Development of a Decision Support Model for Managing Supply Chain Design Problems in Global Service Supply Chains

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Abstract. Most large service manufacturing companies outsource support as well as core activities to remain competitive in a globalized economy. Managers are faced with a complex decision problem as they must find a balance between maximizing the benefit from business process outsourcing while keeping risk as low possible. Many outsourcing initiatives failed in the past. Research suggests that one of the main reasons is poor decision making with an insufficient regard of all relevant factors, especially qualitative ones. We look at the problem from a supply chain design perspective and further develop the application of decision support methods originally developed with a focus on product manufacturing, to the manufacturing of services. We review existing approaches and develop our own conceptual decision framework.

Keywords: Decision support · Supply chain design · Business processes · Outsourcing · Service supply chain

1 Introduction

Large-scale global outsourcing emerged in manufacturing after world war two, continued through information technology and now becomes increasingly prevalent for business processes [1], particularly in service industries [2]. Global supply chain management emphasizes the management of globally dispersed supply chains that emerge from such outsourcing and offshoring activities. Managers need to decide how to organize cooperation between different entities and where to locate which parts of the supply chain. Global supply chain design decisions are highly complex as they are characterized by conflicting goals and a vast number of heterogeneous input factors.

A good understanding of decision problems and decision support tools is crucial to the success of Business Process Outsourcing BPO in global supply chains. Businesses tend to underestimate the impact of outsourcing and offshoring decisions and often base their decisions on simplistic quantitative considerations, mainly cost [3]. In contrast, qualitative criteria are often ignored, even though they have been found to be more important than quantitative ones [4] – possibly because quantitative information is easier to handle, whereas processing qualitative factors requires special know-how and sophisticated analysis tools. It is thus no surprise that recently the terms "reshoring"

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and "backshoring" gained prominence. Srai and Ane [5] found that the most common reason for backshoring are quality concerns, supporting the notion that backshoring decisions are usually not long-term adjustments to changed conditions in the business environment, but rather costly short-term corrections of poor offshoring decisions – often due to insufficient consideration of qualitative factors [3].

Mani, Barua and Whinston [6] found that the success of business process network design correlates with the performance of information systems used by a company. Ellram et al. [2] found that the extent by which service companies engage in BPO to gain competitive advantage correlates with the usage of decision tools to control these operations. An improvement of decision support tools and higher degree of usage by managers could have a significantly positive effect on the performance of service companies. Johnston [7] suggests that service research should be integrated with operations management to develop new methods to improve performance and efficiency of service supply chains.

The purpose of our research is to explore how mathematical optimization methods from the Operations Management domain that were developed with a product manufacturing focus can be employed in a services context to solve global supply chain (network) design problems that arise in BPO. This paper addresses the following research question: "How can existing supply chain management optimization methods be enhanced and adapted to create an effective and easy to use decision support tool for global business process outsourcing in service industries?"

In this paper we propose the development of a decision support model that consists of three well-established methods combined in an innovative way. We start with a short literature review of similar studies in the service supply chain context, and bring out the gaps. We then lay out the design of a new decision support framework and finally conclude with proposed steps for further model development, including application and validation.

2 Literature Review

There is some literature related to the use of decision analysis in service supply chains with a focus on the design of business process networks. However, it does not cover the complexity of the decision analysis in its entirety.

Iannou, Karakerezis and Mavri [8] created a linear programming model to optimize performance of a banking network. The model decides on the number and location of branches as well as on the range of services offered by each. Their approach gives a precise mathematical solution to the network design problem as it clearly states which branches to open where and with what service offering. It thus integrates facility location, service selection and capacity allocation. However, it has some limitations. The model conducts a single objective optimization and offers no possibility for trade-offs. It only measures "overall performance" instead of financial indicators such as maximum profit, which would potentially make the results more convincing to managers. It also only incorporates quantitative performance indicators and does not include qualitative information.

Piplani and Saraswat [9] created a mixed-integer linear programming model to minimize cost in a multinational reverse-logistics network offering repair and refurbishment services for electronic devices. The model covers the entire value chain of activities from return, over repair and refurbishment to re-selling or disposal. It decides on locations for each activity based on cost factors as well as service demand and market price for refurbished products. It contains multiple stages and several possible product flows – devices can be re-sold, sent back to the customer, or disposed of. Just as the prior model however it is a single-objective approach and despite covering an explicitly global problem, it does not include any factors related to transnational complexity, such as worker skill, language or communication.

Henao et al. [10] developed a mixed-integer linear programming tool that addresses the problem of variability and seasonality. Employees are hired long-term and paid continuously, while demand for their specific skill set is often volatile. The program minimizes total personnel cost by deciding on the optimum set of skills that each employee is taught. Total cost is comprised of training cost, cost of employee shortage as opportunity cost of lost sales and cost of employee surplus as idle work hours. Each employee has a fixed time capacity that is allocated to serve demand in the departments they are trained for. This model is a straightforward "translation" of the classic capacitated production allocation problem from product to the service manufacturing sector. Just as the previous two approaches it only includes a single objective and does not consider any qualitative factors.

Several similar approaches that employ mathematical optimization methods from SCM to business process network design exist. However, none of these include multiple objectives or consider qualitative information, neither do they provide visualizations or show different options and trade-offs.

Research of Schuff et al. [11] among pioneers of the decision support domain shows a general disappointment about how little acceptance their tools receive in business. They conclude that decision support systems must become more transparent, visual, interactive and usable. The systems perceived as the most effective by managers are transparent regarding their underlying mechanisms and allow to explore the entire decision space, instead of only delivering a single, presumably optimum solution. As business complexity increases, data visualization becomes more important. Furthermore, systems must become more interactive and involve the users in their design and setup [11]. In the next section we will propose the development of a decision support framework for global business process network design that includes abovementioned features.

3 Model Development

3.1 Introduction

We recognize the challenge to design decision support tools and information systems suited to solving BPO problems. We look at the task from an SCM point of view that is traditionally focused on quantitative optimization methods. We consider business processes as value chains for non-physical goods. A request triggers the creation of a "case", which is passed on and worked upon throughout a chain of back office activities until it is ready and creates value for the customer.

These back-office tasks do not depend on a specific location and require no direct customer interaction. Thus, they are potential candidates for offshoring and outsourcing. At the same time, claims processing is regarded as the traditional "moment of truth" in any client relationship. It is essential to perform it at the highest quality level to not jeopardize customer satisfaction.

Managers must design business process networks to supply the customer with the combined efforts of multiple actors. On a tactical level, they must decide which resource delivers what service at which place and time to whom. On a strategic level, they must figure out how to leverage the opportunities provided by globalization to design their business process network to be as cost-efficient as possible, yet keep quality standards high. They need to find a balance between maximizing value by leveraging the expected benefits of offshoring and minimizing risk by mitigating its possible downsides [12]. Such decision problem is complex as it includes conflicting goals and requires dealing with a magnitude of quantitative and qualitative factors as well as decision and information variables.

3.2 Basic Setup

The design of the decision support framework is now laid out. It shall give a precise mathematical solution to a global business process network design problem by allocating process activities to different locations and calculating the total network cost. It should also act as a decision support tool in the literal sense by making transparent the trade-off between risks and benefits, considering all relevant quantitative and qualitative information and calculating the entire range of efficient outcomes. Managers should be able to discuss and select their preferred configuration based on their expertise and strategy.

We assume three different back office processes which are triggered by customer demand. Which activities are required to be performed and how many minutes the activity takes on average, depends on the process. From the past we know an expected demand for each process and thus also the demand for each activity. We also know the average duration per activity and process. We now need to assign this demand to a set of possible locations. These include the headquarters as well as third-party shared service centers. The locations differ in costs, which include variable costs per time unit, including wages and taxes, assumed collaboration and friction costs which are incurred if an unfinished case is moved from one location to another for the next activity, fixed costs that are incurred if a location is used at all and activity set-up costs which are incurred if a location is to offer a certain activity, for example for software licenses and employee training.

The set-up is similar to a logistics network problem from SCM, but instead of an unfinished product being transported through production facilities, a case is routed via arches through shared services centers that perform a range of activities (Fig. 1).

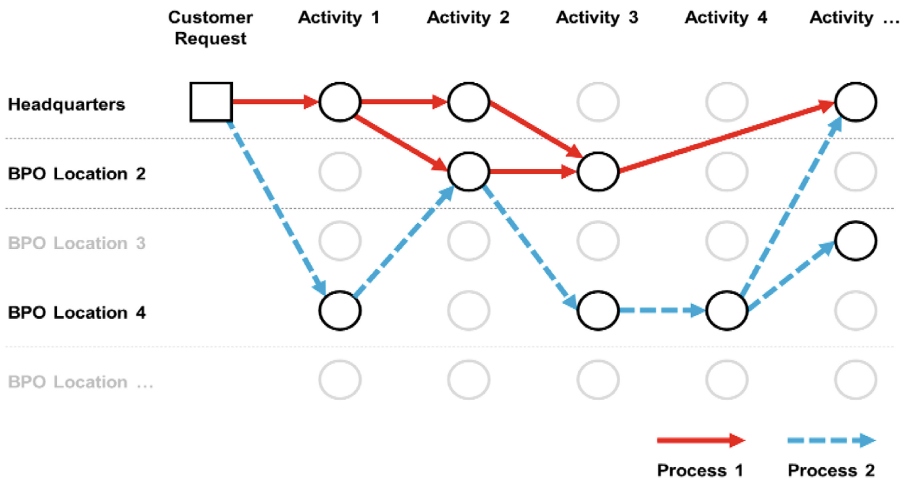

Fig. 1. Basic structure of our problem

Our framework is based on a mixed-integer linear programming (MILP) model. This method allows us to precisely depict and solve a complex network design problem. The target function reflects our first goal, minimizing cost through cross-border labor arbitrage. Our second goal, risk minimization is reflected by another method, the analytical hierarchy process (AHP) of Saaty [13]. The AHP allows us to incorporate qualitative information to describe and rate all relevant risk factors. It has no limitations regarding data types. Qualitative and quantitative information can be assessed simultaneously. Its result is a risk score for each possible location.

The AHP score is integrated as a soft constraint into the MILP and gradually raised. This way the program calculates all efficient trade-offs between cost and risk. All trade-offs connected form the Pareto frontier, which represents the range of efficient solutions to a multi-objective decision problem. Managers can use the Pareto frontier to discuss the relationship between cost and risk. They can conduct sensitivity and scenario analysis. And most important, managers can now see the entire solution space, based on which they can discuss and select the network configuration best suited to their corporate strategy. Below we will describe the model in detail (Fig. 2).

3.3 The Mixed-Integer Linear Program (MILP)

$$min[\sum_{p,a,l} X_{p,a",l"} * T_{p,a} * \frac{W_{a,l}}{60} + \sum_{p,a,l} X_{p,a',a",l',l"} * C_{l'l"} + \sum_{a,l} Y_{a,l} * Act_{a,l} + \sum_{l} Y_l * Fix_l] \quad (1)$$

Fig. 2. The MILP target function

The target function minimizes the sum of all four cost types. The first is labor costs, described by the instances of all activities performed for all processes in all locations, multiplied by the duration of each activity per process and the wage costs in the location it is performed in. The second type is collaboration costs that are incurred when a case is moved from one location to another. This can include any friction such as time loss or need for increased managerial effort. The estimated friction cost per case that is moved from one location to another is multiplied by the number of cases moved between these locations across all activities and processes. The third element is the activity setup cost which is incurred whenever a location is offering capacity for a certain activity. The last element is the fixed location cost which is incurred whenever a location offers any capacity at all (Table 1).

Table 1. Sets and parameters

Item	Description
P	Processes
A	Activities
L	Locations
a′	Previous activity (upstream)
a″	Subsequent activity (downstream)
l′	Location of previous activity
l″	Location of subsequent activity
D (p, a)	Demand D of instances of activity a performed in process p
K (a, l)	Maximum capacity K in minutes of location l to perform activity a
X (p, a″, l″)	Instances X of activity a performed in location l for process p
W (a, l)	Hourly wage W for activity a in location l
T (p, a)	Time in minutes T required for activity a in process p
C (l′, l″)	Collaboration cost C when moving a case from location l′ downstream next to location l″
Act (a, l)	Setup cost for activity a in location l
Fix (l)	Fixed cost for location l
RISK (l)	Risk associated with outsourcing business processes to location l reflected as an AHP preference score (the lower the score, the higher the risk)

$$\sum_{l} X_{p,a,l} = \mathrm{D}_{\mathrm{p,a}} \tag{2}$$

$$\sum_{p} X_{p,a,l} * T_{p,a} \leq \mathrm{K}_{\mathrm{a,l}} \tag{3}$$

$$X_{p,a',l'} = \sum_{l} X_{p,a'',l''} \tag{4}$$

$$Y_l * M - \sum\nolimits_{p,a} X_{p,a'',l''} \geq 0 \tag{5}$$

$$Y_{a,l} * M - \sum\nolimits_{p} X_{p,a'',l''} \geq 0 \tag{6}$$

$$\forall X_{p,a',a'',l',l''} \in N \tag{7}$$

$$\forall Y_{a,l} \in \{0, 1\} \tag{8}$$

$$\forall Y_l \in \{0, 1\} \tag{9}$$

Constraint (2) ensures that all demand D of activity a for process p is satisfied in any of the locations l. Constraint (3) ensures that the working time capacity of location l for activity a is not exceeded. Constraint (4) requires all instances of a process worked on in a location to be passed on to any location for the next activity, if there is one. Constraint (5) ensures that if a location is to accommodate any activity, the binary Variable Y(l) must be set to 1, incurring the fixed costs for this location. Constraint (6) does the same for enabling a location to offer a certain activity, incurring an activity setup cost. Constraint (7) requires the decision variable X to be a positive integer, while constraints (8) and (9) require decision variables Y to be binary.

3.4 The Analytical Hierarchy Process (AHP)

The AHP is used to assess all risk factors related to offshoring and outsourcing activities. The decision criteria should be selected and hierarchically arranged in collaboration with the decision-maker to make sure that the risk assessment reflects the characteristics of the specific problem, industry and environment. We looked at existing AHP applications in the BPO context [14, 15], to create an exemplary AHP. Such model could also be used as the initial basis for discussion with decision-makers in an actual application. It is depicted in Fig. 3. We are aware that these factors might to some extent be overlapping and interrelated. We also assume that the individual risk level per location is independent of the designed network and thus disregard scale effects or learning. Therefore, we do not assume any correlation between capacity allocated to a certain location and its risk factor.

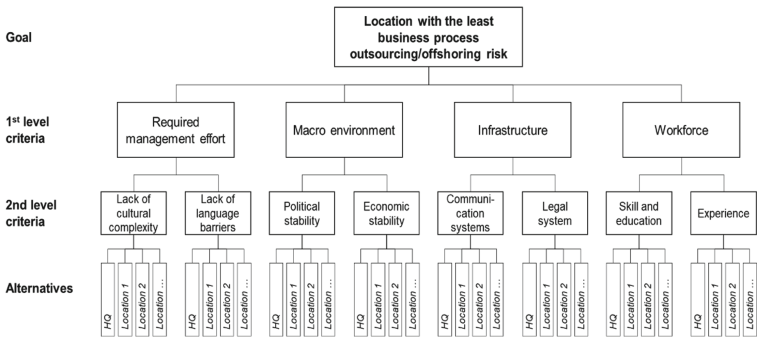

Fig. 3. An exemplary AHP describing outsourcing/offshoring risk

After having selected and hierarchically arranged the criteria, the AHP is conducted together with the managers. First the individual importance of risk criteria and their parent criteria is determined through pairwise comparison of items on the same hierarchical level. Then each alternative is compared to all other alternatives regarding all lowest-raking risk factors. The AHP requires expertise on how each decision alternative performs regarding each criterion. In larger organizations this knowledge is widely dispersed. Thus, prior to the AHP it is necessary to gather this data and prepare it for managers to get a holistic picture. Only then managers can make informed judgements. An alternative to this sequential approach is to directly involve a wide range of experts by using group-AHP techniques [16]. After the pairwise comparisons are made, the individual AHP preference score can be calculated for each location.

3.5 Integrating AHP and MILP to Calculate the Pareto Frontier

The AHP score is integrated into the MILP by calculating the overall network-wide AHP risk score weighted by activity throughput. The greater share a location takes of the overall work performed, the higher is the impact of its individual risk score on the network's overall risk score. After having calculated the initial minimum cost solution, we gradually raise our desired risk score "Risk Target" as a soft constraint for the cost minimization, until the highest possible AHP score is reached, representing the solution with the minimum risk and highest cost, given the constraints (Fig. 4).

$$Risk\ Target \leq \frac{\sum_{pa,l} RISK_l * X_{p,a",l"} * T_{p,a}}{\sum_{pa,l} X_{p,a",l"} * T_{p,a}} \tag{10}$$

Fig. 4. Soft constraint to integrate AHP score into the MILP

All solutions representing trade-offs between benefit and risk are visualized on a Pareto front. Decision makers can now see, discuss and select their preferred configuration (Fig. 5).

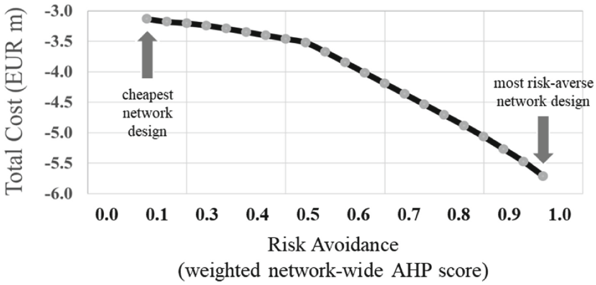

Fig. 5. The Pareto frontier (exemplary)

4 Conclusion

Decision support tools should be made easy to use and understand, otherwise adoption rates and acceptance by managers remain low. There is great potential in improving existing model-based decision support methods to make them more effective and increase their usage and acceptance in practice. Special focus should be put on usability and transparency, while at the same time keeping the underlying techniques as simple as possible.

This paper has proposed the design of an SCM decision support framework for service industries. It is constructed to support strategic process outsourcing design decisions with a time horizon of several years. We believe that it can be developed into an effective tool to improve decision-making in global BPO problems. It gives a precise solution to the network configuration problem while incorporating conflicting goals as well as quantitative and qualitative data. It is based on three well-established methods combined in a new way. Compared to existing methods to merge linear programming and AHP, the Pareto frontier approach does not attempt to calculate one single presumably optimum solution, but instead creates transparency over the full range of efficient trade-offs. This way managers can use the result as the base for discussion and select a configuration that fits their strategic goals.

As the next step, we will test our conceptual model on a real-life business process outsourcing problem. This will help us test our assumptions of decision support performance criteria, as well as the effectiveness of the approach itself.

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