Iterative triangulation: a theory development process using existing case studies. J Oper Manage 16(4):455–469
London T, Hart SL (2004) Reinventing strategies for emerging markets: beyond the transnational model. J Int Bus Stud 35(5):350–370
Maloni MJ, Brown ME (2006) Corporate social responsibility in the supply chain: an application in the food industry. J Bus Ethics 68(1):35–52
Matos S, Hall J (2007) Integrating sustainable development in the supply chain: the case of life cycle assessment in oil and gas and agricultural biotechnology. J Oper Manage 25(6):1083–1102
Mcelroy MW, Jorna RJ, Engelen JV (2008) Sustainability quotients and the social footprint. Corp Soc Responsib Environ Manage 234:223–234
Natura (2012) http://www.natura.net (Accessed Feb 23, 2012)
Pedersen ER (2009) The many and the few: rounding up the SMEs that manage CSR in the supply chain. Supply Chain Manage: Int J 14(2):109–116
Porter ME, Kramer MR (2011) The big idea: creating shared value. Harvard Bus Rev 89(1–2)
Prahalad C (2005) The fortune at the bottom of the pyramid. Pearson Education/Wharton School Publishing, New Dheli
Prahalad CK, Hammond A (2002) Serving the world' s poor, profitably. Harvard Bus Rev
Prahalad CK, Hart SL (2002) The Fortune at the bottom of the pyramid. Strategy+Business (26)
Seuring S, Muller M (2008) From a literature review to a conceptual framework for sustainable supply chain management. J Cleaner Prod 16(15):1699–1710
Seuring S et al (2008) Sustainability and supply chain management: an introduction to the special issue. J Cleaner Prod 16(15):1545–1551
Yin RK (2009) Case study research: design and methods, 4th edn. Sage Publications Ltd, Beverley Hills, CA
World Bank (2012) http://data.worldbank.org (Accessed Feb 23, 2012)