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A holistic model for understanding the dynamics of outsourcing

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ABSTRACT

Outsourcing is a complex process as many external and internal factors that look convincing in the first place might, however, lead to a failure in the long run. Motivated by this, we wanted to get a holistic understanding of such outsourcing decisions. Thus, we created a comprehensive System Dynamics simulation model including all relevant variables to examine the dynamic nature of outsourcing in a holistic manner and over time that consists of more than 200 interrelated variables. Our results show, amongst others, that higher process specialisation that requires substantial investments by the supplier appears to be favourable for an outsourcing company and shifting a larger quantity to such a supplier achieves better cost savings and thus accounts for a better overall outsourcing result. On an operational level, we identified an innovation trap, a bargaining power shift, a plagiarism trap, and a knowledge trap. Based on that, we give specific managerial recommendations to tackles these aspects. We conclude that, amongst others, it is important for innovative companies with rather complex processes and parts to carefully plan which and how many employees to release so as not to lose the knowledge on those outsourced processes and parts.

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Outsourcing; dual sourcing; simulation; system dynamics; decision

1. Introduction

Outsourcing is an agreement between two companies where one company hires another one to be responsible for the planned or existing activity that is or could be done internally.

The process of outsourcing first started with the outsourcing of assembly in the late 1960s. This was later followed by the outsourcing of manufacturing in the mid-1980s, of design in the 1990s, and of information technology in the 2000s (Antelo and Bru 2010; Dolgui and Proth 2013). Research and development closely followed that of information technology (Appiah-Adu, Okpattah, and Djokoto 2016).

On the bases of globalisation and world connectivity, outsourcing has become an inevitable requirement for an efficient and cheap manufacturing (Berger and Lewis 2011). Outsourcing, also referred to as strategic sourcing, is nowadays a globally adopted practice in most of the industrial sectors (Venkatasesha 2014). It is becoming a standard and well-established approach for companies to strategically manage materials in an ever-changing business environment (PRG 2020).

There are publications dedicated for defining outsourcing as 'divesting resources and capabilities applicable to perform value-creating activities as other firms can perform them better' (Espino-Rodriguez and Padrón-Robaina 2006, 52), or even as sourcing 'non-strategic activities or business processes necessary for the manufacture of goods or the provision of services' from 'higher capability firms' (Baraldi et al. 2014, 554). While some authors, such as von Hartmann and Bengtsson (2015), Agrawal et al. (2016) and McCarthy and Anagnostou (2004), define the outsourcing process as hiring a supplier to conduct an activity that was earlier performed by the company itself, Lysons and Farrington (2006) describes outsourcing from a process-oriented perspective as a sequence of identifying, selecting, and developing suppliers. Furthermore, Farrington emphasises the significance of outsourcing by stating that focusing on manufacturing means learning how not to make parts that suppliers can make more efficiently and that divert a company from cultivating its own core skills.

All in all, whether we choose to call it 'one of the most noticeable global economic trends' (Appiah-Adu, Okpattah, and Djokoto 2016, 31) or 'one of the most popular operation strategies' (Gunasekaran et al. 2015, 1081), it is safe to say that outsourcing is 'more than a "yes" or "no" decision with a multitude of hybrid alternatives' (Arnold 2000, 29) and that it is a decision which opens up at

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least one further decision in a market-based relationship (Baraldi et al. 2014).

There are numerous contributions on the positive effects of outsourcing that will be discussed in the next section. However, those upsides of outsourcing may be threatened due to market-, country-, or industry-related changes (e.g. Canham and Hamilton 2013) which may even lead to reshoring (Baraldi et al. 2018). Research about such kind of reshoring shows that rising costs, poor product quality, and scarcity of skilled human resources in the host country are the driving forces of reshoring (Foerstl, Kirchoff, and Bals 2016; Fratocchi et al. 2016; Stentoft et al. 2016). So, it is of interest to understand the reasons behind these obviously failed outsourcing endeavours.

Currently, there is no comprehensive model available to understand the long-term dynamic effects of outsourcing decision. There are several conceptual works based on theoretical frameworks, though, e.g. on transaction cost economics (see e.g. Dedrick and Kraemer 2010), resource-based view (see e.g. Kenyon, Meixell, and Westfall 2016), relational view theory (e.g. Halldorsson and Skjott-Larsen 2006), evolutionary economics (e.g. Mirani 2006), incomplete contracts theory (e.g. Aubert, Rivard, and Patry 1996), agency theory (e.g. Barthélemy 2003), knowledge-based view (e.g. Pati and Desai 2005), social exchange theory (e.g. Whitten and Wakefield 2006), or on the combination of those frameworks (see e.g. McIvor 2008). Furthermore, empirical analyses in the form of case studies (see e.g. Freytag, Clarke, and Evald 2012; Baraldi et al. 2018; Magnani, Zucchella, and Strange 2019) also do not give a full overview. Thus, a comprehensive model that takes into account all relevant factors discussed to fully understand the extent and the long-term dynamic impact of outsourcing decisions would be highly beneficial.

We do not consider all types of outsourcing activities, but rather those where an innovation-driven company decides to outsource a rather complex part or a component that it used to manufacture in-house that are deeper than transactional relations. Gilley and Rasheed (2000) refer to this kind of outsourcing as substitution-based outsourcing. More general, this can be seen as strategic outsourcing, although Holcomb and Hitt (2007) see this as its simplest form. Developing a framework that combines both transaction-based and resource-based view, they regard strategic outsourcing as relying on specialised capabilities that supplement the outsourcing firm's existing capabilities deployed along its value chain that creates additional value which goes beyond cost economies. Examples for strategic outsourcing are business functions, such as manufacturing, logistics, facilities management, research and development, engineering design, or customer support, which highly specialised companies emerged on the market for.

In outsourcing complex parts, it is necessary to understand complexity first. In general, complexity is divided into structural and functional complexity (Braha and Maimon 1998; Deshmukh, Talavage, and Barash 1998; Rodriguez-Toro et al. 2003), where the former is a function of the quantity of information of the system's internal structure and the latter refers to information to specify the intended structure function and goals. Relating to the complexity of parts, products, or components, ElMaraghy and Urbanic (2003) define this kind of complexity by introducing a corresponding index that is a function of the product information entropy. They also define product complexity elements, such as material, design (i.e. three-dimensional designs with special features like undercuts, hollow spaces, or intricate internal structures), specifications (dimensions, tolerances, geometry, etc.) and components. Against the backdrop of outsourcing, they highlight the process complexity as also important. They define it as a function of product design, volume requirements, and work environment.

Given this complexity, resulting outsourcing-related implications are the following that need to be taken into account when developing a novel model to better understand the dynamics and long-term implications of outsourcing decisions to reach and maintain the required quality level:

- supplier (and supplier's resource and talent) development that is a long-term and resource-consuming activity requiring commitment from both sides (Talluri, Narasimhan, and Chung 2010)
- high and specific investments in setting up the partnership
- higher level of communication and information sharing
- shift of innovation potential and bargaining power (to the supplier)

Such a comprehensive model offers a two-fold managerial contribution. First, by using the developed and validated model we conducted several experiments to recommend a strategical approach for obtaining profitable outsourcing activity and we show the key determinants to be considered in order to have a successful outsourcing relation. Second, practitioners may use this model for their own decision-making process. It will be possible to understand the implications of outsourcing a certain component to a certain supplier and to observe the change of important decision-related parameters over time. Additionally, relevant variables that have a major effect on the success can be identified which then can be

seen as action items to be closely monitored or tackled in order to avoid pitfalls. Thus, our model is supportive not only in decision-making but also in improving the relationship so as to get the most out of the outsourcing-based relation.

The contribution to the research field on outsourcing can be seen in its holistic and generic approach that puts all relevant variables related to an outsourcing endeavour, not only quantitative but also qualitative ones, in a causal and time-related dependency and relation. Here, due to the abovementioned consideration of complex parts, we especially added long-term effects of mainly qualitative variables, such as bargaining power, innovation potential, etc., as they are generally overlooked in existing models or are discussed theoretically in literature. Additionally, contrary to existing models that are based on static initial assumptions which however are subject to changes once the relationship is built, our model considers the change of those variables over time through their reinforcing or balancing interdependencies.

In addition to that, our model may also contribute to further research. It helps to identify the effects of outsourcing decisions under different conditions, especially success, failure, and weaknesses, that fellow scholars can then identify and address to further develop the existing body of knowledge on outsourcing.

Against the backdrop of this, the main objective of this paper is to understand the dynamics of outsourcing by considering all relevant aspects with their interdependencies and evolution over time. For this, we developed a comprehensive simulation model that will help to understand the long-term effects and risks of such strategic decisions for different cases. To do so, we considered the dynamic nature of the outsourcing activity by defining all relevant variables, be it quantitative or qualitative, that are critical for the success of an outsourcing activity to answer the question under which circumstances it is preferable to outsource both in short and long run perspectives. To this end, we analyse the peculiarities and effects not only of single but also of dual sourcing.

The theoretical fundament for this paper was created by first analysing existing contributions in literature. Afterwards, a comprehensive System Dynamics simulation model was created and calibrated. The simulation is checked for validity using real outsourcing data and results obtained from a global first-tier automotive supplier. Together with a number of tradeoffs, important variables are determined which will drastically improve the decision-making process during outsourcing. We further examine the outcomes of sourcing strategy decision-making for multiple company profiles through stochastic experiments, such as Monte Carlo simulations and optimisation experiments, deriving the most feasible and productive strategy for maximising company profitability. Eventually, the results from the simulation runs are then used to develop recommendations for company managers.

2. Literature review

In literature, we find model-based contributions aiming at conducting comprehensive outsourcing simulations on the one hand, and more descriptive contributions and models discussing the advantages and shortcomings of outsourcing decisions. These contributions serve as the theoretical foundation for our developed model.

2.1. Advantages and disadvantages of outsourcing

Among the rather theoretical and descriptive works on the upsides and downsides of outsourcing, Dabhilkar et al. (2009) outline many reasons and motivations for outsourcing activities that mainly fall under five categories: the desire to save costs, the need to focus on core competencies and more important business functions, the need for better quality, the pressure to increase responsiveness, and the lack of enough in-house innovation capability. Especially the first three aspects are broadly discussed in literature, as can be seen in the followings.

Kimura (2002) argues that one of the biggest arguments in favour of outsourcing is cost reduction. This is in line with the transaction cost theory that sees the main argument to outsource in economising motives (Grover and Malhotra 2003). By outsourcing processes to suppliers who specialise in them and who have several clients, firms take advantage of the economies of scale of their suppliers and consequently are able to save more than before. Jayaram and Tan (2010), for example, claim that logistics outsourcing can significantly reduce logistics costs, logistics fixed assets, and inventory. Additionally, Lo (2014) argues that outsourcing R&D leads to savings in product development costs and organisational costs.

Another argument stresses the fact of focusing on core competencies (see e.g. Besenfelder, Kaczmarek, and Uygun 2013). This is in line with the resource-based view. Bustinza, Arias-Aranda, and Gutierrez-Gutierrez (2010) hint at the fact that outsourcing is a strategic tool for focusing the company's resources on things that the competition cannot copy. So, more effectively integrating and using resources may increase inventory turns, shorten product development cycles, and reduce the time-to-market for new products (Petersen, Handfield, and Ragatz 2005). Furthermore, complementary resources also contribute to economies of scale, enhancing responsiveness and innovative potential, increasing quality, and improving firm's scope of capabilities

by uniquely combining complementary capabilities of specialists on the market (Holcomb and Hitt 2007). Appiah-Adu, Okpattah, and Djokoto (2016) adds that outsourcing serves to minimise risks while simultaneously maximising returns as the company focuses only on those things that they can do better than the competition.

Interestingly, some authors (e.g. Hoetker 2005) claim that capability considerations in the resource-based view trade-off with cost-based considerations in the transaction-based view, whereas others (e.g. Madhok 2002; Holcomb and Hitt 2007) claim that those concepts are complementary and support each other.

Haoues et al. (2013) further claim that outsourcing increases the flexibility of the company. With outsourced processes and, correspondingly, only a few assets, firms can better respond to demand instabilities. Appropriate outsourcing can reduce lead times, increase flexibility, and ultimately render an organisation more competitive.

Based on an empirical study, Asatiani, Penttinen, and Kumar (2019) found that cost reduction, focus on core competences and process improvements are the motivational factors that lead to outsourcing of business processes and functions to a larger degree (i.e. whole processes), and companies that outsource mainly to acquire external expertise outsource only a limited number of processes within a specific business function.

Although outsourcing is largely seen in a good light, it is important to note that there exist publications which do not speak in favour of outsourcing. It is seen as a very complex process as many external and internal factors that look convincing in the first place might, however, lead to a failure in the long run. Even if the supplier is reliable and all the planning was done accurately, many things can go in the wrong direction. Many companies getting satisfying services and products from their suppliers in the first place have returned to in-house production after the failure or inefficiency of the outsourcing activity (Ishizaka and Blakiston 2012). According to Agrawal et al. (2016) outsourcing leads to lower performance since it can also lead to unexpected higher costs resulting from problems with the chosen suppliers and from increases in process complexity. So, firms have a strong tendency to underestimate the costs related to managing the outsourcing process.

To mediate such downsides, Gopalakrishnan and Zhang (2019) propose vendor certification. They conclude that although such certification may directly help supplier growth, it however may damage supplier innovation due to strict terms and rules to be followed. This indirectly hinders their growth and innovation potential.

According to Beasley, Bradford, and Dehning (2009) another problem arises with focal firms. In most cases the clients' requirements demand specific investments whereas vendors/suppliers might insist on long-term contracts for security purposes. Should problems arise long before these long-term contracts run out, focal firms might find themselves imprisoned by a supplier with whom they are failing to realise the expected performance levels. In such a case, additional unforeseen or hidden costs in the form of early cancellation costs will arise if the focal firm attempts to exit the relationship and start a business with another supplier. Additional problem with focal firms may arise because of poor ethical choices by their vendors (e.g. children labour). Hsu, Liou, and Chuang (2013) list other reasons, such as labour union issues, employee morale problem, and cultural misunderstandings. Outsourcing does have attractive promises, but the fact that it usually comes with unexpected and hidden costs and complexities cannot be ignored.

With such mixed results, it becomes important to assess the reasons for both success and failure in outsourcing simultaneously. To provide clarification, some authors have made the step of pinpointing the determinants of success in outsourcing relationships. Additionally, some major determinants of success or failure in outsourcing projects are proposed as well. Antelo and Bru (2010) argue that an outsourcing project is already either a failure or a success right from the beginning, because of the critical nature of the cost–benefit analysis in the make-or-buy decision. Putting too much emphasis on cost saving, especially through offshoring to developing countries while neglecting the design execution and evaluation of the organisational aspects may lead to disaster. Communication between both parties during the outsourcing relationship has also been given much credit for being the decisive factor for the outcome. Hansen and Rasmussen (2013) state that other parameters, such as the impact on other operations and the degree of alignment of both parties on long-term goals, must be considered in addition to external and environmental factors.

All those works are rather descriptive, and the results are mainly based on observations and case studies. For this paper, we considered all the pros and cons of outsourcing in those rather descriptive contributions. They serve as a theoretical foundation for the development of the variables and feedback loops of our model.

2.2. Simulation-based approaches for outsourcing

Among the model-based approaches, McCray and Clark Jr (1999) were the firsts to analyse in a rather comprehensive way the factors impacting and the consequences of outsourcing IT services by addressing the complex interactions between endogenous and exogenous organisational variables involved in the information

system function of business organisations. Their System Dynamics based model is useful as a tool for analysing the current information system function of an actual company or for exploring various outsourcing options. They conclude that the success of the outsourcing alliance is heavily dependent upon management policies. Outsourcing of IT services has a profound impact upon the information system service levels in terms of decreasing ability to respond to changes in the marketplace.

Dutta and Roy (2005) also examined outsourcing of IT services with a focus on the growth pattern of offshoring by means of System Dynamics. They built a two-country simulation model of offshoring growth and show how the dynamic behaviour of offshoring is likely to evolve beyond the current high-growth period, thus, offering a causal foundation for its growth pattern.

Nikabadi and Hoseini (2019) conducted a study among Iranian companies in the electric power industry to understand the effects of human resources and work experience on outsourcing decisions by means of a System Dynamics model. They conclude that a close collaboration of internal employees and external contractors is expedient and that having more than one supplier (i.e. through dual or multi-sourcing) is more effective. In addition to that, they put forward that training new employees using skilled and expert employees is improving the quality of outsourcing projects.

Furthermore, multiple simulation-based research contributions are dedicated for analysing sourcing strategy effectiveness based on economic profitability of an outsourcing company. Armezoni et al. (2014) conducted a simulation-based study of single and dual sourcing strategies considering supplier reliability and order placement techniques, concluding that if supplier reliability varies between 90% and 70% then dual sourcing strategy is favourable due to lower costs and secure stock.

On the other hand, a more comprehensive simulation model has been introduced by Ivanov (2017), incorporating capacity disruptions, big data and varying demand and inventory patterns to provide a proactive outsourcing decision-making system. The research introduces a dynamic model with suppliers, outsourcing company, distribution centres, and a back-up distribution centre used in case of capacity disruption, providing a framework for identifying the most optimal sourcing strategy based on demand fluctuations and supply chain disruptions.

These simulation-based studies have either a functional or an industry focus. Although all those models for outsourcing decisions claim to have a comprehensive view, they, however, do not take into account all relevant factors that affect and are affected by outsourcing decisions. Their models suggest conditions for regime change between insourcing and outsourcing. Those results are highly path-dependent under short horizons.

2.3. Mathematical optimisation models

Apart from System Dynamics modelling, Anderson et al. (2019) developed a dynamic optimisation model to provide an explanation for a partial outsourcing strategy taking into account that learning happens at both the subsystem level and the overall systems level which interact where integration capabilities dynamically build and decay.

Kaur, Singh, and Majumdar (2019) developed a model supporting decision-makers to jointly address outsourcing decisions by using mixed integer non-linear programming with Multi-Criteria Decision-Making (MCDM) approaches, such as Analytical Hierarchal Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The model that considers qualitative and quantitative criteria tries to find an optimum of total costs.

Wei et al. (2019) developed a decision model for a manufacturing information system outsourcing project selection problem. They use bi-objective goal programming by taking into account cost and benefit objectives to be solved by applying TOPSIS and fuzzy sets.

There are further papers dealing with questions how best to manage outsourcing activities, mainly based on mathematical approaches by identifying methods of cost reductions through optimal quantity and order allocation. Yan, Kou, and Lu (2019) have introduced a two-echelon supply chain model composed of two suppliers and an outsourcing company which are exposed to random disruptions with the purpose of identifying an optimal order quantity allocation. The model is based on computations of random probabilities of supply chain disruptions, customer demand and product selling price, evaluating the impact of each variable on the supply chain, and providing a mathematical model for outsourcing decision-making.

Consequently, considering the random capacities and supply chain disruptions, Wang, Gilland, and Tomlin (2010) have developed a dual sourcing model for outsourcing process improvement, arguing that the combined strategy of dual supplier sourcing and supplier development have a potential to provide a significant value for an outsourcing company.

In collaboration with a car maker, Sanci et al. (2021) developed a decision support framework that is based on a multistage stochastic programming model incorporating several mitigation strategies to pick the best one against disruptions. Amongst other, they show that a strategy that is optimal in times with no disruption

risks may lead to higher total costs in cases of disruption risks.

Additionally, Cabuk and Erol (2019) integrate costs of inventory, ordering, transportation, purchasing and price discounts to develop a mixed-integer programming model allowing for multiple supplier and component evaluation to identify the best set of suppliers and order quantities by minimising the costs.

All these approaches have a narrow and problem-specific focus taking into account quantitative variables, but they lack the consideration of further variables that have a huge impact on such decisions. They only consider costs and try to find an optimum. The cost savings due to supplier quantity and order allocations, transportation and supplier reliability as well as risks associated with supply chain disruptions are the preliminary aspects widely discussed in multiple works whilst evaluating sourcing strategies.

Other important criteria, such as the innovation potential, quality issues, supplier relationship with an outsourcing company, contract negotiation and bargaining power, manufacturing investments and process experience, company workforce and efficiency related parameters are overlooked during the modelling process due to uncertainties regarding parameter quantification and complexity of building reasonable interconnections and relationships between various components. Understanding the causality of the individual outsourcing activity together with such peculiarities will help to investigate how outsourcing decisions play out and how they can be tailored to fit the uniqueness of each company.

Furthermore, many designed models lack practical foundation allowing for real-life data applications to provide meaningful insights and support outsourcing companies in strategy formation.

In addition to that, they are static, thus do not consider the evolution over time. Since outsourcing is more than an initial make-or-buy or quantity allocation decision and has repercussions in the long run, a time-dependent view is highly necessary. For the purpose of this paper, the quantifiable parameters in those studies will be used in the definition of formulas in our model.

3. Modelling the relational dynamics of outsourcing

Other than the previously discussed contributions, we wanted to consider all relevant variables simultaneously and their effects on each other over time to see mid and long-term effects of such decisions. Thus, we developed a model that takes all relevant qualitative and quantitative influences on this decision into account that are prevalent in and around a firm. For this, we used System Dynamics (SD) modelling. In the following, we will take a closer look at the main influencing factors using this technique. Further explanations on the System Dynamics methodology can be found in Sterman (2000) and Forrester (1969). An example SD model can be seen in Uygun and Jafri (2020).

Based on a literature analysis (see Section 2.1) and empirical research, our SD model to examine the dynamic nature of outsourcing includes three organisations, namely the manufacturing-based outsourcing company and two suppliers providing the exact same outsourced component. The model time unit is measured in months and for the course of the research the evolution is observed for 100 months. The complete list of model elements and computations can be found in the Supplements. The model consists of more than 200 variables, several feedback loops (see e.g. Figures 1–3) and 7 major stocks (see Table 1).

To better keep track of the whole model, all connections between the variables are defined by colours. There are five colours in the model. Orange lines contain all variables associated with the supplier (costs, embeddedness in networks, resources, difficulties, etc.; see Figure 1). Red lines contain all variables associated with the outsourcing company's costs and profits. Green lines contain all the variables that are related to more qualitative aspects showing the relationship between the outsourcing company and the supplier (trust, opportunism, shared consequences, etc.; see Figure 2). Dark violet lines define the variables which are associated with the company's workforce, its intellectual resources and innovation capabilities (employees, tacit knowledge, employee motivation, innovation potential, etc.; see Figure 3). Purple lines define all other variables, which are mainly constants and initial values that define the initial settings (geographical distance, cultural distance, technological uncertainty, etc.). The simulation model is created using both Vensim by Ventana Systems and AnyLogic Simulation Software (version 8.5.2). The latter is used to run additional Monte Carlo simulations and optimisation experiments.

Due to the fact that there are more than 200 variables, we will define only those, which are of utmost importance for the analysis of the final results. Table 1 shows all important stocks together with their causes in tree form. The model has several major stocks, such as supplier's manufacturing costs, unit price (price per unit of the outsourced part), cost savings (aggregate savings accumulated from the costs that were saved per unit), transaction costs, hidden costs, and innovation & workforce savings (aggregate savings from reduction in workforce and loss

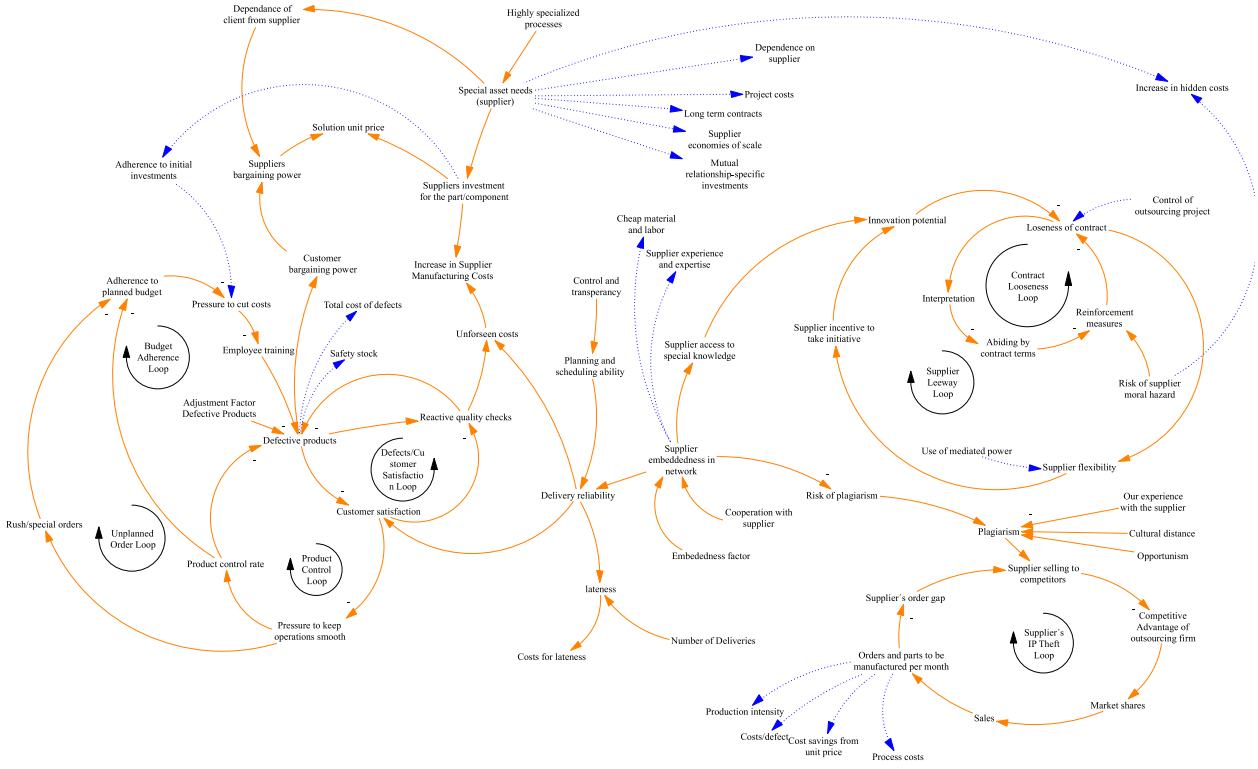


Figure 1. Supplier-related loops (cut out).

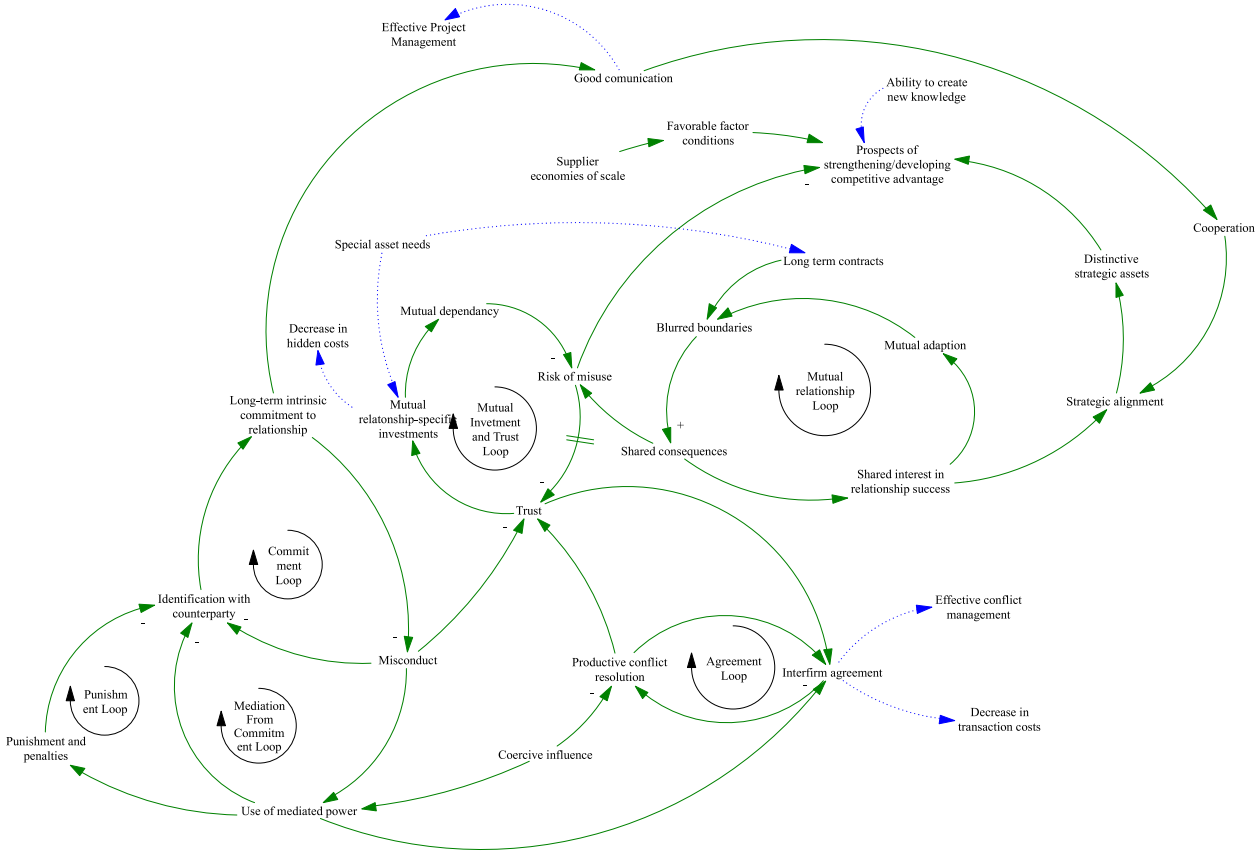


Figure 2. Relationship-based loops.

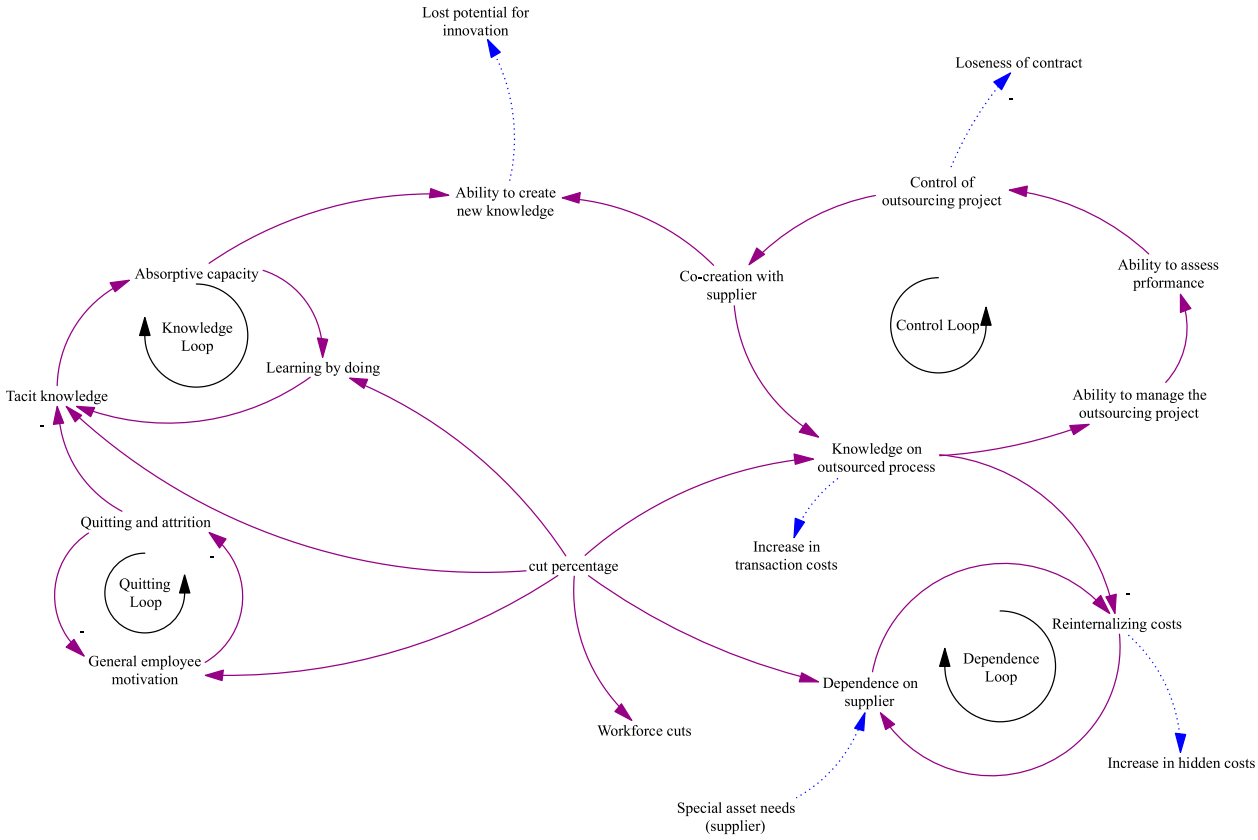


Figure 3. Loops associated with the company's workforce, its intellectual resources and innovation capabilities.

in average yearly revenue accumulated from innovation), that ultimately go into the overall *Outsourcing Balance*.

The Outsourcing Balance compares all costs and savings and determines the success of the outsourcing activity. The higher the value the more successful the activity. It is increased by the two major stocks cost savings and innovation & workforce savings and is decreased by the two major stocks transaction costs and hidden costs. Hidden costs arise from not knowing each other well. Those costs are mainly increased by geographical and cultural distance, etc. and are decreased by mutual relationship-specific investments. The formula-based definition of these and all other variables is given in the Supplements.

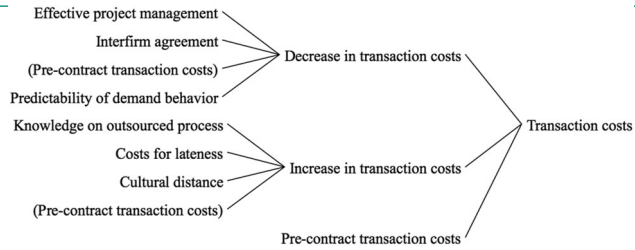
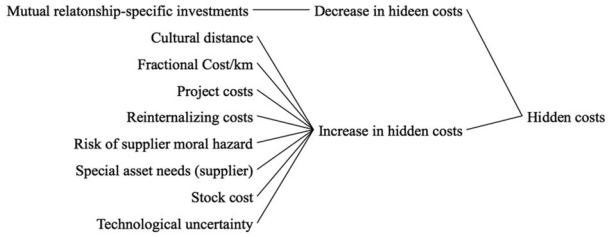
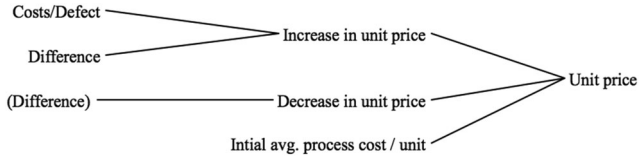
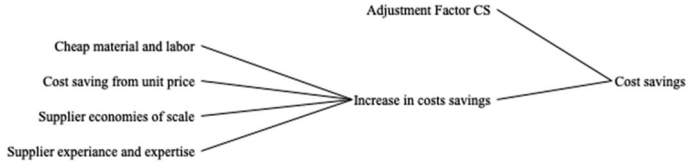
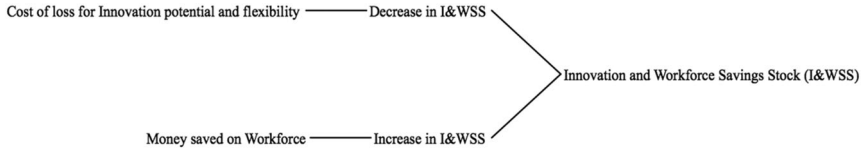
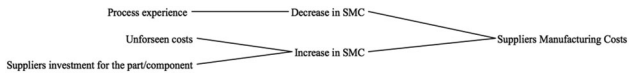
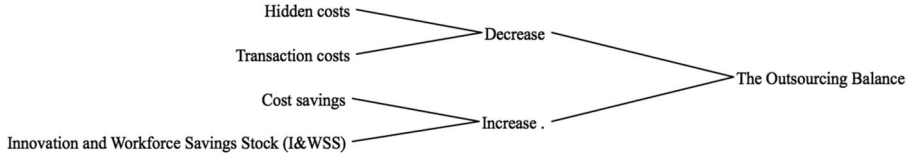
As it can be seen in Table 1, there is a number of stocks in the model that are important due to the fact that they describe the critical determinants of outsourcing. Primarily, costs are important, more specifically Transaction costs and Hidden costs. Secondly, savings are also important, which are defined by Cost savings and Innovation & Workforce Savings Stock (I&WSS). Cost saving can only increase, whereas I&WSS (as well as the Unit Price) can be both negative and positive. All those variables then go into the Outsourcing Balance that shows the aggregate value. On the other hand, Supplier's Manufacturing costs play an important role, i.e. if they pass a certain threshold, the supplier might decide to terminate the outsourcing contract.

The System Dynamics simulation model has several feedback loops that show different dynamic aspects of the supplier, its operations, activities, experience, and knowledge. In Figures 1–3 those loops are being discussed thematically by extracting them from the comprehensive model that is given in the Supplements. The dashed blue arrows in these figures show the connections to other loops, variables, or stocks.

Supplier-related loops (in yellow) can be found in Figure 1. The descriptions are given in Table 2. Please note that for better visibility only inversely related arrows are marked explicitly (with a minus '-' sign). All other arrows are directly related, and the plus sign is not explicitly shown. Also, mainly the positive possibility of those loops is described in the tables, but they can also be negative which then turns them to vicious cycles. Adjustment factors that are used to calibrate the model are also hidden .

There are loops in the simulation model (in green) that are qualitative in nature and related to relationship which are necessary to get a holistic understanding of the outsourcing endeavour (Figure 2). These variables mainly have categorical values (Table 3).

Table 1. Important stocks and their causes.

Stock	Causes tree
Transaction costs (TC)	
Hidden costs (HC)	
Unit price (UP)	
Cost savings (CS)	
Innovation and Workforce Savings Stock (I&WSS)	
Supplier's Manufacturing costs (SMC)	
Outsourcing Balance	

The loops in Figure 3 (in dark violet) are associated with the company's workforce, its intellectual resources and innovation capabilities. The idea of these loops is to show how getting rid of employees due to outsourced processes might affect the success of the outsourcing project. All of these loops are highly dependent on the one variable called '*cut percentage*' which shows the percentage of total workforce that is being laid-off as a result of moving manufacturing process from inhouse to a supplier. The effects of cut percentage are shown in the explanations of the individual loops. All those loops are reinforcing ones (Table 4).

4. Validation of the simulation model

Thus far, the described model comprising the main dynamics in outsourcing is based on theoretical and hypothetical values. To reflect reality, we need to verify the parameters and variables with real-world data and cases.

4.1. Applying real data

For the validation of the simulation, real-life data was used from actual outsourcing cases. The data is provided

Table 2. Description of the supplier-related loops (R = reinforcing; B = balancing).

Loop	Type	Description
Supplier Leeway	*B*	*Accounts for the trade-off between contract looseness and the supplier's innovation potential. Here, contracts with high degrees of looseness/leeway (i.e. low degrees of granularity) result in high supplier flexibility which gives the supplier room and grey area in which it can experiment.*
Contract Looseness	*B*	*In addition to the previous loop, this one accounts for the dynamics of the contract´s level of detail (looseness) and reinforcement measures. When a contract is too loose (i.e. fuzzy with less specific terms & conditions), the supplier will have more room for interpretation of such terms which may lead to not abiding by customer's specifications. So, the supplier will face more reinforcement measures that will lead to a tighter contract and, thus, better sticking to contract terms.*
Product Control	*B*	*Accounts for the control of producing good parts. With lower pressure there is less control on production and its quality, which after a certain time frame increases the chance of manufacturing defective products.*
Defects/ Customer Satisfaction	*B*	*Accounts for the relation between defective products and customer satisfaction. Less satisfaction prompts the supplier to increase reactive quality checks of the manufactured components which eventually decreases the number of defective products.*
Unplanned Order	*R*	*Accounts for the deviation from the planned budget due to unplanned orders (caused e.g. by defective products that need to be replaced by good ones). If the adherence to budget is high, there is less pressure to cut costs, meaning that employee training will be taken care of, resulting in less defective products, high customer satisfaction, less pressure to keep operations smooth and less rush/special orders.*
Budget Adherence	*R*	*This loop is almost identical to the previous loop and accounts for the deviation from the initial budget due to higher/lower product control rates. The only difference is that this loop does not inquire the variable showing the rush/special orders.*
Supplier's Theft of Intellectual Property	*R*	*This loop accounts for the effect of stealing intellectual property and selling it out to competitors. If the risk of plagiarism is low, then the supplier will not share or sell the parts to other customers, i.e. the competitive advantage will not decrease for the outsourcing company, sales will also be stable, and there will be no need to decrease the number of ordered components.*

Table 3. Description of relationship-related loops (R = reinforcing; B = balancing).

Loop	Type	Description
Commitment	*R*	*It is less probable that the supplier will turn to opportunism if there is a high commitment for the long-term intrinsic relationship. If there is no opportunism both for the supplier and for the outsourcing company, the identification with the counterparty is easier and there is support for the long-term intrinsic commitment relationship.*
Mediation from Commitment	*R*	*Mediated power is the power gotten by the use of extrinsic motivations. The outsourcing firm's power is mediated by its size, financial power and reputation. So, mediated power prohibits mutual respect. If the variable for opportunism is high, then the use of this kind of mediated power will increase for both parties causing the decrease in identification with the counterparty, negatively effecting the long-term intrinsic relationship.*
Punishment	*R*	*This loop is based on the previous loop with the difference that if the use of mediated power is high, then there will be punishments and penalties from either party (further) decreasing the identification with the counterparty, resulting in negative effects on the long-term intrinsic relationship.*
Agreement	*R*	*If there is an interfirm agreement between the supplier and the outsourcing company, then it is more likely that they will have a productive conflict resolution when difficult situations come up.*
Mutual Relationship	*R*	*If the supplier and the outsourcing company have long term contracts, then the boundaries between them are more blurred or open. With less boundaries, there are shared consequences that lead to shared interests in relationship success, resulting in mutual adaption, making the boundaries even more blurred.*
Mutual Investment and Trust	*R*	*With higher shared consequences, there is less risk of opportunism, which settles trust between two parties that leads to mutual relationship-specific investments which results in mutual dependency decreasing the risk of opportunism even more.*

by a global first-tier automotive supplier company for cases with bilateral relationships. Thus, numbers are provided for two outsourcing cases which are specifically derived to describe the outsourcing settings according to the initial variables introduced in the simulation model. Technically, the second supplier in the model is ignored. The specific data for the two cases is given in Table 5.

Case one depicts the outsourcing of a simple part, which is ordered in moderately small quantities. The outsourcing company has experience with the supplier and the predictability of the demand behaviour is high. The supplier is located close to the outsourcing company and has all the technological capabilities to manage the orders.

In case two, the outsourced component is highly specialised and complex. The outsourcing company had some but not too frequent relations with the supplier. Orders are moderately high in terms of the components that need to be manufactured, and the demand predictability is also moderate, i.e. that there might be some small uncertainties. The supplier is located in the city next to the outsourcing company.

4.2. Simulation validation results

This section explains the logic behind the results attained after running the data for those two outsourcing cases

Table 4. Description of workforce-related loops (R = reinforcing; B = balancing).

Loop	Type	Description
Quitting	*R*	*If many people get released from the company, other employees start to lose motivation, which leads to poor work results and thus quitting and attrition.*
Knowledge	*R*	*Quitting and attrition together with the cut percentage decrease the tacit knowledge (i.e. employeeś experience and skills) existing in the company. When a certain number of employees leave the company, they take their knowledge with them which leads to less absorptive capacity (i.e. ability of employees to learn from each other's experiences and skills) which leads to less people learning by doing, resulting in even bigger decrease of tacit knowledge.*
Control	*R*	*The higher the knowledge of the company on the outsourced process, the higher the ability to manage it and the higher the ability to assess the process performance. This leads to high control of the outsourcing activity, resulting in co-creation with the supplier which gives the company ability to create new knowledge.*
Dependence	*R*	*If the company lays off big percentage of the workforce, then the externalisation increases which increases the reinternalising costs. On the contrary, if the cut percentage is small, then the company is less externalising and has fewer reinternalising costs.*

which were deeply discussed with the data-providing firm. It is important to mention that the main variables in the model, such as the Unit price, match well but some other numbers obtained after running the simulation still remain hypothetical, as the simulation contains variables that are simply not considered or used by the company due to the lack of corresponding metrics which makes it impossible to compare those variables in the simulation with the actual values. Furthermore, the simulation inquires categorical values, which remain theoretical. Hence, for those variables the simulation rather shows the pattern and logic behind different outsourcing settings, which can be used to define real-life cases and outcomes. The paper aims at finding logical patterns behind the graphs, which are close to reality.

After running the data for case 1, following results were obtained. The unit price increases due to numerous factors. In the beginning, the supplier invests in setting up and improving manufacturing processes, which can be seen in the drastic increase of the Unit price within the first 5 months (Figure 4(a,b)). Once the manufacturing processes have been standardised by the supplier, the price tends to decrease similarly to the Supplier's Manufacturing Costs.

Undermining the fact that there are numerous customers on the market who are willing to receive services from the supplier while no other suppliers have the capability to offer such services, the bargaining power of the supplier increases, as discussed above. On the other hand, the outsourcing company or the customer has lower bargaining power over the supplier, which also plays a role in the increase of the Unit price (Figure 4(a,b)).

Table 5. Variables for the two real-life cases.

Initial variables that are used to describe the setting	Case 1	Case 2
Monthly avg. Salary per Employee	20–25% (€ 1458)	10–15% (€ 875)
Initial regional market shares of receiving company	0.1	0.05
Initial Sales of the receiving company	€ 2.7M	€ 14M
Initial Gain from Innovation for receiving company	0.15	0.05
Product Introduction rate at the receiving company	20	2
Initial avg. process cost/unit at the receiving company	0.2	3.00
Selling Price for each part/product	0.23	3.60
Pre-contract transaction costs	500	20000
Predictability of demand behaviour	0.98	0.7
Workforce: Employees	60	116
Cut percentage (workforce cuts out of a total workforce of 5000)	2 out of 10	15 out of 500
Companies experience with the supplier	0.90	0.65
Parts to be manufactured	50,000	900,000
Highly Specialised Process	0.2	0.7
Geographical Distance	0 km	20 km
Technological uncertainty for the receiving company	1.1	1.5
Risk of moral hazard at the receiving company	1.2	1.2
Embeddedness factor of the receiving company	0.8	0.8
Control and transparency of receiving company	0.7	0.8
Number of Suppliers on the market	10	30
Number of Customers on the market for the supplier	20	20
Number of Deliveries per month	90	30
Coercive Influence	0.1	0.5

Another factor that increases the Unit price is the defective products. As the supplier faces problems related to manufacturing, the number of defective products manufactured also increases during the first year. This, as a result, increases the costs for both the supplier and the outsourcing company, therefore the Unit price suffers as well. After roughly 30 months, the quality of the supplied parts improves drastically, equalling the costs to almost 0, which plays a role in the further decrease of the Unit price between the months #40 and #100.

The Supplier's Manufacturing Costs increase due to new investments (Figure 4(c,d)). After about 35 months the supplier becomes experienced in the process and starts standardising and optimising its manufacturing processes, as a result, decreasing the costs on his side, and the Unit price on the side of the receiving company.

Transaction costs tend to increase in the beginning but after about 55 months return to the level of initial costs, and afterward decrease further (Figure 4(e)).

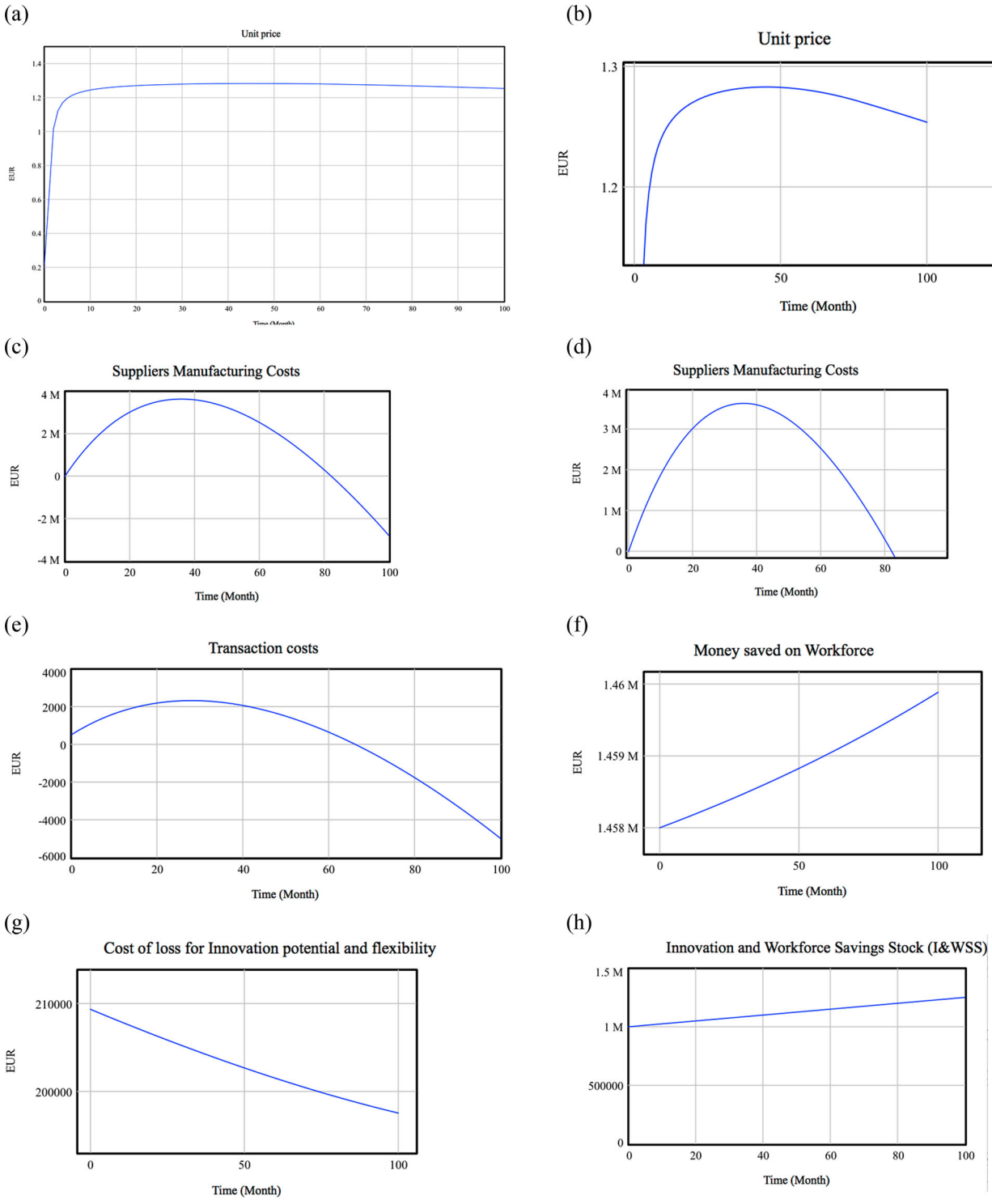


Figure 4. Results of the Case 1.

The causes for this are as follows: due to new business settings, Transaction costs slightly increase. As there is no geographical and cultural distance between the supplier and the receiving company, Transaction costs do not show a critical increase. Additionally, an important factor is that the company knows the supplier well, as it has already received some other services from him. Additionally, there is a high number of deliveries performed monthly, which also serve as additional costs in terms of the transaction. After 30 months, the bottlenecks in the delivery process get solved, and taken into account that there is no geographical, cultural or relational distance between the supplier and the customer, Transaction costs decrease. This also explains the fact why Hidden

costs remain constant and do not change throughout the whole outsourcing activity.

As the workforce is getting laid off, the benefits/savings can be seen as well (Figure 4(f)). Over a period of 100 months this number slightly changes as laying off workforce leads to quitting and attrition (demotivation) of other employees. Overall, it does not have a negative effect as the knowledge and skills are not being totally lost since the cut percentage of the workforce is small.

The innovation potential decreases as well (Figure 4(g)). This can be considered as a minor decrease. As the part/component is not complex, the innovation potential, more or less, is being maintained and therefore the losses are of minor amount.

From the aggregated graph of the savings on workforce and loss/gain of innovation potential (Figure 4(h)), the savings by laying off workforce outweighs the loss of innovation potential, thus saving costs for the receiving company.

As a consequence, the developed model with its adjustment factors was adjusted and calibrated in several iterations and intense discussions with the data-providing firm, thus capturing this real-world outsourcing scenario very accurately.

The simulation validation results for case 2 is given in Figure 5. Here, the part is more complex and sophisticated, the supplier made big investments in setting up and improving his manufacturing processes due to which the Unit price increases in the beginning but steadily decreases. As the part is more complex, the innovation potential is being lost but the money saved on laying off workforce outweighs the loss of innovation potential, resulting in savings for the receiving company. However, the amount saved is less significant than that of case 1 due to the loss of the innovation potential.

In Figure 6 the Outsourcing Balance can be seen which is the aggregate value of every stock and variable. If positive then the outsourcing activity was successful, otherwise it can be considered unsuccessful. For case 1, the outsourcing activity is successful as the outsourcing balance is always positive (Figure 6(a)). It can also be seen that after 35–40 months the graph drastically (exponentially) increases. This can be explained by the decrease of the unit price, transaction costs and workforce & innovation savings after, on average, 40–50 months.

For case 2, the outsourcing activity, in the beginning, goes to negative, meaning that in the short run it will not be successful (Figure 6(b)). But looking at the results, in the long run, it can be seen that the results are more satisfying than in case 1. It can also be seen that between the 60th and 100th month the graph drastically increases; almost by a factor of 4. So, due to the fact that the company is outsourcing a complex part, it will be extremely important to plan the outsourcing activity for a longer period, as in the beginning (for the first 2.5 years) there will be various costs for both the supplier and customer which might lead to the failure of the activity if assessed on a short term. Figure 7 combines all costs for this case.

4.3. Comparison with the actual results

Looking at the original data provided by the first-tier automotive supplier, the results obtained from the simulation tend to have a logical pattern, when it comes to the change of the unit price over time. Figure 8 represents the change of the unit price from 2014 to 2018 for case 1, and from 2014 to 2019 for case 2 which almost exactly occurred in this manner in reality.

In case 1 (blue line), the unit price for the outsourced product increases on a yearly basis, not necessarily meaning that the outsourcing activity is overall insufficient for getting a successful outcome. Even though the unit price tends to increase, other factors, like hidden costs and transaction costs, decrease. Additionally, due to the simplicity of the outsourced part, the innovation potential does not get lost. On the contrary, savings on the fired workforce tend to inflate the amount of aggregated savings on the whole outsourcing activity. Overall, it can be said that the simulation efficiently shows the tradeoffs of outsourcing decision and underlines the aspect that can be taken into consideration for decision making. It shows that the supplier is beneficial for this case, and especially the location of the supplier plays a major role in bringing success to the activity.

Differently, in case 2 (orange line) there is a constant decrease in unit price over the period of 6 years. In this case, the graph shows that the unit price in the final time step is less than the initial price agreed on in the beginning of the outsourcing activity. The increase in the first periods can additionally be explained by the categorical values which are discussed above. Looking at the logic, it can be seen that, almost exactly to the real-world, the unit price decreases. Considering the complexity of the outsourced part, geographical distance and the experience of the outsourcing company with the supplier, the transaction costs and hidden costs tend to increase, which in the beginning add up to the negative results, but only in the short run. In the long run, both transaction and hidden costs tend to decrease, as the relationship and practical experience between the company and the supplier is getting more standardised and stabilised. The final results are satisfying as every determinant of the outsourcing has benefits for the company results.

In conclusion, it can be said that the simulation yields valid results. As mentioned earlier, the most important

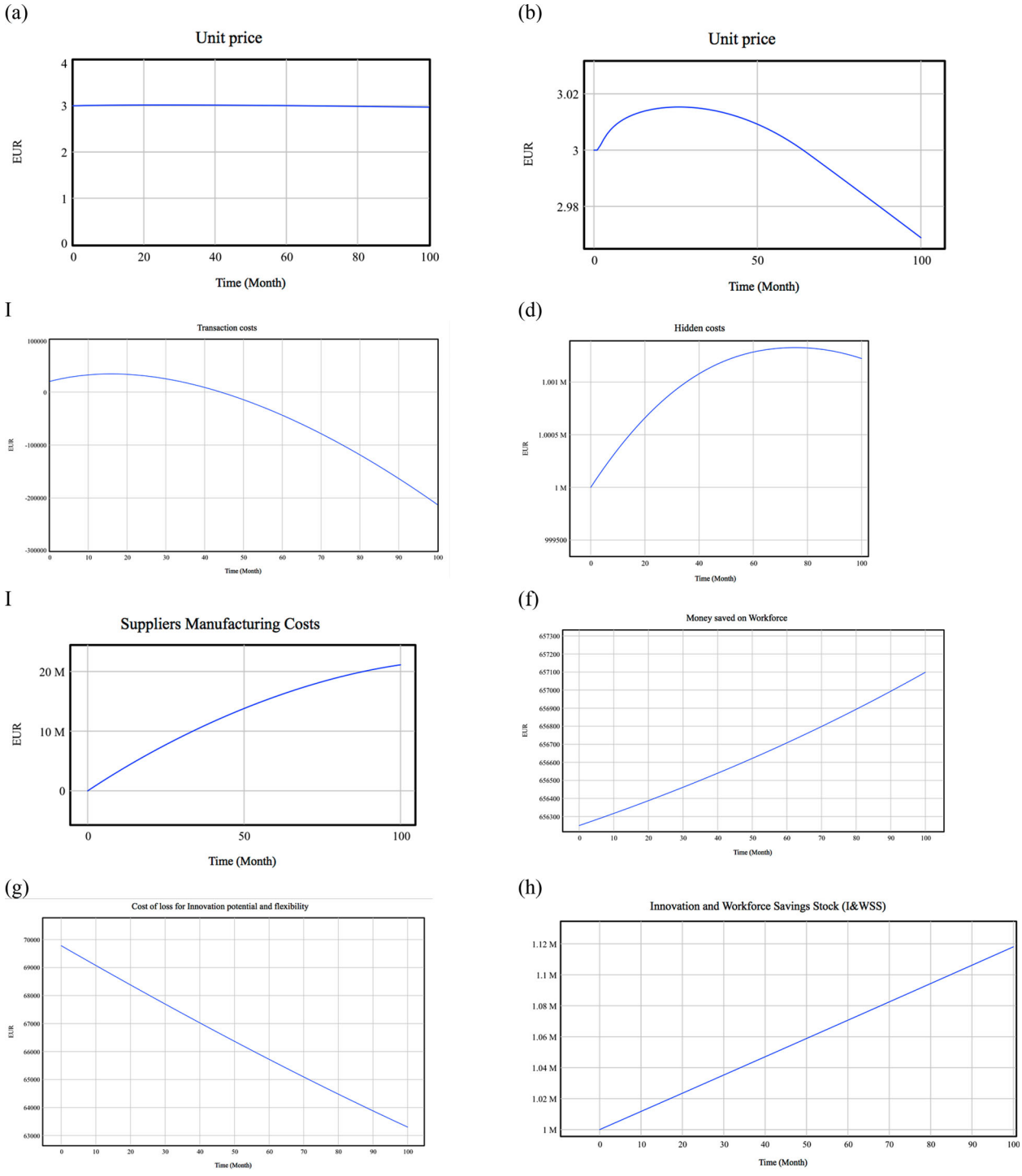


Figure 5. Results of the Case 2.

aspect of this simulation is to define the logic behind the changes, rather than the precise numbers and amounts since some cost and benefit factors are not measured by companies or even can hardly be measured at all. Here, we assumed realistic values. The logic behind the graphs is evident, and the risks can easily be defined. Our simulation model can be used to visualise the tradeoffs that might appear during an outsourcing activity, and its results can be used to ease the decision-making process for the managers of the outsourcing company.

5. Simulation experiments

Against the backdrop of the calibration as well as validation and motivated by the validation partner (first-tier automotive supplier), we further tested the model by

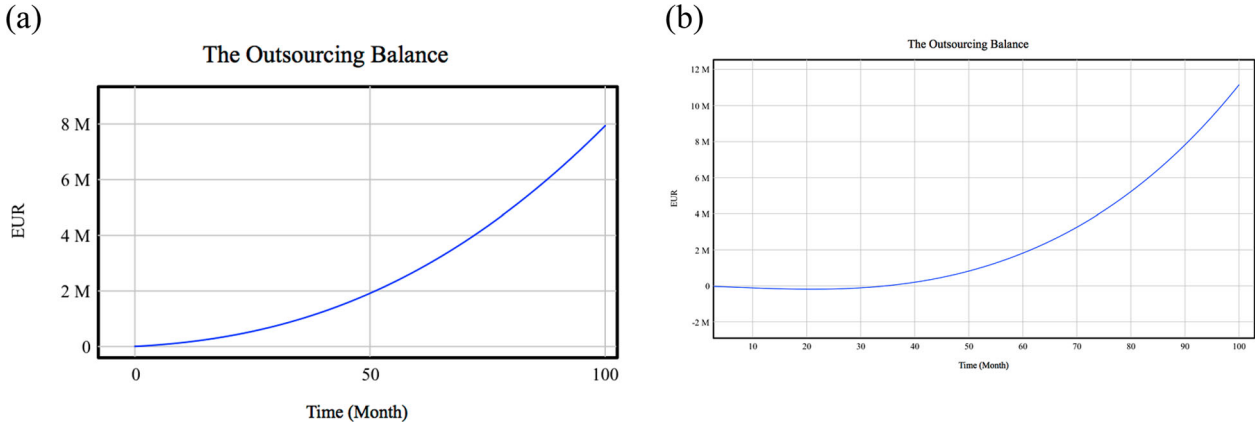
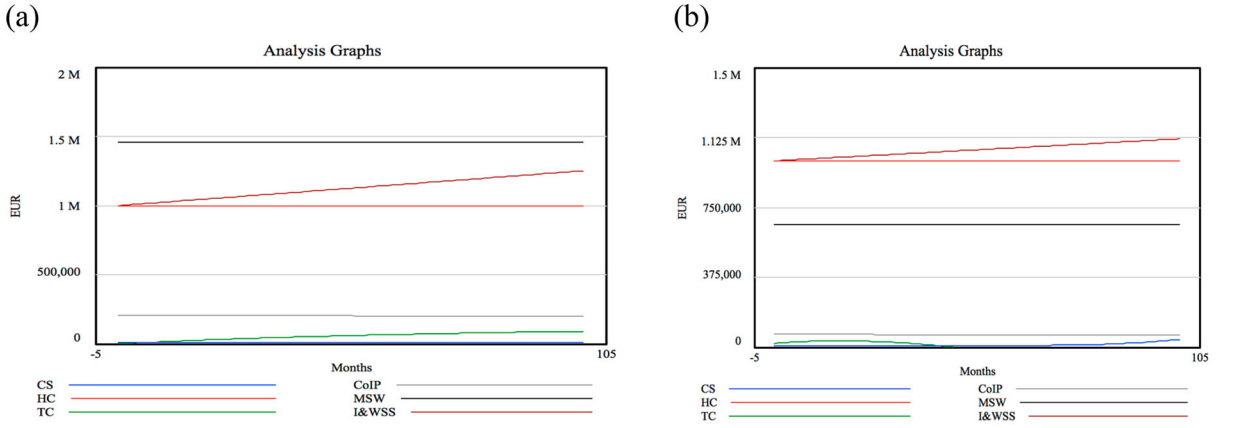


Figure 6. The Outsourcing Balance; (a) Case 1 (b) Case 2.



CS = Cost Savings on unit Price | HC=Hidden Costs| TC=Transaction Costs | CoIP=Cost of Innovational Potential | MSW=Money Saved on Workforce| I&WSS = Innovation and Workforce Savings |

Figure 7. Aggregate Analysis Graph (a) Case 1 (b) Case 2.

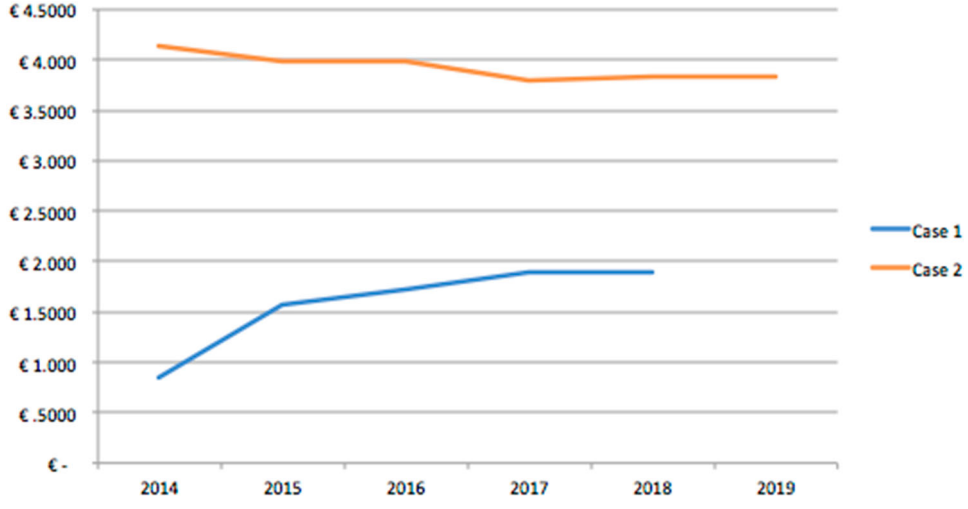


Figure 8. Real unit prices of the automotive supplier.

means of different theoretical experiments as suggested e.g. by Sargent (2013). To examine model capabilities and their potential of handling different outsourcing scenarios along with model sensitivity validation, relevant simulation experiments are conducted. Furthermore, to provide manufacturing organisations with a reasonable decision-making framework, a statistical approach is used, and various simulation outcome probabilities are analysed. The experiments depict how different aspects of the outsourcing decision-making affect the company supply chain, identify the applicability of the outsourcing strategy for the specific outsourcing company profiles and provide an optimal methodology for increasing outsourcing activity profitability.

5.1. Extreme case analysis of suppliers

To understand the extreme cases, i.e. the best and worst combination of supplier parameters on the overall success of the outsourcing endeavor, an optimisation experiment is applied. An optimisation experiment is the process of running a substantial number of simulations with varying parameter values within a predefined range to identify the best combination of values for achieving an objective. Therefore, the optimisation experiment is introduced for the purpose of

(a). understanding the extent of possible outsourcing strategy outcomes for a defined manufacturing company in terms of the Outsourcing Balance, and
(b). analysing which factors lead to a negative and positive Outsourcing Balance, building a foundation for an optimal outsourcing decision-making framework.

To identify the most and least profitable combination of supplier parameters, the experiment is conducted twice, first with an objective of maximising the Outsourcing Balance, and second, minimising the Outsourcing Balance. Table 6 gives the supplier parameter variation range and company profile related fixed variables.

The expressions for supplier parameter values indicate minimum, maximum and step values, and are altered within 500 simulation runs for each experiment to form unique combinations. The attributes of an outsourcing company are fixed for the purpose of solely investigating combination of two supplier parameters and their impact on the Outsourcing Balance. Additionally, the Process Specialisation parameter is varied to examine how manufacturing complexity affects success of an outsourcing activity. Figure 9 demonstrates outsourcing simulation outcomes for both experiments and complementary Table 7 indicates respective supplier parameter values.

Table 6. Optimisation experiment setup.

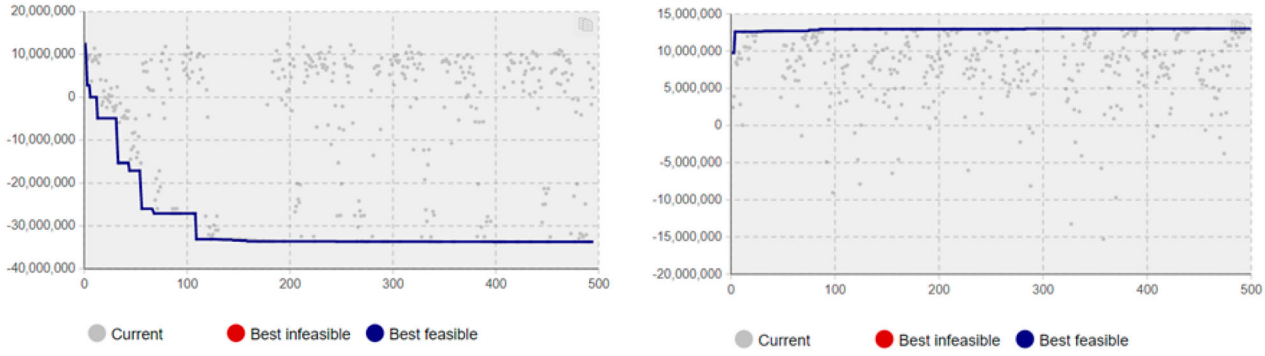
Parameters	Values
Selling Price	0.23
Initial Sales	50,000
Initial Market Share	0.2
Supplier1 Plagiarism Risk	(0.1, 1, 0.1)
Supplier2 Plagiarism Risk	(0.1, 1, 0.1)
Initial Avg. Process Cost	5
Supplier1 customers	(10, 50, 10)
Supplier2 customers	(10, 50, 10)
Process Specialisation	(0.5, 1, 0.1)
Number of Suppliers	10
Supplier1 Quantity	0.5
Supplier2 Quantity	0.5
Supplier1 Deliveries	(10, 60, 10)
Supplier2 Deliveries	(10, 60, 10)
Supplier1 Precontract TC	(1000, 10,000, 1000)
Supplier2 Precontract TC	(1000, 10,000, 1000)
Supplier1 Geographical Distance	(500, 15,500, 1000)
Supplier2 Geographical Distance	(500, 15,500, 1000)
Demand Predictability	(0.3, 0.8, 0.1)
Cut Percentage	0.1
Initial Ability to manage projects	1
Initial Ability to assess performance	1
Initial Tacit Knowledge	0.5
Total Workforce	5000
Monthly avg. salary per employee	1500
Initial gain from innovation	20
Supplier 1 Coercive Influence	(0.1, 1, 0.1)
Supplier 2 Coercive Influence	(0.1, 1, 0.1)
Supplier 1 Risk of Moral hazard	(0.1, 1, 0.1)
Supplier 2 Risk of Moral hazard	(0.1, 1, 0.1)
Technological Uncertainty	0.5
Initial collaboration with suppliers	1
Initial control	1

Table 7. Optimisation experiment derived values.

	Values minimising profitability		Values maximising profitability	
Parameter	Supplier 1	Supplier 2	Supplier 1	Supplier 2
Risk of Plagiarism	0.9	0.9	0.1	0.1
Number of Customers	10	10	50	50
Deliveries per Month	60	60	10	10
Precontract TC	10,000	10,000	1000	1000
Geographical Distance	15,000	15,000	500	500
Coercive Influence	0.1	0.1	1	1
Risk of Moral Hazard	0.9	0.9	0.1	0.1
Process Specialisation	0.5		1	

The Optimisation Experiment illustrates multiple possibilities of the simulation outcomes with 8 supplier-related parameter variations. The most optimal combination of supplier parameters listed in Table 7 indicates that the manufacturing company has a potential to obtain highly profitable outsourcing activity in 100 months, while in contrast, the worst combination might result in even more significant losses. Therefore, an outsourcing company requires careful consideration and quantitative analysis of each decision impact on its profitability.

Derived supplier parameter values for both experiments indicate that decreasing number of supplier deliveries per month, choosing suppliers with shorter



a) Minimizing Outsourcing Balance

b) Maximizing Outsourcing Balance

Figure 9. Optimisation Experiment.

distances as well as focusing on supplier reliability, trustworthiness and commitment are substantial considerations for ensuring successful outsourcing activity.

Additionally, it is crucial to emphasise that higher process specialisation appears to be favourable for an outsourcing company as suppliers are enforced to devote high manufacturing investments. Consequently, suppliers' willingness for long-term commitment, effective cooperation and productive relationship preservation is strengthened due to mutual dependency and shared interests. In contrast, low process complexity might lead to subpar supplier engagement, ultimately increasing the threat of supplier opportunism.

5.2. Quantity Allocation Experiment

Determining sourcing model capabilities and significance of careful supplier parameter consideration, the Quantity Allocation Experiment further examines the effects of optimal parameter combination, however, solely focusing on the quantity allocation decision-making effectiveness. The aim of the experiment is to determine the optimal quantity allocation strategy based on given supplier parameters.

For the purpose of this experiment, an outsourcing company and two suppliers are introduced with fixed parameters. The model is simulated five times, alternating percentage of total production capacity step-by-step per supplier. Table 8 below describes profiles for an outsourcing company and chosen suppliers.

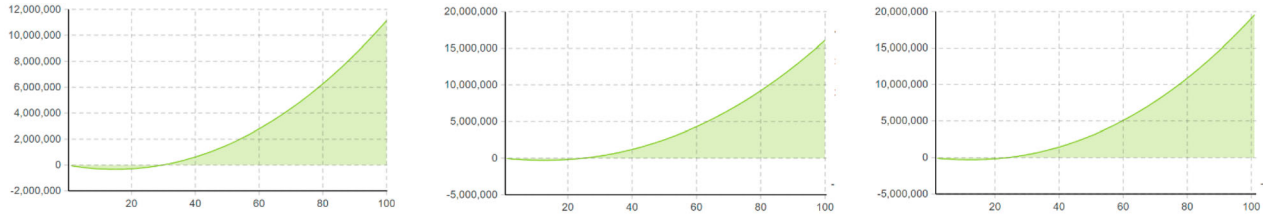
Overall, supplier 1 which is located far away is favourable over supplier 2 in terms of higher manufacturing process experience, long-term commitment, embeddedness in network, effective communication as well as lower precontract costs and number of deliveries. On the other hand, supplier 2 is substantially closer to the outsourcing company, provides higher transparency and has considerable initial process experience. The figures below illustrate changes to the Outsourcing Balance according to quantities manufactured by suppliers.

Table 8. Company profiles.

Variable	Supplier 1	Supplier 2	Outsourcing Company
Avg. salary per employee	–	–	2500
Coercive influence	0.7	0.2	–
Control & transparency	0.4	0.6	–
Cut percentage	–	–	0.1
Deliveries	10	20	–
Demand predictability	–	–	0.1
Embeddedness in network	0.6	0.2	–
Geographical distance	2000	100	–
Initial ability to assess performance	–	–	1
Initial ability to manage suppliers	–	–	1
Initial actual manufactured	100,000	10,000	–
Initial avg. process costs	–	–	3
Initial collaboration with suppliers	–	–	1
Initial control	–	–	1
Initial market share	–	–	0.3
Initial process experience	100,000	50,000	–
Initial sales	–	–	1,000,000
Initial long-term commitment	0.9	0.5	–
Number of customers	50	5	10
Precontract Transaction Costs	5000	10,000	–
Process specialisation	–	–	0.8
Productive conflict resolution	0.6	0.4	–
Relationship specific investment	0.7	0.2	–
Risk of moral hazard	0.1	0.7	–
Risk of plagiarism	0.2	0.5	0
Selling price	–	–	0.23
Technological uncertainty	–	–	0.5
Workforce	–	–	5000

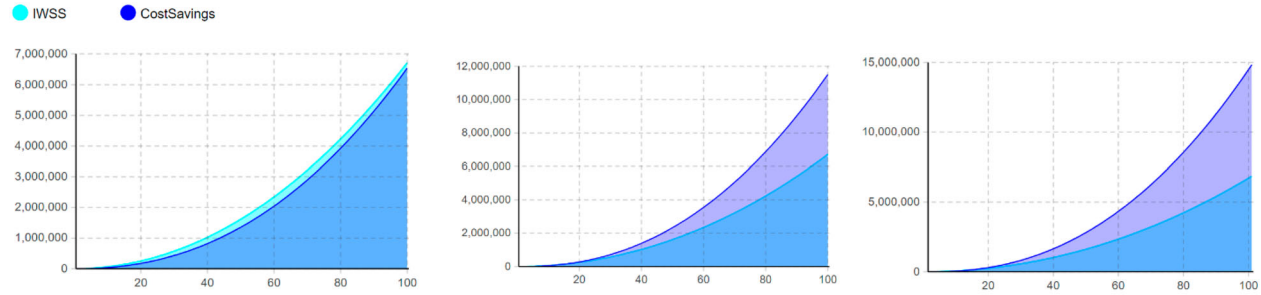
As can be seen in Figure 10, the Outsourcing Balance based on different quantity allocation ratios between suppliers improves significantly when Supplier 1 handles larger production capacity. Total growth from scenario (a) to (c) is 72%. In fact, the Outsourcing Balance increases substantially mostly due to increased Cost Savings. Figure 11 demonstrates Cost Savings per respective quantity allocation setting.

Ai and Xu (2021) found that a more reliable supplier may benefit in a dual sourcing strategy if its costs are



a) Supplier 1: 20%; Supplier 2:80% b) Supplier 1 & 2: 50% c) Supplier 1: 80%; supplier 2:20%

Figure 10. Outsourcing Balance based on Quantity Allocation.



a) Supplier 1: 20%; Supplier 2:80% b) Supplier 1 & 2: 50% c) Supplier 1: 80%; supplier 2:20%

Figure 11. Cost Savings based on Quantity Allocation.

relatively low. To better understand this, we can see in our model that Cost Savings are strongly affected by supplier performance due to variable dependence on the solution unit price, manufacturing costs, supplier experience and expertise, and economies of scale. If larger quantity is produced by a more cost-efficient and specialised supplier, the impact of geographical distance might be neglected. Therefore, an outsourcing company substantially increases Cost Savings, leading to a highly profitable Outsourcing Balance.

5.3. Prediction of probable outcomes by means of Monte Carlo simulation

Monte Carlo is a method of simulation outcome probability computation based on stochastically varied parameters. The purpose of the experiment is to identify the probability distribution of profitable and unfruitful outsourcing outcomes. Furthermore, the experiment aims to differentiate company profiles based on the applicability of a sourcing strategy due to its potential for success. Finally, the method helps to better understand the key parameters and analyse their individual impact on the Outsourcing Balance.

The Monte Carlo Experiment is conducted twice for two differentiated company profiles based on their initial sales, market share, total workforce, and experience. Parameters of Suppliers 1 and 2 are stochastically varied using probability distributions bounded on both sides. Table 9 indicates outsourcing company profiles and supplier parameter probability distributions for both Monte Carlo Experiments distinguishing large and small manufacturing company profiles. The size is based on employee numbers; the large company employs 5,000 and the small one only 500 employees.

Triangular and pert distributions indicate minimum, maximum and mode of the range, while uniform distribution allows equally random value selection in the given range. Parameters of Supplier 1 and 2 are varied identically to examine all possible outsourcing strategy simulation outcomes for large and small companies. Figure 12 illustrates Outsourcing Balance probability distributions for each experiment conducted.

Outsourcing Balance probability distribution histograms indicate normal distribution with slight left skewness for both cases. However, for large company total probability of obtaining positive outsourcing balance is more than 90%, while in contrast, for small company this is only roughly 18%.

The experiment outcomes indicate that (a) large manufacturing companies tend to have higher probability of obtaining profitable outsourcing balance, while small companies are under strong risk of obtaining unfruitful outsourcing activity; (b) if carefully evaluated, a successful sourcing strategy is applicable for companies with larger market share, sales and experience due to their ability of gaining high cost savings.

For further analysis of profitability factors, Figure 13 introduces an Outsourcing Balance component breakdown and illustrates probability distribution of the

Table 9. Settings for Monte Carlo experiment.

Variables	Supplier 1	Supplier 2	Large Company	Small Company
Avg. salary per employee	–	–	1500	1000
Coercive influence	pert (0.1, 0.8, 0.4)	pert (0.1, 0.8, 0.4)	–	
Cut Percentage	–	–	triangular (0.1,0.3,0.1)	triangular (0.1,0.3,0.1)
Control & transparency	pert (0.1, 0.9, 0.5)	Pert (0.1, 0.9, 0.5)	–	
Demand predictability	–	–	0.6	0.6
Geographical distance	uniform (100, 15,000)	uniform (100, 15,000)	–	
Initial ability to assess performance	–	–	triangular (0.1, 0.99, 0.5)	triangular (0.1, 0.99, 0.5)
Initial ability to manage suppliers	–	–	triangular (0.1, 0.99, 0.5)	triangular (0.1, 0.99, 0.5)
Initial avg. process costs	–	–	3	3
Initial collaboration with suppliers	–	–	triangular (0.1, 0.99, 0.6)	triangular (0.1, 0.99, 0.6)
Initial control	–	–	triangular (0.3, 0.99, 0.5)	triangular (0.3, 0.99, 0.5)
Initial market share	–	–	0.7	0.01
Initial sales	–	–	1,000,000	1000
Number of customers/suppliers	10	10	20	5
Precontract TC	uniform (10,000, 300,000)	uniform (10,000, 300,000)	–	–
Process specialisation	–	–	0.7	–
Risk of moral hazard	pert (0.1, 0.99, 0.5)	pert (0.1, 0.99, 0.5)	–	–
Risk of plagiarism	pert (0.1, 0.99, 0.5)	pert (0.1, 0.99, 0.5)	0	–
Selling price	–	–	0.23	0.23
Technological uncertainty	–	–	0.7	0.7
Workforce	–	–	5000	500

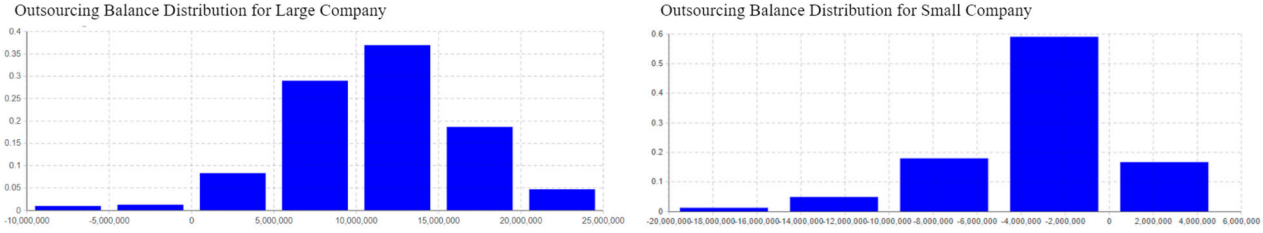


Figure 12. Monte Carlo Probability Distributions.

key stocks for large and small company Monte Carlo Experiments.

Transaction costs are normally distributed and almost identically spread in both cases. The spread over the horizontal axis indicates vast variety of possible values for both companies based on supplier choice. Furthermore, the identical range of transaction cost probable values indicates that the costs mostly depend on the supplier parameters such as geographical distance, precontract costs, control and transparency rather than company parameters. Comparably, while Hidden Costs histogram has significant right skewness, the values are similarly clustered in both cases, indicating that companies have trivial control over Hidden Costs which mostly depend on supplier performance.

Cost Savings and Innovation and Workforce Savings Stock show contrasting trends for large and small company profiles. While large company Cost Savings have normal distribution and high spread, these are uniformly distributed for the small company, indicating that supplier choice strongly impacts Cost Savings for the large company, however, has a trivial impact for the small company.

Furthermore, the large company has more potential for high Innovation and Workforce Savings Stock due to greater initial innovation potential, as well as substantial number of employees compared to a small company, thus, higher trade-off for large benefits.

5.4. Fixed Key Determinant Experiment

The Fixed Key Determinant Experiment examines model dynamics, closely observing each key determinant based on implementation of stepwise adjustments with an objective of improving the Outsourcing Balance. The purpose of this experiment is to find the best strategic approach for maximising outsourcing activity profitability by identifying the least complex and most effective outsourcing decisions.

The procedure for conducting a Fixed Determinant Experiment includes multiple simulations for examining how adjustments of one key determinant effect the overall profitability. Four rounds of experiment simulations are carried out for each one of the key determinants being fixed and the initial Outsourcing Balance being unprofitable.

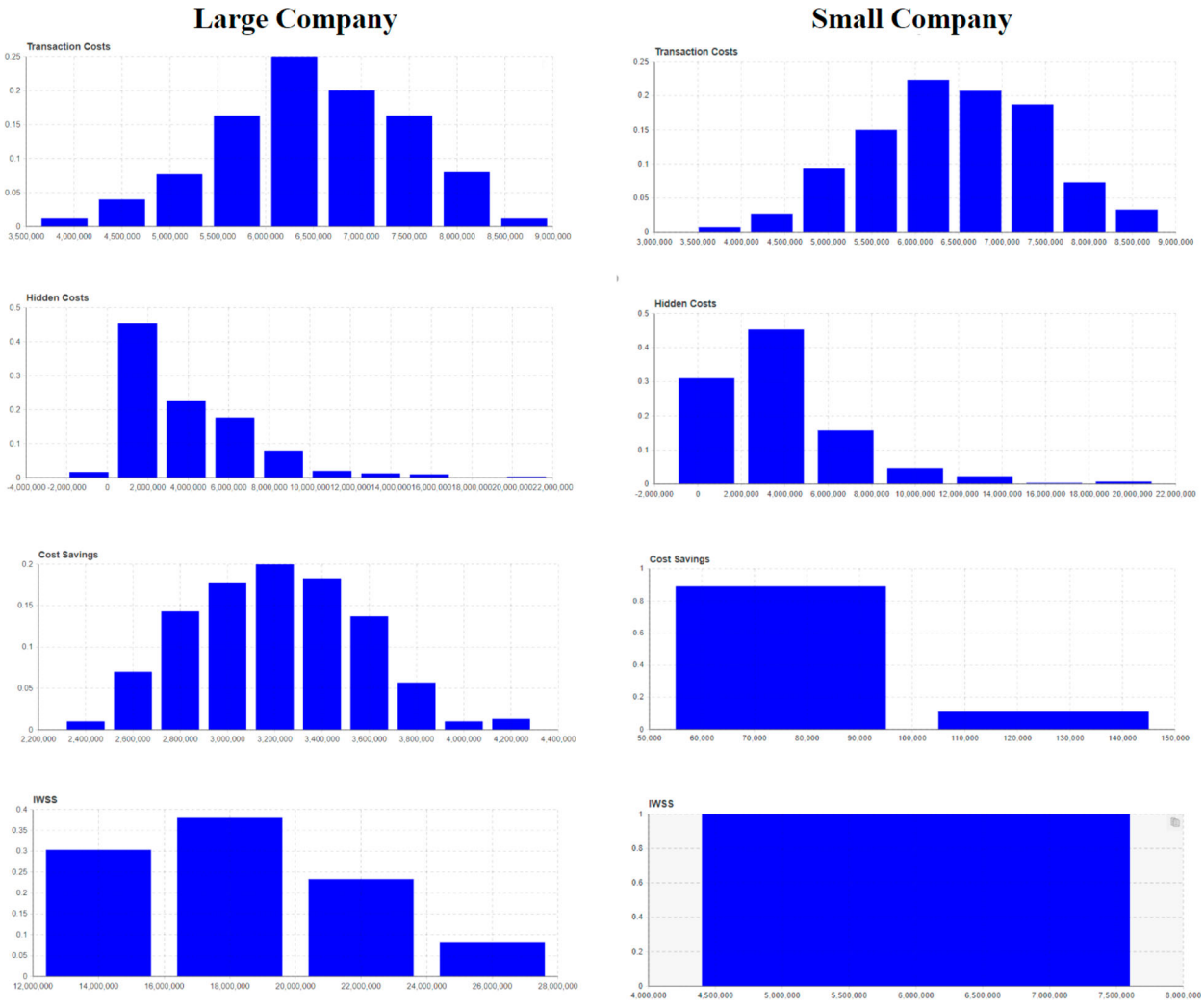


Figure 13. Monte Carlo Experiment Distribution: Key Stocks & Determinants.

Figure 14 summarises the outcomes of each simulation run and visualises the impact of each determinant on the Outsourcing Balance.

The dataset illustrates that I&WSS and Transaction Costs have the highest impact on the outsourcing activity success in terms of profitability. In contrast, Hidden Costs have the lowest effect on the Outsourcing Balance improvement. Nevertheless, adjusting solely one determinant might not be sufficient for obtaining an optimal sourcing activity, thus, an outsourcing company should consider the most cost-effective strategy for targeting key determinant improvement.

Thus, as discussed in the Monte Carlo experiment, while Transaction Costs have a wide range of outcomes and potential to be minimised, an outsourcing company requires reevaluation of its supplier base and switching to suppliers with smaller distance, higher experience and willingness for long-term commitment. Similarly, Cost Savings and Hidden Costs involve contract renegotiation to increase supplier reliability to obtain lower solution price, however, still resulting in comparably lower profitability impact than Transaction Costs. On the other hand, while the Innovations and Workforce Savings Stock has relatively fixed range, an outsourcing company has high potential for increasing savings by focusing on internal restructuring and better resource allocation.

5.5. *Identifying critical parameters on the success of outsourcing*

For the purpose of forming a strategic approach, the parameters comprising each determinant are reviewed and assessed based on complexity of parameter adjustment from an outsourcing company perspective. Table 10 indicates the main fixed parameters affecting each determinant.

Closely observing the main fixed parameters, it can be inferred that Innovations and Workforce Savings Stock is highly dependent on company internal settings as it includes outsourcing company's ability to effectively

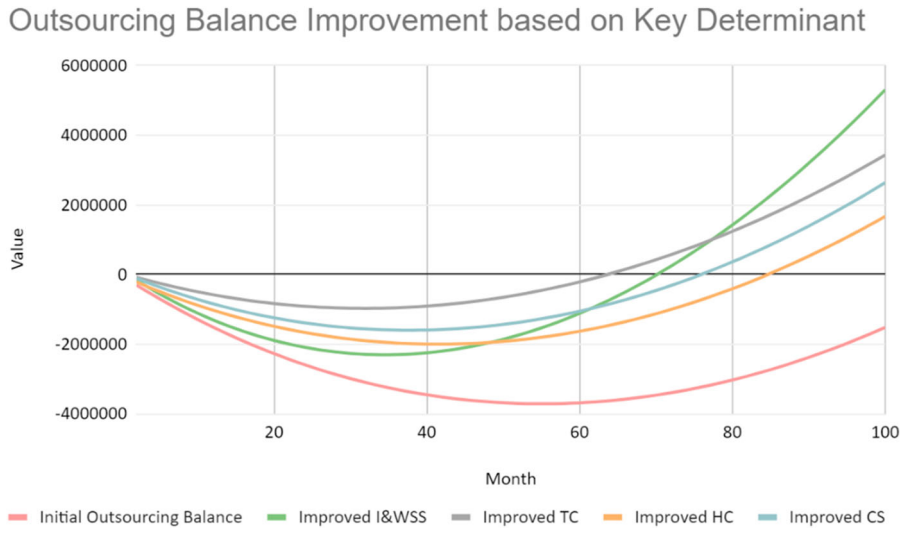


Figure 14. Fixed key determinant experiment.

manage its intellectual resources. On the other hand, Transaction and Hidden Costs are mainly associated with supplier parameters such as distance, risks and willingness to build a long-term mutually beneficial relationship. Lastly, Cost Savings are a mixture of initial company and supplier profiles, the complexity of component production and manufacturing abilities as well as the quantity allocation between suppliers.

In addition to the previous experiment, we also conducted a parameter variation experiment with those fixed initial parameters. This time we just considered one supplier only. In order to find those critical parameters of the outsourcing activity from our simulation model, each initial value from the validated simulation was changed from lowest to highest, and the results on the Outsourcing Balance were recorded for each change.

Table 11 shows 21 critical parameters that influence the success of the outsourcing activity. Variables are numbered with the importance scale from 21 to 1 (the higher the number the higher the importance), which also show the power of each variable's influence on the final outcome.

Those parameters were simulated one by one, five times each. Starting with the smallest input number and ending with the biggest. The values were changed according to their types. Percent-based ones were changed from 0 to 1 with an increment/step value of 0.2. Our simulation model has two types of multipliers. There are individual multipliers, like *Technological uncertainty* and *Risk of supplier moral hazard*, which change from 1 to 2 with the increment of 0.2. The second type of multipliers have values ranging between 0 and 2 that were changed with the increment of 0.4. These multipliers are connected to constant parameters, like *Total Workforce*, *Geographical Distance*, *Initial Sales*, etc. in order to compare their effects on the Outsourcing Balance to other variables, which have types of percentage, multiplier, etc. Units were changed from 0 to 20 with the increment of 4. After each change in the initial value, the Outsourcing Balance was calculated, and the results were compared in percent change. The idea for this is to see how the change of the variables effect the Outsourcing Balance (aggregate results of the whole simulation). Comparing the extent of the change for each parameter helps to define which critical parameter has the biggest influence on outsourcing and also underlines which determinant requires more attention and precision during decision making and planning process.

For determining the importance/strength of the critical parameter over the success of the outsourcing activity each of the 21 parameters were simulated separately and the following observations were made. The data collected from the different results of the simulation runs can be seen in Figure 15.

After collecting all data, the change between each run was calculated. The change between the runs can be found in Tables 12 and 13.

6. Discussion on key findings

6.1. Strategic recommendations: where to focus?

The matrix in Figure 16 depicts a categorisation of the four key stocks/determinants (as discussed in section 5.4) based on two parameters, determinant impact on the outsourcing strategy profitability based on its relative value (vertical axis; based on the analysis in Table 11) and difficulty to adjust the determinant internally due to the need of changing suppliers (horizontal axis). The

Table 10. Mapping of major fixed initial parameters to key stocks/determinants.

I&WSS	Cost savings	Transaction costs	Hidden costs
Productive conflict resolution	Initial sales	Number of deliveries	Control and transparency
Use of mediated power	Initial market share	Our experience with the supplier	Risk of supplier moral hazard
Communication	Avg. Process costs	Multiplier of geographical distance	Coercive influence
Initial ability to assess performance	Highly specialised processes	Predictability of demand behaviour	Stock costs
Initial Co-creation with the supplier	Risk of plagiarism	Multiplier of pre-contract transaction costs	
Initial control of outsourcing project	Quantity	Costs for lateness	
Initial ability to manage the outsourcing project	Embeddedness factor	Technological uncertainty	
Initial Tacit knowledge	Number of customers		
Multiplier of initial gain from innovation	Selling price		
Employee training	Initial process experience		
Cut percentage			
Multiplier of Total Workforce			
Multiplier of Monthly av. salary per employee			
Number of employees			

purpose of the proposed matrix is to provide manufacturing companies with a better understanding of key determinants and recommend a strategical approach for obtaining profitable outsourcing activity.

The Innovation and Workforce Savings Stock and Transaction Costs have the highest impact on company profitability due to comparably large values. While both determinants are similarly significant, an outsourcing company might find increasing the Innovation and Workforce Savings Stock more fruitful rather than decreasing Transaction Costs due to

(a). I&WSS mostly depending on company's internal efficiency in terms of the ability to manage outsourcing processes and the tradeoff of innovation potential for high savings,

(b). Transaction Costs are the result of supplier's poor performance, lateness costs due to large geographical and cultural distance, and unwillingness to cooperate.

Table 11. Critical parameters (I&WSS: Innovation & Workforce Savings Stock; TC: transaction costs; CS: Cost Savings; HC: Hidden Costs).

Parameter	Key determinant	Average change	Scale of importance
Cut percentage	I&WSS	538.91%	21
Multiplier of total workforce	I&WSS	220.82%	20
Multiplier of monthly av. salary per employee	I&WSS	219.00%	19
Our experience with the supplier	TC	216.34%	18
Multiplier of geographical distance	TC	33.14%	17
Multiplier of initial gain from innovation	I&WSS	16.06%	16
Initial Tacit knowledge	I&WSS	9.09%	15
Initial co-creation with the supplier	I&WSS	6.77%	14
Embeddedness factor	CS	6.30%	13
Number of deliveries	TC	5.64%	12
Highly specialised processes	CS	5.12%	11
Predictability of demand behaviour	TC	4.84%	10
Technological uncertainty	HC	3.82%	9
Risk of supplier moral hazard	HC	3.81%	8
Initial control of outsourcing project	I&WSS	3.10%	7
Control and transparency	HC	2.93%	6
Initial ability to assess performance	I&WSS	1.48%	5
Number of Customers	CS	0.97%	4
Initial Ability to manage the outsourcing project	I&WSS	0.73%	3
Multiplier of pre-contract transaction costs	TC	0.62%	2
Coercive influence	HC	0.15%	1

Therefore, to minimise Transaction Costs an outsourcing company needs to reevaluate the existing supplier base or renegotiate for more favourable terms, spending substantial number of resources.

Similarly, in addition to fixed costs, such as lateness or stock expenses, Hidden Costs are strongly influenced by external factors such as supplier special asset needs, relationship-specific investments, and cultural distance, therefore, are complex to adjust.

On the contrary, Cost Savings depend on company internal initial setup including its market share, sales, and process costs prior to outsourcing strategy implementation. However, the impact of Cost Savings is still comparatively insignificant, whilst Transaction and Innovations and Workforce Savings Stock are the primary determinants for the outsourcing strategy success.

Therefore, the recommended approach for improving the Outsourcing Balance is, first, targeting Innovations and Workforce Savings Stock through company internal decisions on workforce layoffs. On the basis of this internal decision processes, one may then evaluate whether to switch to other suppliers for obtaining significant improvements through decreasing Transaction

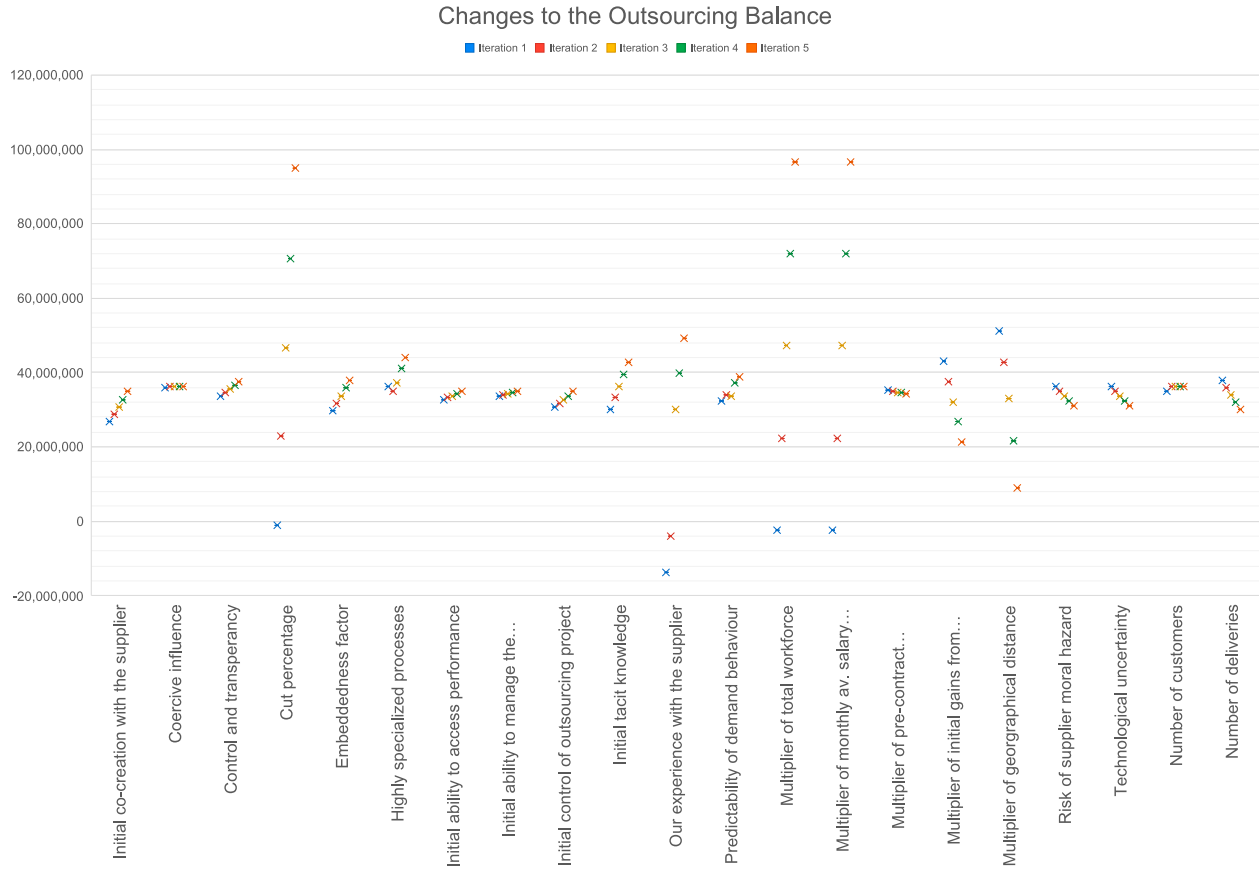


Figure 15. Impact of the critical parameters on the Outsourcing Balance.

Costs and renegotiating terms with suppliers to increase Cost Savings followed by decreasing Hidden Costs. In the following section, the concrete aspects on how best to fulfil these key determinants will be discussed.

6.2. Operational recommendations: how to focus?

In more detail, the simulation model reveals helpful findings on how to improve the key stocks/determinants. We will first outline the research findings and contributions and then give managerial recommendations.

- I&WSS: Laying off too many employees is detrimental

Our research shows that the cut percentage for laying off employees, as the most critical parameter, is a double-edged sword. Laying-off employees results in less personnel costs but for highly innovative companies (as per the assumption of this paper) leads to a decrease in the innovation potential. Companies need to find a proper balance.

Laying off employees (through the cut percentage) has a direct impact on employee motivation and efficiency. Our simulation model takes two points into consideration. The first one directly shows how much money is saved due to laid off workforce which effects the cost savings. The second point refers to how layoffs effect the motivation of other employees. If a big percentage of workforce is fired, then other employees start feeling unsafe and it also effects their work performance.

Additionally, the tacit knowledge that is kept within the company by individual employees is being lost if a big percentage of workforce is released. Our simulation shows that it is very important to keep the employees at a certain level and, ideally, not to outsource full processes that were done by employees inhouse previously or at least keep the knowledge on these processes inhouse. As can be seen in Figure 1, firing too many employees leads to a decrease in employee motivation, forcing (even more) quitting and attrition. The more employees quitting, the stronger the fear in the company, which will negatively be affecting the performance of both innovation and operations. Hidden costs and transaction costs increase, and the innovation potential is getting lost.

Other parameters that are highly dependent on the cut percentage are (1) the *Multiplier of Total Workforce* depicting the change in the total workforce is one of the critical parameters which has a big effect on the Outsourcing Balance, (2) the *Multiplier of monthly av. salary per employee* that determines the costs and savings for the

Table 12. Absolute changes of values of the critical parameters.

Changes of the outsourcing balance					
Value change (Type % 0–1)	0.2	0.4	0.6	0.8	1
Initial co-creation with the supplier	26,800,000	28,825,000	30,800,000	32,840,000	34,831,700
Coercive influence	36,100,000	36,150,000	36,200,000	36,260,000	36,320,000
Control and transparency	33,605,000	34,635,000	35,625,000	36,690,000	37,718,000
Cut percentage	−1,015,000	22,800,000	46,800,000	70,500,000	95,000,000
Embeddedness factor	29,690,000	31,740,000	33,800,000	35,859,000	37,910,000
Highly specialised processes	36,180,000	34,831,700	37,366,000	41,250,000	43,940,000
Initial ability to assess performance	32,840,000	33,330,000	33,830,000	34,330,000	34,831,700
Initial ability to manage the outsourcing project	33,830,000	34,080,000	34,330,000	34,580,000	34,831,700
Initial control of outsourcing project	30,830,000	31,840,000	32,840,000	33,830,000	34,831,700
Initial market shares	34,831,700	34,831,700	34,831,700	34,831,700	34,831,700
Initial tacit knowledge	30,130,000	33,260,000	36,390,000	39,530,000	42,660,000
Our experience with the supplier	−13,690,000	−3,990,000	29,978,000	39,680,000	49,380,000
Predictability of Demand Behaviour	32,350,000	34,000,000	33,650,000	37,300,000	38,950,000
Value Change (Multiplier 0–2)	0.4	0.8	1.2	1.6	2
Multiplier of Total Workforce	−2,290,000	22,450,000	47,200,000	71,950,000	96,700,000
Multiplier of Intial avg. process cost / unit	34,831,700	34,831,700	34,831,700	34,831,700	34,831,700
Multiplier of Monthly av. salary per employee	−2,307,000	22,450,000	47,210,000	71,970,000	96,720,000
Multiplier of Pre-contract transaction costs	35,150,000	34,930,000	34,720,000	34,510,000	34,290,000
Multiplier of Selling Price for each part	34,831,700	34,831,700	34,831,700	34,831,700	34,831,700
Multiplier of Initial Sales	34,831,700	34,831,700	34,831,700	34,831,700	34,831,700
Multiplier of Initial Gain from innovation	42,960,000	37,540,000	32,122,000	26,700,000	21,280,000
Multiplier of Geographical Distance	51,240,000	42,870,000	33,010,000	21,680,000	8,911,000
Value Change (Multiplier 1–2)	1.2	1.4	1.6	1.8	2
Risk of supplier moral hazard	36,130,000	34,830,000	33,530,000	32,229,000	30,928,000
Technological uncertainty	36,130,000	34,830,000	33,530,000	32,230,000	30,920,000
Value Change (Unit 0–20)	4	8	12	16	20
Initial number of products	34,831,700	34,831,700	34,831,700	34,831,700	34,831,700
New Product Introduction rate	34,831,700	34,831,700	34,831,700	34,831,700	34,831,700
Number of Customers	34,831,700	36,170,000	36,177,000	36,177,000	36,177,200
Number of Deliveries	37,760,000	35,800,000	33,850,000	31,900,000	29,940,000
Number of Suppliers	34,831,700	34,831,700	34,831,700	34,831,700	34,831,700

company in relation to the cut percentage, i.e. the higher the salary, the bigger the savings even if small percentage of workforce is layed off.

So, based on these findings and as a specific contribution to the research field of outsourcing we find a so-called innovation trap, i.e. getting rid of redundant employees due to outsourced processes saves costs but may reduce the company's innovation potential which in the long run, as can be seen in our model, will be highly detrimental.

So, for managers it is recommended to consider which and how many employees to release, i.e. highly capable employees with a extensive experience and specialist knowledge on products and processes may be kept and reassigned to other tasks (e.g. to quality assurance, etc.) so as not to lose the knowledge on those outsourced processes and parts since it is important to

(a). avoid demotivation among the workforce,
(b). stay innovative,
(c). be able to assess the quality of the outsourced parts,
(d). further improve those parts by qualified employees that than may train the supplier.

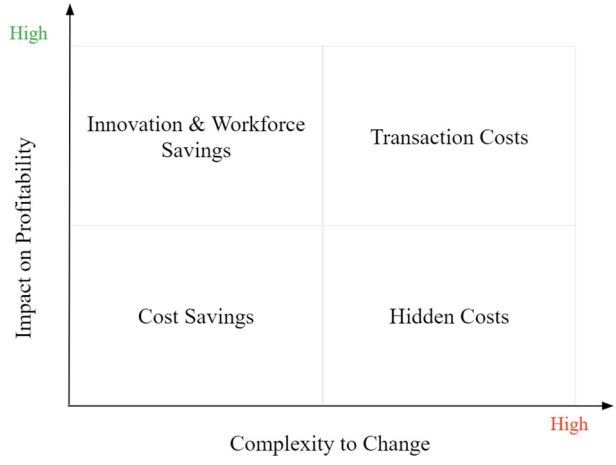


Figure 16. Outsourcing Determinant Matrix.

- Cost Savings: Finding a capable supplier is important

As per Figure 1, if the outsourced part is complex and highly specialised, then it is always better to have a capable supplier with high reliability and quality. Looking at the model, in certain cases, it is also acceptable to

Table 13. Percent changes of values of the critical parameters.

	Change percentage of the outsourcing balance					
Value change (Type % 0–1)	0.2	0.4	0.6	0.8	1	Average change
Initial co-creation with the supplier	0	7.56%	6.85%	6.62%	6.06%	6.77%
Coercive influence	0	0.14%	0.14%	0.17%	0.17%	0.15%
Control and transparency	0	3.07%	2.86%	2.99%	2.80%	2.93%
Cut percentage	0	−2346.31%	105.26%	50.64%	34.75%	538.91%
Embeddedness factor	0	6.90%	6.49%	6.09%	5.72%	6.30%
Highly specialised processes	0	−3.73%	7.28%	10.39%	6.52%	5.12%
Initial ability to assess performance	0	1.49%	1.50%	1.48%	1.46%	1.48%
Initial ability to manage the outsourcing project	0	0.74%	0.73%	0.73%	0.73%	0.73%
Initial control of outsourcing project	0	3.28%	3.14%	3.01%	2.96%	3.10%
Initial market shares	0	0.00%	0.00%	0.00%	0.00%	0.00%
Initial tacit knowledge	0	10.39%	9.41%	8.63%	7.92%	9.09%
Our experience with the supplier	0	−70.85%	−851.33%	32.36%	24.45%	216.34%
Predictability of demand behaviour	0	5.10%	−1.03%	10.85%	4.42%	4.84%
Value Change (Multiplier 0–2)	0.4	0.8	1.2	1.6	2	Average Change
Multiplier of total workforce	0	−1080.35%	110.24%	52.44%	34.40%	220.82%
Multiplier of initial avg. process cost / unit	0	0.00%	0.00%	0.00%	0.00%	0.00%
Multiplier of monthly av. salary per employee	0	−1073.13%	110.29%	52.45%	34.39%	219.00%
Multiplier of pre-contract transaction costs	0	−0.63%	−0.60%	−0.60%	−0.64%	0.62%
Multiplier of Selling Price for each part	0	0.00%	0.00%	0.00%	0.00%	0.00%
Multiplier of initial sales	0	0.00%	0.00%	0.00%	0.00%	0.00%
Multiplier of Initial Gain from innovation	0	−12.62%	−14.43%	−16.88%	−20.30%	16.06%
Multiplier of Geographical Distance	0	−16.33%	−23.00%	−34.32%	−58.90%	33.14%
Value Change (Multiplier 1–2)	1.2	1.4	1.6	1.8	2	Average Change
Risk of supplier moral hazard	0	−3.60%	−3.73%	-3.88%	−4.04%	3.81%
Technological uncertainty	0	−3.60%	−3.73%	−3.88%	−4.06%	3.82%
Value Change (Unit 0–20)	4	8	12	16	20	Average Change
Initial number of products	0	0.00%	0.00%	0.00%	0.00%	0.00%
New product introduction rate	0	0.00%	0.00%	0.00%	0.00%	0.00%
Number of customers	0	3.84%	0.02%	0.00%	0.00%	0.97%
Number of deliveries	0	−5.19%	−5.45%	−5.76%	−6.14%	5.64%
Number of suppliers	0	0.00%	0.00%	0.00%	0.00%	0.00%

have a below average supplier, but only if the outsourced part/component is simple to manufacture.

The embeddedness and reliability of the supplier determines the quality of the parts that the company receives. If the supplier has poor control over the manufacturing processes (i.e. less process experience) than there is a higher risk that the company will receive defective products. Defective products increase the unit price (thus reducing cost savings) and hidden costs. When outsourcing a simple part/component, which does not cost much to manufacture, this fluctuations in the quality of the orders can be roughly calculated so that there will be no big consequences on the costs side. But when the part/component is complex and highly specialised, then each defective product may cost the company much more, which in the long run might lead to the failure of the outsourcing activity. So, managers should also assess the embeddedness of suppliers in innovation networks.

It is noteworthy that if there is a high number of customers on the market similar to the outsourcing company, then the bargaining power of the supplier is higher. This parameter, however, is purely dependent on the supplier and the complexity of the part. Highly specialised processes require a supplier with up-to-date technological resources and capacities to manufacture a complex part. Such suppliers are harder to find compared to the ones that manufacture simple and standard parts.

The more the supplier invests in such novel processes, the more professionalised and specialised it will get in terms of production. As a result, after a certain period of time, the supplier's manufacturing costs will decrease, and simultaneously the supplier with this special knowledge and expertise will reach out to more customers so that the supplier's bargaining power towards the outsourcing company will increase and the supplier will gain an upper hand in further negotiations. The more customers on the market, the even higher the bargaining power of the supplier, which effects the unit costs for components and, as a result, affects the outsourcing balance.

The Cost Savings have a potential to be improved by adjusting allocated supplier manufacturing quantities, thus, influencing supplier's economies of scale, using cheaper input, supplier's expertise, as well as renegotiating supplier's solution price in case of company having considerable bargaining power.

So, as specific contribution to the research field of outsourcing we identified in above-discussed cases a power shift, i.e. a shift in the bargaining power from the outsourcing company to the supplier that ultimately may increase the costs and negatively affect the outsourcing balance in the long run.

So, it is recommended for managers to work with highly capable suppliers that are embedded in innovation networks and allocate larger amounts to them as well as agree on long-term contracts with favourable terms and conditions to avoid unjust price increases. The supplier's experience and expertise together with larger outsourcing quantities will lead to economies of scale at the supplier and will decrease the unit price, ultimately leading to higher cost savings.

- Transaction Costs: Strong collaboration with the supplier is beneficial

A strong collaboration with the supplier is very helpful. An initial co-creation with the supplier is important in the early phase of outsourcing. Either party has to invest time and has to work together to keep continuous improvements in the relationship in terms of operations. High co-creation ensures smooth operational processes and better control of the outsourcing activity, leading to lower costs and higher monetary gains.

According to the simulation model, the initial control of the outsourcing project has an effect on the outsourcing endeavour, but it is only considered to affect the results in the short-term. In the starting phase of the outsourcing project, it is necessary to have a control over all processes, and most importantly over the supplier's work. This parameter is critical in terms of the initial growth and the development of the outsourcing. If the control is low, then the growth and benefits will be small in the beginning, i.e. it is more likely that other parameters might have a stronger negative effect on the final success. Furthermore, if the company is not familiar with the technologies necessary for the successful operations with the supplier, then the result will be a drastic increase in hidden costs.

The better the relationship and the experience, the less the chance the outsourced manufactured parts will have defects. Besides that, as can be seen in the loops in Figure 1, the risk of plagiarism increases when there is a bad relationship between the supplier and the company. This also gets influenced by the experience and reliability of the supplier and geographical distance. The geographical distance determines not only transaction costs but also hidden costs that can outweigh the savings in the unit price which may lead to the failure of the whole outsourcing activity.

Additionally, the more complex the ordered part/component is, the higher the chance will be that its IP rights might get stolen and misused in the countries located far away. This causes a decrease in the innovation potential and, in the long run, will negatively be affecting the market shares and sales of the company. Similarly, the risk of supplier's moral hazard can also be associated with trust and relationship. If the supplier has moral hazards (similar to the risk of plagiarism), there will be a bigger chance that it will give up on the outsourcing company by selling orders to other customers or by decreasing the quality and efficiency of manufacturing and logistics operations.

So, as a specific contribution to the research field we see in certain circumstances in our simulation runs a plagiarism trap. Companies tend to have efficient relations with suppliers by cutting costs in transaction processes, but if they do so, the supplier tends to plagiarise.

So, for managers, it is recommended to work with suppliers as valued partners and closely together especially in the beginning of the partnership to reduce transaction costs that can be decreased by having effective project management, favourable and fair (initial) interfirm agreements, and stable and predictable demand behaviour. This will avoid IP infringements and will enable high-quality parts delivery. Additionally, an increase in transaction costs can be avoided by better knowledge on the technology and the supplier which will reduce cultural distance and improve knowledge on outsourced processes.

- Hidden Costs: Investing in the relationship reduces moral hazard

A continuous investment in the relationship with the supplier is beneficial. Hidden Costs are strongly influenced by less knowledge on the technology, loose collaboration and weak interaction with the supplier. The more this is pronounced the higher the hidden costs will be.

Although the impact of technological uncertainty on the outsourcing activity is low compared to other critical parameters (see Table 11), it still affects the increase or decrease in hidden costs. If the company is not familiar with the technologies necessary for the successful operations with the supplier, then the result will be a drastic increase in hidden costs.

As can be seen in Table 1 and the overall model in the Supplements, besides initial parameters, such as transportation costs (costs per km) or stock costs, all loops have a connection to hidden costs mainly through cultural distance, reinternalisation costs, and risk of supplier moral hazard.

Based on our analyses in this paper, we identified a knowledge trap that can be seen as another specific

contribution to the respective research field. This means that the outsourcing company will in any case loose (some or all of its) knowledge on the outsourced processes which will then increase the hidden costs and negatively affect the outsourcing balance.

So, in an effort to control hidden costs it is recommended for managers to invest in mutual relationship-specific investments and build trust to avoid supplier moral hazard (as discussed above) and cultural distance as well as stay up-to-date with the technology related to the outsourced part and processes to avoid technological uncertainty.

6.3. General discussion

Overall, it can be said that during outsourcing the company faces a number of tradeoffs to be solved in order to have a positive outsourcing balance consisting of costs (Hidden costs and Transaction costs) on the decrease side and savings (Innovation and workforce savings and Cost savings) on the increase side. The main tradeoffs that can be identified are shown by stocks, explained in Table 1. Thus, managers of innovative companies with rather complex parts need to understand and decide if they prefer to deal with higher costs but highly utilise their innovation potential and assets, or to keep costs lower and reduce their potential to innovate. Every company has a different infrastructure, produces different products and aims at different markets. Therefore, the setting for each one is unique.

In general, for highly innovative companies that outsource complex parts, it is a great risk to pick a supplier they do not know well and that may end up performing below-average with poor portfolio and is located far away. Even if the offered price for the outsourced part is much less compared to the in-house production or some other suppliers, still there is a risk that the outsourcing company will end up drastically decreasing the Outsourcing Balance by increasing the transaction and hidden costs. Additionally, if the supplier is hard to communicate and work with coupled with large layoffs, the innovation potential of the company gets lost, which adds up to the other costs and accumulates to very large numbers. Therefore, such cases will lead to the failure of the outsourcing activity in the long run.

If the outsourcing company's part/component is not highly innovative (i.e. a standard part), then the most important requirement becomes a cheap and reliable supplier. If the supplier can provide cheap parts/components, then the only risks that can hurt the company will be costs. Considering the geographical distance of the supplier, transaction costs can increase. Together with that, if the supplier is of average or mediocre expertise and experience, there is a risk that the company will receive defective products from time to time. This fluctuation in quality leads to increases in hidden costs on the one hand and increases of the unit price offered by the supplier on the other.

7. Final considerations and outlook

Our model has proven to enable a thorough strategy evaluation by predicting the future impact of each outsourcing decision. The Outsourcing Balance provides an estimation of the overall profitability due to supplier choice. The key stocks or determinants configuring the Outsourcing Balance depict the profitability of the strategy for different areas in supply chains. The behaviour of success determinants pinpoints the causalities of each decision, enabling the user to run multiple outsourcing scenarios for strategy re-evaluation.

Moreover, our sourcing model validation demonstrates that some parameters are more influential on the system output than others. The objective of developing a feasible framework for enabling outsourcing companies to evaluate their strategic sourcing decisions for supplier selection has been accomplished with our System Dynamics modelling approach. The methodology allows for various outsourcing decision simulations and predicts the outsourcing company performance trends in long-term perspective based on complex system configurations.

Furthermore, the key determinants or stocks of the system, i.e. Innovation & Workforce Savings, Cost Savings, Transactions Costs, Hidden Costs, indicate the areas of improvement and profitability to enable success assessment. The outsourcing decision-making simulations are capable of assisting the outsourcing company in

a. identifying cost-effective and profitable supplier setup which align with the company needs,
b. determining the success of outsourcing by referencing the key stocks/determinants,
c. re-evaluating the strategic sourcing approach and individual decisions by identifying the areas of improvement.

It is significant to mention the limitations of the model developed as these indications will better reveal the topics to target for future research. The preliminary purpose of our model is to establish a valid foundation as a feasible framework for an outsourcing decision-making system for manufacturing-based relationships. However, the current version of the SD model only depicts deterministic events and variables of the outsourcing processes and does not encompass the stochastic external

factors such as various supply chain risks. Thus, further model enhancements are required to incorporate economic, environmental and socio-political aspects for improving the precision of predicted system behaviour, including the supply chain disruption probabilities and respective risks.

The model described in this paper has a big spectrum for further applications and research. There is room for creation of numerous new scenarios, and there are plenty of opportunities for analysing the dynamic environment of an outsourcing endeavour. It is important to mention that our simulation model itself can be extended with new loops and causal relations. For example, ethical sourcing dynamics can be added to the model as well. Sourcing from low wage countries is always critical since poor work standards and unlawful exploitation of workers within the factories of such cheap suppliers can happen. Those firms are exposed more and more by media outlets which evoke public outcries. So, initially low prices may be offset by being sued and forced to pay reparations. These would lead to a negative outsourcing balance in the long run, let alone irreversible damages to the company's reputation. Apart from that, the coopetition effect as proposed by Deng, Guan, and Xu (2021) could be integrated in the model as well, since they put forward that a supplier serving two customers that are competitors exhibits better learning-by-doing effects which may lead to cost decrease and thus higher profit for either outsourcing company.

Furthermore, service-related outsourcing dynamics may be addressed as well. Here, it would be interesting to investigate how to adjust our model with additional variables and feedback loops and how to skip manufacturing-related variables and loops. Ideally, using higher level variables that dynamically deactivate unnecessary variables and loops as well as activate required ones may be suitable.

The findings of this research also provide potential for further investigation of the dual outsourcing strategy. Our model is a powerful tool to determine the most profitable and successful outsourcing strategy which essentially suits the needs of the company. The extent of the model ability to support the outsourcing decision-making process is plausible due to its allowance for system in-depth analysis. The conducted research contributes to the future examinations of dual sourcing strategy by validating the SD simulation effectiveness. Additionally, it provides a methodology for improving outsourcing activity success by guiding an outsourcing company through most significant profitability determinants. Therefore, there is enormous potential for further development of SD outsourcing decision-making system by expanding its range of applicability for various outsourcing strategies. Furthermore, the model might serve as a tool for examining multiple widely adopted and debated procurement activities such a reshoring, multi or hybrid-sourcing. As to reshoring, it can be said that many companies move back to in-house production after outsourcing overseas because of the discussed critical parameters which in long-term perspectives can affect the outsourcing activity negatively.

Overall, it can be concluded that our simulation model can be used to understand the risks associated with making outsourcing decisions and can be helpful for managers to define the trade-offs that will be met over time. Our model performs well and is calibrated and validated by using real-world data and cases. Nevertheless, fluctuations may occur between the model's results and real-world results which mainly goes back to hardly quantifiable values as well as categorical values that can only be modelled in pre-defined steps.

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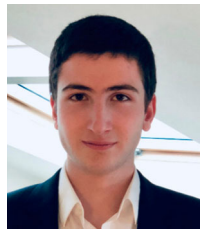

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No potential conflict of interest was reported by the author(s).

Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary materials. Any other data that support the findings of this study are available from the corresponding author upon request.

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