Cost estimation accuracy in supply chain design

The role of decision-making complexity and management attention

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Abstract

Purpose – The purpose of this paper is to investigate how management attention and supply chain complexity affect the decision-making process and cost estimation accuracy of supply chain design (SCD) decisions.

Design/methodology/approach – The research follows an embedded case study design. Through the lens of the behavioural theory of the firm, the SCD decision process and realised outcomes are investigated through longitudinal data collection across ten embedded cases with varying degrees of supply chain decision-making complexity and management attention.

Findings – The findings suggest that as supply chain decision-making complexity increases, cost estimation accuracy decreases. The extent to which supply chain decision-making complexity is readily recognised influences the selection of strategies for information search and analysis and, thus, impacts resulting cost estimation errors. The paper further shows the importance of management attention for cost estimation accuracy, especially management attention based on conflicting goals induce behaviours that improve estimation ability.

Research limitations/implications – A framework proposing a balance between supply chain decision-making complexity and management attention in SCD decisions is proposed. However, as an embedded case study the research would benefit from replication to externally validate results.

Originality/value – The method used in this study can identify how supply chain complexity is related to cost estimation errors and how management attention is associated with behaviours that improve cost estimation accuracy, indicating the importance of management attention in complex supply chain decision-making.

Keywords Case study, Supply chain design, Hidden cost, Supply chain complexity, Behavioural theory of the firm, Cost estimation, Management attention, Supply chain decision-making

Paper type Research paper

Introduction

Supply chain design (SCD) decisions define a company's operating structure and form the basis for operational performance. SCD has primarily been treated as a configuration problem, in which mathematical problems are formulated to identify an optimal design according to predetermined performance criteria (Meixell and Gargeya, 2005). However, as supply chains become increasingly complex (Bozarth *et al.*, 2009) and the foundation for supply chain decision-making becomes increasingly uncertain (Christopher and Holweg, 2017), the academic and managerial relevance of developing increasingly sophisticated mathematical models for SCD has been questioned (Christopher and Holweg, 2017; Ferdows *et al.*, 2016). In parallel the mathematical approach to SCD has been supplemented by qualitative contributions. Examples include research on the benefits and modes of partnership (Lambert and Cooper, 2000), governance modes for global value chains (Gereffi *et al.*, 2005) and methods of ensuring congruence in supply network configurations

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(Ferdows *et al.*, 2016). However, few studies focus on decision-making processes in supply chain management (Manuj and Sahin, 2011). Specifically, while SCD principles are well researched, the process of making SCD decisions in organisations has been neglected. Further, while the behavioural aspects of decision-making processes have gained increasing attention in supply chain management (e.g. Carter *et al.*, 2007), extant research has focused on operational decisions made at the individual level (e.g. ordering decisions) rather than group or cross-group decisions at the tactical or strategic level (Schorsch *et al.*, 2017). Indeed, Wieland *et al.* (2016) pointed to a limited understanding of "handling complexity when making joint SCM decisions" (p. 210).

The need to better understand SCD decision making is evident: SCD changes can lead to hidden costs (Larsen *et al.*, 2013; Fratocchi *et al.*, 2016), and there are numerous examples of decisions based on erroneous managerial assessments subsequently being reverted (Foerstl *et al.*, 2016). Such cases emphasise the importance of an improved understanding of SCD decision-making processes and the factors influencing decision-making effectiveness (Kaufmann *et al.*, 2009).

This research extends existing research on how supply chain complexity influences decision-making complexity (Manuj and Sahin, 2011) and cost estimation accuracy (Larsen *et al.*, 2013) by exploring how these variables interact. While complexity explains decision makers' bounded rationality and how estimation errors occur, it does not account for decision makers' behaviours. Marshall *et al.* (2015), for example, found that political goals affect actors' self-interest in decision making, impacting behaviours in outsourcing decision making. Conflicting goals among decision makers could result in either constructive debate, which could reduce erroneous assumptions (Lindblom, 1959) and increase cost estimation accuracy, or a competitive environment, in which a lack of trust and collaboration could exaggerate estimation errors (Simmers, 1998). Similarly, while some decisions are starved of management attention, others receive heightened focus (Nadkarni and Barr, 2008). It is not clear how such aspects of managerial behaviour influence the accuracy of cost estimates in SCD decisions.

Building on the behavioural theory of the firm (BTF) (Cyert and March, 1963), this research contributes to the understanding of how SCD decisions are influenced by management attention and supply chain complexity. To explore this topic, the following research question is posited:

RQ. How do management attention and supply chain complexity affect the decision-making process and cost estimation accuracy of SCD decisions?

While SCD changes are associated with such objectives as cost reductions, market access, access to technology and flexibility (Ferdows *et al.*, 2016), in this research, decision-making effectiveness is measured by the accuracy of cost estimations. This perspective on the effectiveness of decision-making does not encompass all intended outcomes of SCD changes, however cost is a critical performance measure driving SCD (Krægpøth *et al.*, 2017). Furthermore, searches for alternate SCDs are usually initiated based on quantitative goals like costs (Kirchoff *et al.*, 2016).

The research question is addressed through an embedded case study at a leading global original equipment manufacturer (OEM) of complex capital-intensive goods. The case study investigates ten cases of SCD change with varying degrees of supply chain complexity and management attention.

The paper is structured as follows. The next section describes the theoretical background concerning how supply chain complexity and management attention relate to SCD decision making through the lens of the BTF. Then, the research methodology is presented, followed by a discussion of the case findings. Finally, the conclusion summarises the findings and identifies areas for further research and research limitations.

Theoretical background

SCD decisions and decision-making complexity

SCD decisions can be defined as "decisions regarding the number and location of production facilities, the amount of capacity at each facility, the assignment of each market region to one or more locations, and supplier selection for sub-assemblies, components, and materials" (Meixell and Gargeya, 2005, p. 532). These decisions are non-repetitive, span multiple stakeholders, relate to discrete changes in the configuration of resources and define frameworks for procurement, production, warehousing, transport, planning (Klibi *et al.*, 2010), research and development (R&D) and engineering (Handfield and Lawson, 2007).

The assessment of expected outcomes is a critical step in the SCD process (Fredriksson and Jonsson, 2009), as the supply chain's importance for cost performance and the low reversibility of SCD decisions increase the importance of accurate *ex ante* cost estimations (Klibi *et al.*, 2010; Foerstl *et al.*, 2016). The wide-ranging impact of SCD decisions entails cost consequences beyond direct product cost. SCD decisions, thus, impact coordination (MacCarthy and Atthirawong, 2003; Schulze *et al.*, 2012), inventory build-up, service level (Meixell and Gargeya, 2005) and exposure to and ability to cope with uncertainty (Klibi *et al.*, 2010; Christopher and Holweg, 2017). In sum, accurately estimating the cost of future alternative SCDs is a complex task.

Our work build on the definition of supply chain decision-making complexity proposed by Manuj and Sahin (2011) to reflect "the difficulty faced by a decision-maker when managing a supply chain. It [supply chain decision-making complexity] is a measure of the collective effort required for problem definition, data collection, problem analysis, solution implementation, and control" (Manuj and Sahin, 2011, p. 523). Existing research emphasise the difficulty of decision making resulting from the complexity of the supply chain, as indicated by "the structure, type and volume of interdependent activities, transactions, and processes in the supply chain" (Manuj and Sahin, 2011, p. 523), the extent of changes to the supply chain (Asmussen *et al.*, 2017) and the level of dynamism (Bozarth *et al.*, 2009). Kaufmann *et al.* (2009) identified strategies for extending the boundary of rationality by assessing multiple perspectives and decomposing the decision problem to reduce bias in complex supply-related decision making.

SCD decisions are often researched assuming an ability to understand the dynamics of alternative SCDs (Tang and Musa, 2011), and that a structured process yields the best possible decision-making (Fredriksson and Jonsson, 2009). While research addressing the bounded rationality of decision-makers assumes a mechanistic relationship between supply chain decision-making complexity and cost estimation errors (Manuj and Sahin, 2011; Larsen *et al.*, 2013) by not accounting for how decisions are made. Thus, potentially missing important insights that could improve SCD decision making. The next section introduces the BTF as the theoretical lens for analysing the SCD decision-making process.

Behavioural theory of the firm

As people's cognitive abilities related to gathering information and computing outcomes are limited (e.g. Arrow, 1986), individuals are not capable of investigating all alternative outcomes in complex decision-making to reach an optimal equilibrium, as assumed by standard economic theory. We build on elements from the BTF (Cyert and March, 1963) to gain deeper insights into the decision-making process and its behavioural frame. The BTF has been used as a theoretical lens for researching supply networks (e.g. Eriksson *et al.*, 1997), building on the assumption that, to mitigate uncertainty and decision-makers' bounded rationality, SCD change should be considered an "incremental learning process, where trial and error, exploration and knowledge transfer are the critical variables" (Camuffo *et al.*, 2007, p. 372) reflecting evolutions in both decisions and SCD. We, on the contrary, focus on decision making itself to explore what influences the accuracy of complex supply chain decision making.

The BTF introduces bounded rationality and its role in decision-making processes (Cyert and March, 1963). The decision-making process is linked to core elements of the BTF: satisfying rather than maximising, the aspirational level initiating problemistic search and the decision process serving sequential goal fulfilment (Greve, 2008). If performance is not meeting aspirational levels, then a search is commenced for alternative solutions (Kirchoff *et al.*, 2016) that can serve varying goals (Greve, 2008). However, as search is simple minded and biased (Kaufmann *et al.*, 2009) and the impacts of SCD changes are cross-functional, standard search behaviours entail a risk of estimation errors, if such bias are not addressed.

Management attention

Research suggests that management attention reduces uncertainty in supply-related decision-making (Wouters *et al.*, 2009; Riedl *et al.*, 2013). Management attention can be understood as "the noticing, encoding, interpreting, and focusing of time and effort by organisational decision-makers on both (a) issues: the available repertoire of categories for making sense of the environment: problems, opportunities, and threats; and (b) answers: the available repertoire of action alternatives: proposals, routines" (Ocasio, 1997). Thus, it reflects the "degree to which something (an event, trend, idea, category, etc.) occupies the consciousness of individuals" (Cho and Hambrick, 2006). Management attention on SCD decisions can have different effects. For example, the use of cross-functional decision-making committees foster rational decision making by extending the boundary of rationality by including various supply chain functions in the decision-making process (Kaufmann *et al.*, 2009). In addition, multiple cross-functional stakeholders are expected to propose multiple alternative and conflicting solutions (Wouters *et al.*, 2009), leading to additional search and detail-gathering efforts (Shimizu, 2007). Senior management expectations concerning justifications for decisions also lead to increased information gathering (Wouters *et al.*, 2009; Riedl *et al.*, 2013), resulting in more comprehensive decision making. While management attention has been found to reduce perceived uncertainty and increase perceived decision making success for supplier selection, it is unclear whether similar effects can be expected for more complex multi-dimensional decision-making, such as SCD changes, in which higher levels of information asymmetry between project teams and decision-makers potentially diminish senior management's ability to improve decision-making accuracy (Wouters *et al.*, 2009).

Research design

This explorative study investigates the interplay between supply chain decision-making complexity and management attention and their effects on cost estimation accuracy through the perspective of the BTF. The unit of analysis is the decision-making process, and effectiveness is assessed as a decision's accuracy in terms of deviations between *ex ante* predictions and *ex post* realised costs. Case studies are useful for researching the decision-making process because they operate at the intersection of theory, structures and events, enabling this research to ground theoretical concepts in reality by investigating a phenomenon in its real environment using multiple sources (Stuart *et al.*, 2002).

The decision-making process is influenced by several organisational elements, such as political goals (Gavetti *et al.*, 2012) and the perceived importance of decision speed (Perlow *et al.*, 2002). To control for the impacts of such intervening factors and isolate the effects of supply chain decision-making complexity and management attention, an embedded case study design was used (Yin, 2013). A longitudinal approach was chosen to examine each SCD decision as an evolving process (Karlsson, 2008).

Several factors were pivotal in the selection of the case company. First, the researchers sought an OEM engaged in extensive SCD work, with a globally dispersed manufacturing network. This allowed the researchers to follow a range of SCD cases within an organisation with experience working with SCD changes. Additionally, the case company was driven by a strong cost focus, which enabled the researchers to study cost estimation accuracy in an accuracy-critical environment. Finally, the OEM had maintained its industry-leading position for several decades in an industry characterised by several supply- and market-side transitions, making it suitable as a case company for investigating SCD decision-making.

Two criteria were used to identify suitable embedded cases. First, to ensure the relevance and importance of cost estimation accuracy, the projects and decision making needed to be driven primarily by cost considerations. Second, the SCD decisions needed to concern sufficiently high costs to merit considerable effort. A threshold of €1m in annual cost impact was chosen to ensure high-stake decision making. From 2014 to 2017, ten SCD decisions complying with these criteria were made and implemented. These ten decisions related to eight sub-parts of the OEM's supply chain and are listed in order of initiation in Table I. Two sub-parts underwent two decision-making processes (B.1+B.2 and D.1+D.2). For B.1 and D.1, decisions were made, however, early in the implementation, new decision-making processes were initiated thereby changing the previous decision. Therefore, though the results for B.1 and D.1 are not complete, the results leading to a need to reassess the decisions can be analysed.

To ensure dispersion in terms of both supply chain decision-making complexity and management attention to enable replication (Yin, 2013), the researchers included all SCD decisions driven primarily by cost within the three-year scope. The dispersion in both supply chain decision-making complexity and management attention substantiated the theoretical sampling used to address the identified research question (Dubois and Araujo, 2007).

Data collection

From 2014 to 2017, data were collected on the *ex ante* cost predictions, decision processes, implementation processes and *ex post* realised outcomes of the SCD projects. During this time period, two authors spent 50 per cent of their time physically present at the OEM's headquarters, manufacturing locations and suppliers.

The data collection entailed interviews, observations and reviews of emails, meeting minutes, PowerPoints, Excel spreadsheets and other case-relevant documentation. In total, 68 semi-structured interviews were conducted with project, sourcing, production and R&D managers, as well as finance partners and executive decision makers. *Ad hoc* talks and informal discussions provided additional insight and context to the decision processes. A key element was the researchers' participation in ongoing status meetings for each project, normally on a monthly or bi-weekly basis. Direct observations from steering committees and decision meetings provided insight into the decision-making processes, the materials available at the point of decision and the assumptions and behaviours of individual decision makers. For each of the cases, quantitative data were collected regarding prices, inventory levels, labour hours, quality and delivery time to derive cost estimation accuracy and control for changes. Additionally, review meetings were conducted with key stakeholders and finance department representatives from each case to assess realised cost performance and identify any deviations to the cost estimations presented at the point of decision making. This ensured broad stakeholder involvement and a clear documentation of cost estimations, which increased the internal validity of the findings through data source triangulation and

Case	Description	Driver for supply chain design	Annual spend (mEUR)	Supply chain decision-making complexity	Management attention	Cost estimation error
A	Outsourcing assembly line for auxiliary module to supplier of key component	Total cost reduction. Freeing up facility	15–25	Medium (2)	Low (1)	Significant (2)
B.1 and B.2	Offshoring assembly of module from European and US factory to Indian facility	Total cost reduction. Utilising available production capacity in India	25–75	High (3)	Low (1) → High (3)	Critical (1) → Marginal (3)
C	The case considered outsourcing of wire production conducted in Chinese factory to a specialized domestic supplier	Total cost reduction. Avoiding investments in production equipment	1–5	Medium (2)	Medium (2)	Marginal (3)
D.1 and D.2	From a situation of make and buy of an auxiliary module. Decision concerning transfer of design, production and distribution responsibilities to existing global suppliers	Total cost reduction. Utilising supplier competences for improving product design. Freeing up warehouse space at regional factories	1–5	High (3)	Low (1) → High (3)	Critical (1) → Significant (2)
E	Hydraulic module was delivered from two European suppliers to regional assembly factories. Suggested to utilise internal factory in India for assembly of module, as well as qualifying local Indian suppliers of sub-components	Total cost reduction. Supporting Indian market development	1–5	Medium (2)	Medium (2)	Marginal (3)
F	From a situation of make and buy to buy only of two machined parts. Transfer of production equipment to existing supplier already delivering machined parts	Total cost reduction. Reducing complexity of sourcing setup. Focusing factory on core-competences	1–5	Low (1)	Low (1)	None (4)
G	Outsourcing pre-assembly of steel structure to Chinese supplier of welded components	Total cost reduction. Reducing complexity of regional assembly factories	5–10	Medium (2)	High (3)	Significant (2)
H	Outsourcing pre-assembly of steel structure to Chinese supplier of welded components	Total cost reduction. Reducing complexity of regional assembly factories	1–5	Medium (2)	High (3)	Marginal (3)

Table I.
Case overview

avoided reliance on perceptual performance measures. The information for each case was consolidated in a continuously developed case protocol, which provided a rich dataset for ongoing coding and analysis. These procedures addressed the shortcomings of previous survey-based research on cost estimation accuracy (Larsen *et al.*, 2013). Further, the avoidance of perceptual performance measures strengthened internal validity and reduced exposure to recall biases and post-rationalisation, as supply chain professionals struggle to quantify the outcomes of supply chain decision-making *ex post* (Manuj and Sahin, 2011).

Data analysis

The data analysis builds on a within-case analysis (Eisenhardt, 1989) to formulate case narratives for each decision process and the influences of supply chain complexity and management attention on cost estimation accuracy. Following the initial analysis, the ten cases were compared to explore patterns across the varying levels of supply chain decision-making complexity and management attention.

Ordinal scales were used to reduce the case data (Ketokivi *et al.*, 2017) within the three constructs: supply chain decision-making complexity, management attention and cost estimation error. Supply chain decision-making complexity and management attention were assessed based on three-category ordinal scales: low (1), medium (2) and high (3). For the former, changes in item numbers, suppliers, manufacturing locations, downstream locations and global connections were combined with codes from the decision process to determine decision difficulty, which was further discussed with company employees to achieve assessment congruence. The latter was based on the scope and intensity of managerial involvement in decision making. "Low" reflected involvement by only the immediately affected functions, usually managers, directors and, in some cases, vice presidents. Reporting and decision making were conducted through existing reporting structures or a few dedicated meetings with management. "Medium" reflected the involvement of management levels above those directly impacted, such as vice presidents and senior vice presidents, with reporting through existing reporting structures and/or a few dedicated meetings with management. "High" reflected cases involving higher-level management and frequent dedicated meetings. Cost estimation errors were classified into two types relating to either the scope of cost calculations or the estimated numerical value. Combining these two, the consequence of the cost estimation error was then assessed according to a four-category ordinal scale reflecting the error's severity: critical (1), significant (2), marginal (3) or none (4). "Critical" meant that the decision was not satisfying and that alternative SCDs were expected to have performed better. "Significant" reflected substantial deviations to the expected cost scenario. For significant errors, while the chosen solution remained the most rational alternative, decision-makers might have prioritised resources differently, considering the realised cost performance. "Marginal" referred to cases involving only minor deviations between expected and realised outcomes that did not challenge the initial decision. "None" meant that the actual performance matched predicted performance. The ranking was assessed based on the detailed case evidence in collaboration with involved stakeholders and the finance department at the case company. Tables AI–AIII contain the details of the data reduction for the three variables (supply chain decision-making complexity, management attention and cost estimation error, respectively).

Case findings

Drivers of supply chain decision-making complexity and the impact on SCD decisions

A detailed analysis of the cases provided insight into the link between supply chain complexity and decision-making complexity and its consequences for the decision-making process, as summarised in Table II.

It was evident that supply chain decision-making complexity did not directly result from the number of items or suppliers. Instead, decision-making complexity increased when the number of impacted stakeholders and their heterogeneity increased. Differences among

Table II. Supply chain characteristics linked to supply chain decision-making complexity

Supply chain complexity	Impact on supply chain decision-making complexity	Issue for decision-making process	Explanatory quote	Observed in case
Number of items	Different sourcing responsible impacted	Late involvement of impacted stakeholders	"We have not been involved in this until know. I don't know what assumption underpins this and the decision to outsource" (Manager, Sourcing)	B.1, H
		Disconnect between system data and reality	"I just used the data supplied by the system, but apparently that was faulty, and 100 times higher than actual cost" (Project Manager, Manufacturing)	B.1, H
Bottleneck items impacted	Capacity constraints on individual suppliers	Use of standard cost not reflecting cost if volumes are changed	"It is difficult to establish a baseline for this. Because it depends on how the volumes are split across different locations, what the demand is for each region and not only for this module, but also all our other products" (Manager, Sourcing)	B.1, G, H
	Long qualification time for new suppliers	Postponing realisation of projects or requiring the use of alternative suppliers	"The supplier has not been approved, so we need to import the components from our existing European supplier" (Manager, Sourcing)	D.2, G
Extent of global operations	Exogenous uncertainty	Changing exchange rates	"The cost competitiveness of the different solutions is dependent on how the exchange rate develops. But we don't have any guidelines for considering exchange rate uncertainty" (Manager, Sourcing)	B.1, D.1, E
		Changing demand	"Selecting the best cost solution depends on how the demand is split across the different regions" (Manager, Sourcing)	D.1
	Diversity in local market, financial, political and legislative conditions	Unexpected up- or downstream dependencies	"Due to the unstable financial conditions of the Indian market, we are hedging our contribution margin when selling. By producing locally and exporting we can obtain a natural hedge, significantly reducing our hedging cost" (Specialist, Finance)	D.1
Number of production facilities	Diversity in stakeholder demands	Late involvement of impacted stakeholders	"There are different possibilities for receiving goods in the different factories. While the two European facilities have the crane, the equipment required for receiving the goods, it is necessary to invest in this in the Chinese factory" (Project Manager)	G, H
Extending lead times and longer planning horizons	Changing operational dynamics	Erroneous prediction of system behaviour	"We need to plan manually the split between the two suppliers to accommodate the volume agreements. It takes quite some time, but also makes it more difficult to forecast correctly. Especially with the longer time horizons" (Production Planner, Manufacturing)	A

stakeholders' resource positions, strategies and needs increased the need for information collection, processing and alignment. Diverse and unaligned needs manifested in relation to both the number of items (B.1, H, i.e. impacted sourcing managers responsible for different categories and working with different sourcing strategies) and the number of production facilities (G, H, i.e. different resource positions across factories). Consequences occurred when the impacted stakeholders were not involved until late in the decision making or implementation process, creating a disconnect among system data, decision assumptions and those who could easily validate both. Incorrect master data or simplistic assumptions regarding detailed aspects of the supply chain (e.g. supplier commitments or available production equipment) led to significant cost estimation errors. The consequences were severe when such alignment issues were related to bottleneck items critical for cost performance (B.1, H).

Bottleneck items were, thus, also a substantial driver of decision-making complexity. For capacity-constrained items with cost differences among alternative suppliers, cost performance was dependent on volume allocations, which again created dependencies across factories. Hence, cost estimations became dependent on factors exogenous to the decision (i.e. demand swing for a factory in a different region), increasing the difficulty of quantifying the cost impact of an SCD change (B.1, G, H). Further, for bottleneck items, qualifying new suppliers was a tedious process, increasing the difficulty of accurately predicting implementation timelines and, thereby impairing cost estimation accuracy (D, G).

The extent of global operations amplified exposure to exogenous changes in demand and exchange rates, both of which increased supply chain decision-making complexity. Some of the introduced supply chain decision-making complexity involved determining which set of exchange rates to use. Further, system data entered in a single currency obscured currency conversions, resulting in several calculation errors causing significant cost estimation errors (B.1). Finally, there was no effort to explicitly consider (e.g. through scenario planning) the decision-making complexity caused by increased exposure to foreign exchange rates and demand swings (B.1, D.1, E).

Global operations introduced different market and legislative characteristics that influenced cost estimations in seemingly unrelated decision-making processes. In case D.1, exporting out of India would have reduced hedging costs when selling to the domestic Indian market. The need to consider such local conditions in global SCD decisions significantly increased supply chain decision-making complexity. However, this local benefit was not captured in the decision making focused on ensuring the lowest global landed cost, resulting in a significant scope error.

Changing lead times and planning horizons similarly increased supply chain decision-making complexity by introducing discussions on how such changes influenced operational performance, mainly inventory levels, requiring decision makers to weigh, for example, extended lead times against reduced purchase prices. The failure to adequately address such operational dynamics resulted in unexpected consequences, leading to an overestimation of the reduction in inventory when production was outsourced (A).

To cope with non-trivial (medium and high) supply chain decision-making complexity, project teams deployed different strategies, as depicted in Figure 1.

In cases with evident supply chain decision-making complexity, the project team began by explicitly identifying a suitable strategy for the decision task. For example, in case C, the sourcing manager commented: "We have 1200 different items; we cannot obtain a quotation and cost for all of these items. We need to find a way of making this simpler". This called for a structured approach to identify a sample of 20 representative wire sets for the cost estimation. The deliberate choice of sampling as a strategy for reducing supply chain decision-making complexity raised a discussion on the need to ensure the cost estimation accuracy through control mechanisms, such as a detailed validation of inputs (e.g. purchasing prices and process times). This detailed validation process resulted in several revisions to the cost estimations, thereby improving the cost estimation accuracy by setting an aspirational level for the validity of the cost estimation in addition to the aspirational level for the estimated cost performance.

By contrast, less evident supply chain decision-making complexity led to fewer deliberate and explicit discussions of suitable strategies for information search and analysis. In Case G, a manufacturing specialist commented: "This should be simple. It is just moving an existing assembly process with some brackets, steel flanges [and] screws from our factory to the supplier. Thirty items; that's it. We already have the production work instructions and other process documentation available and can transfer this to the supplier. It should be simple to get the business case done and go do". Such perceptions of complexity were shared by the team responsible for the project's maturation. It was, thus, not necessary to work in a systematic way (as observed in Case C). The aspirational level for decision-making concerned the predicted performance, with limited emphasis on the validity of the underlying data. However, after the decisions were made, it became evident that the changes concerned two bottleneck items managed by a different sourcing manager not involved in the decision. As a result, substantial complexity related to commitments to existing suppliers and interdependencies with other factories had not been addressed in the initial information search and processing. Thus, the specialist recognised that "we underestimated the complexity of the change to the supply chain, especially the involvement of several category [sourcing] teams". Similar patterns were observed in cases B.1 and H, which were characterised by non-obvious complexity drivers in which the level of supply chain decision-making complexity was initially underestimated and deliberate coping strategies were not enacted.

When faced with complex decision making, decision makers intentionally or unintentionally decomposed the decision problem into sub-problems. To reduce decision-making complexity in case D.1, the overall SCD problem was partitioned into several decisions that were treated independently. These questions included: should design be outsourced to existing suppliers by sourcing the module as a black box? Should the product be produced in the Indian facility? Should distribution be changed to involve direct shipments from production to customers in the American and European markets? While these questions were closely interlinked, the first was addressed in isolation by comparing the buying of the existing module (assembled by the supplier but designed by the OEM) with the buying of a similar module designed by the supplier. Addressing this decision in isolation significantly reduced the complexity of the decision-making situation and satisfied the aspirational level of product development decision makers, who were primarily concerned with product development and direct product costs. However, the partitioning of the SCD problem created a frame in which information search, analysis and aspirational levels reflected the goals of product design and sourcing, ignoring

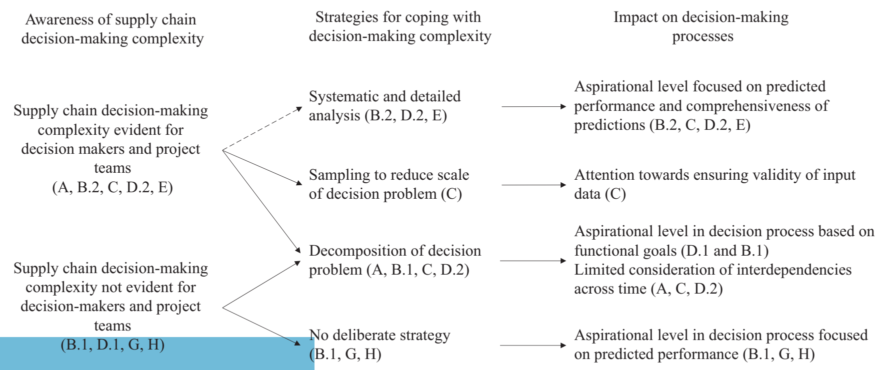


Figure 1.
Strategies for coping with decision-making complexity and impact on decision making

upstream and downstream supply chain interdependencies. Upstream interdependencies included the impact of possibly producing in the internal facility in India, as the product design was no longer done by the OEM, and downstream interdependencies included distribution costs to important emerging markets, which introduced critical cost estimation errors related to the scope of cost estimations. Although detailed financial validation was conducted, the functionally narrow scope meant that these upstream and downstream dependencies were not addressed.

The last group of SCD decisions was characterised by systematic and detailed analysis to address the decision-making complexity. Information searches were conducted along the supply chain based on the systematic mapping of alternative SCDs and the active involvement of several functions, such as quality, procurement, production engineering and finance (A, B.2, C, D.2, E). Decision-makers were similarly focused on understanding the drivers of cost differences, having consecutive meetings to review SCD scenarios and asking detailed questions regarding assumptions and data (B.2, C, D.2, E). The dotted line in Figure 1 shows that the use of such resource-intensive coping strategies was prompted by the strong management attention these cases received, rather than a response to the decision task.

The role of management attention

One relevant question concerns the interplay between supply chain decision-making complexity and management attention. Decisions with high complexity are expected to invoke management attention if the information processing capability is deemed insufficient to adequately process the required information, resulting in an escalation through hierarchical structures. However, no such link was found, as management attention was not allocated based on supply chain decision-making complexity directly. Instead, management attention was allocated in three different ways: when the negative impact of an SCD change became visible for functions not involved in decision making (evident following the initiation of decisions B.1 and D.1), when the performance of the current SCD was below aspirational levels (C, E, G, H) and when the project progress was below aspirational levels (G, H). In these situations, more managerial layers from more functions were involved more frequently. When management attention was invoked, distinct differences could be seen in decision-making behaviours, dependent on management attention building on either coherent (C, G, H) or conflicting goals (B.2, D.2, E). These behaviours and their impacts on the decision-making process are summarised in Table III.

When management attention was based on coherent goals, decision-makers' behaviours focused on reaching an SCD that satisfied aspirational levels based on past performance. When aspirational levels were not satisfied, more information was sought. Such searches were enacted by extending cost calculations, scrutinising cost calculations and developing competing solutions. Each of these steps sought to improve an unsatisfying SCD. The first attempted to quantify the cost consequences in overhead functions impacted by the SCD decision, e.g. procurement (C, G and H), thereby extending existing cost calculation procedures focused on direct product cost and profit/loss impact. The second focused on justifying the proposed SCD by reviewing and challenging data already collected, contributing little to revise and improve the proposed SCD. If additional information searches helped improve the competitiveness of the new SCD, contributions were one-dimensional, e.g. improving external suppliers' quotes (C) or transport costs (G), to reach the aspirational level determined by historic performance. Thus, despite the cross-functional nature of SCD changes, the information search and the search for alternatives remained functionally separated. This carried a risk of cost estimation errors due to interactions between functionally separated information, e.g. factory expectations concerning logistics inflow and handling not being aligned with the supplier (G, H). In the third, decision makers requested more diverse solutions to be explored, but these had limited impact on the accuracy of cost estimations.

Management attention based on	Behaviour observed	Effect on the decision-making process	Explanatory quotations	Observed in case
Coherent goals	Develop competing solutions	Developing alternative solutions improving total cost performance	"It seems that all of the solutions presented focus on existing suppliers, and normally located in India or China. Are that really the only options we have available?" (SVP, Technology)	C, G, H
	Extend cost calculations	Extend cost calculations to justify projects	"We need to consider also the cost savings coming from reduced complexity in our factories, procurement, technology" (SVP, Manufacturing)	C, G, H
	Scrutinise cost calculations	Challenge inputs and assumptions to reach a satisfactory solution	"Why is the transport cost from the supplier to the [European] factory higher than the existing transport cost?" (SVP, Manufacturing) "Have the supplier been challenged on their price?" (SVP, Sourcing) "Have you utilised the specialist functions within transport engineering to improve the solution?" (SVP, Manufacturing)	G, H, C
Conflicting goals	Develop competing solutions	Developing alternative solutions supporting individual/group objectives	"What are the consequences if we do this in India?" (Factory Manager)	D.2, E, B.2
	Scrutinise cost calculations	Detailed investigating and validation of numbers underpinning cost estimations to support individual/group objectives	"Are the cost of really this high?" Factory Manager. What is the reason for the difference between the cost? How is the cost structure of the supplier compared to our cost?" (SVP, Sourcing)	B.2, D.2
	Extend cost calculations	Extending the scope of cost factors considered to underpin advantages of individual solutions	"You need to quantify how much that is worth" (SVP, Manufacturing) "What is the cost impact of for the Indian market?" (SVP, Manufacturing)	D.2
	Changing aspirational level	Changing aspirational level from historic performance to future performance of alternatives	"You need to ensure you compare the outsourced setup, with how it would look with internal manufacturing in the future. How will price negotiations, labour cost, and all of this develop for internal manufacturing?" (VP, Sourcing)	B.2, D.2, E
Both	3rd party validation	Obtaining validation from a neutral party, e.g. Finance	"It is a requirement to have finance sign-off on the business case before presenting to management" (SVP, Sourcing)	C, D.2, E, G, H
	Time pressure	Management attention induced time pressure and stretched targets for project follow-up	"I was tough to finish the analysis and quotation on time. We have been working around the clock to finish it" (Manager, Sourcing)	B.2, D.2, G, H

Table III. Behaviours for extending rationality induced by management attention

When management attention was based on conflicting goals, though the types of behaviours observed were similar, the behaviours were enacted in clearly dissimilar ways. Decision makers sought to ensure the development and exploration of scenarios allied to individual objectives. This extended the search for information outside the initial search scope, reducing cost estimation errors due to a too narrow scope of cost estimations. As competing solutions were developed, the aspirational level changed from exceeding past performance to outperforming competing alternatives. This imposed a future orientation on the cost estimation, requiring competing project teams to consider future consequences as well as similar cost calculation scopes to enable comparison. Consequently, individual project teams were required to seek additional information (B.2, D.2, E). Inputs and assumptions for the competing alternatives were scrutinised as impacted stakeholders questioned underlying details to ensure the cost calculations reflected the impacts on their organisational units. If what was perceived as a significant impact on a given coalition was not captured by the principles of cost calculations, tasks were issued to quantify such impacts. This monetary quantification was again subjected to scrutinising and questions. Thereby the conflict-based management attention created a continuous and dialectic process of thesis and antithesis to seek an optimal solution, consuming significant time and resources.

The observed behaviour suggests that management attention building on conflict helped prevent errors and political behaviours through the continuous scrutiny of data and inputs and the investigation of competing scenarios. Conversely, attention based on coherence in objectives led to behaviour driven by rationalising and finding satisfying solutions, not improving the accuracy of the underlying cost estimation.

In addition to these behaviours, high levels of management attention introduced the expectation that the finance department would conduct a third-party validation of cost estimations. Such reviews involved the project team presenting the cost estimations and key assumptions, followed by finance staff cross-checking inputs in the cost estimation. This form of review was suited for addressing errors in estimation values, but only for variables already in the scope and primarily related to the calculation of existing baselines, as these could be validated based on historical data. Hence, increasing management attention, whether based on conflict or coherence, helped reduce the risk of cost estimation errors. This effect was more noticeable for conflict-based management attention through behaviours in which the aspirational level for the decision focused on outperforming future-oriented alternatives. However, reaching the higher aspirational level led to escalating commitments of resources for data collection and analysis.

Discussion and case synthesis

The case findings are synthesised into four propositions concerning the relationships among supply chain characteristics, supply chain decision-making complexity, management attention and cost estimation accuracy.

First, specific supply chain characteristics were found to increase supply chain decision-making complexity:

> *P1.* The following supply chain characteristics increase supply chain decision-making complexity: the number of items, bottleneck items, the extent of global operations, the number of production facilities and the extension of lead times and planning horizons.

As supply chain decision-making complexity increased, so, too, did the risk of cost estimation errors. However, when faced with supply chain decision-making complexity, project teams and decision makers responded with different strategies for either expanding the boundary of rationality or decomposing the decision problem (Kaufmann *et al.*, 2009). The choice of strategy was dependent on the perception of supply chain decision-making complexity, and the choice of strategy had a substantial impact on information search and processing, as indicated by changing aspirational levels for the decision process (Cyert and March, 1963). These findings complement existing research on the importance of debiasing strategies to improve decision making, especially regarding the decomposition of decision problems (Kaufmann *et al.*, 2009). It is thus important that project teams and decision-makers recognise the level of supply chain decision-making complexity and consciously enact appropriate strategies. When decision-making complexity was not recognised, decision-makers unintentionally relied on decomposition strategies. Considering the cross-functional nature of SCD changes, this decomposition of decision problems based on functional responsibilities introduced a substantial risk of cost estimation errors, leading to the second proposition:

P2a. The risk of cost estimation errors for SCD decisions decreases with the enactment of strategies that introduce an aspiration to achieve accurate cost estimations (e.g. the use of sampling).

P2b. The risk of cost estimation errors for SCD decisions increases as decision-makers rely on decision problem decomposition to cope with supply chain decision-making complexity.

The case findings point to the need to consider the trade-off between management attention for decision-making and cost estimation accuracy, as some SCD decisions are starved of resources and managerial attention, while others receive abundant resources and attention due to perceived managerial importance (Nadkarni and Barr, 2008). Consistent with decision-making theory, which proposes a trade-off between decision speed and accuracy (Kocher and Sutter, 2006), it is suggested that, rather than supply chain decision-making complexity determining cost estimation accuracy (as implicitly suggested by Manuj and Sahin, 2011), supply chain decision-making complexity determines the function of the trade-off between resources invested in decision-making and cost estimation accuracy. Management attention then plays an important role in explaining cost estimation errors through escalating commitments of time and resources for information search and analysis to satisfy aspirational levels.

The findings extend existing empirical research by providing evidence that management attention helps explain cost estimation errors for new SCDs: elements not addressed by extant literature in the domain (Larsen *et al.*, 2013; Manuj and Sahin, 2011). Specifically, management attention imposes behaviours that extend the boundary of rationality (Kaufmann *et al.*, 2009) through increased comprehensiveness, dialectic processes and future-oriented aspirational levels and information searches. This lead to the third proposition:

P3. Management attention is positively linked to the aspirational level for SCD decision-making and the resources consumed in meeting this aspirational level.

Faced by low complexity, management attention contributes in a limited way to cost estimation accuracy, as a high level of comprehensiveness (Riedl *et al.*, 2013) can be easily achieved in decision making. However, as the supply chain decision-making complexity increased, so did the effort and difficulty of obtaining a comprehensive understanding of future alternatives, as well as information asymmetry. While increased involvement by decision makers can ensure an appropriate scope for cost estimations, it becomes increasingly difficult for decision-makers to evaluate underlying details and assumptions (Wouters *et al.*, 2009). For high-complexity decisions, decision makers should focus on ensuring appropriate behaviour and cross-functional collaboration to improve decision-making and cost estimation ability. The findings explain how management attention influences cost estimation accuracy by changing the aspirational level of decision making.

As the cases revealed no direct link between management attention and supply chain decision-making complexity, an important implication is that decision situations are not automatically allocated management attention as the difficulty of decision-making increases. Neither was management attention driven by the cost impacted by the

SCD decisions. This suggests that management attention is something that itself needs to be managed to ensure an appropriate match between management attention and supply chain decision-making complexity. A simple framework, depicted in Figure 2, is proposed to ensure such a match by balancing decision-making complexity with adequate levels of management attention.

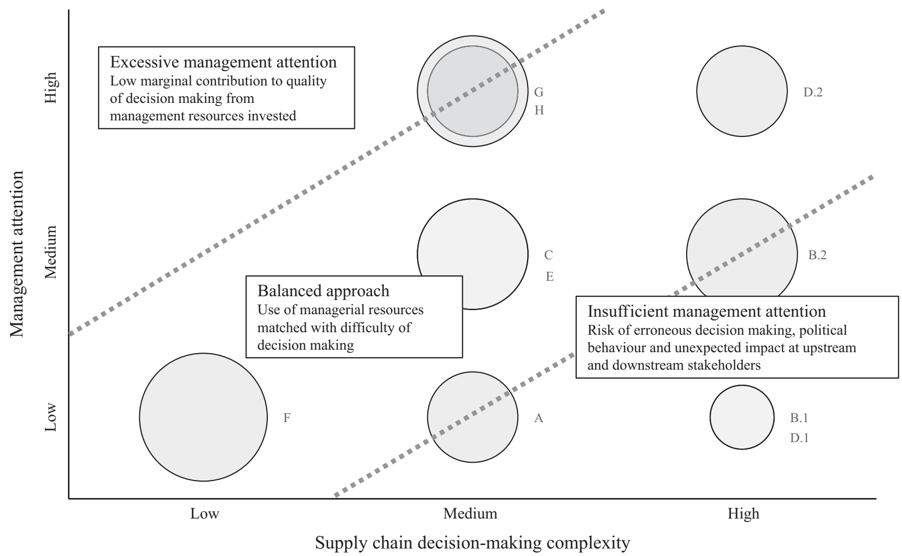
SCD decisions located in the bottom-right corner are starved of management attention and carry a high risk of erroneous decision making, with unexpected impacts on upstream and downstream functions, or are subject to political behaviours, such as quick decision making (Marshall *et al.*, 2015). Conversely, projects located in the top-left corner are characterised by excessive management resources with no or only marginal contributions to decision-making effectiveness. The diagonal, representing a balanced match between management attention and decision-making complexity, is proposed as an ideal situation, leading to the fourth proposition:

P4. Cost estimation accuracy is negatively affected by supply chain decision-making complexity and positively affected by management attention, at the cost of more time and resources spent.

These four propositions and the relationships among supply chain characteristics (drivers of complexity), supply chain decision making complexity, management attention and cost estimation accuracy are summarised in Figure 3.

Concluding remarks

Complementing existing work, this paper investigates decision-making processes regarding SCD decisions and the influences of supply chain decision-making complexity and management attention: an area that has received limited research attention (Larsen *et al.*, 2013; Marshall *et al.*, 2015; Schorsch *et al.*, 2017). This research has important implications for both theory and practice. First, the empirically grounded



Note: Cost estimation accuracy indicated by the size of the solid circle

Figure 2. Balance between management attention and supply chain decision-making complexity

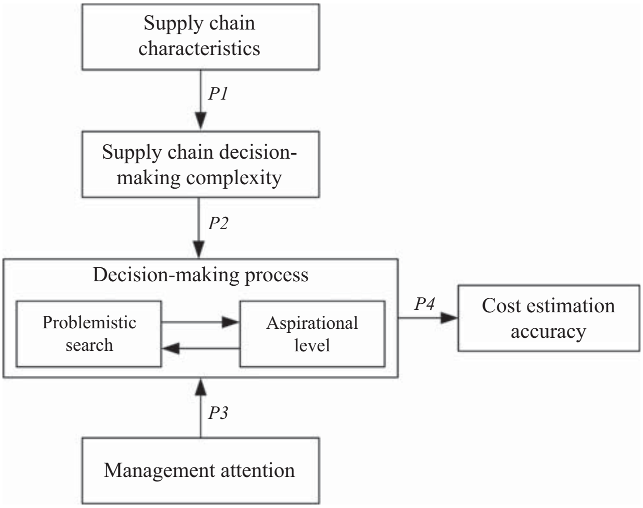


Figure 3. Summary of the exploratory research study

understanding of the decision processes offers insight into how supply chain complexity influences SCD decision-making. Second, building on the BTF, the research shows how management attention influences decision-making processes and impacts cost estimation accuracy through different behaviours induced during decision making.

Several managerial implications can be derived from the findings. First, identifying the factors linked to cost estimation errors allow decision makers and project managers to focus on such elements to reduce the risk of erroneous decision making. It also points to the need to consciously choose strategies to cope with supply chain decision-making complexity. Furthermore, management attention is not directly linked to supply chain decision-making complexity unless issues emerge that invoke managerial attention. As a result, it is important to ensure that SCD decisions are matched with management attention appropriate to the level of supply chain decision-making complexity. One way of guiding management attention is through formulised governance models, such as delegated authority. However, as authority is normally delegated based on cost commitments, this does not ensure that the amount of supply chain decision-making complexity will be matched by appropriate levels of management attention. The findings presented here point to the need to utilise more holistic metrics than costs to guide management attention for supply chain decisions.

This study is limited by its reliance on embedded cases originating from a single company. It would be desirable to replicate the study findings in similar industrial settings and across industries. The research design offered detailed evidence linking cost estimation accuracy with management attention and supply chain decision-making complexity; however, the literature has proposed several rivalling explanations (e.g. decision-makers' experience; see Larsen *et al.*, 2013). Though the research design controlled for organisational experience, it did not control for individual experience. Further research should expand the effects of other behaviours. Empirically validating the propositions would also be of interest. Other promising areas for further research include methods to ensure appropriate levels of management attention and emulate conflict in a constructive approach and the application of behavioural experiments to improve the understanding of the relationships among supply chain decision-making complexity, management attention and estimation accuracy.

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(The Appendix follows overleaf.)

Appendix

Table AI. Supply chain decision-making complexity (→ Indicates a change to a new design) for each supply chain design case

No.	Item numbers	Suppliers	Manufacturing locations	Downstream locations	Global connections	Codes for supply chain decision-making complexity	SC decision-making complexity
A	140 → 6	30 (EU) → 2 (EU)	1 (EU) → 0	10+ (EU)	Low	Ramp down of supply chain. Product design changes. Difficulty in valuating future design improvements by suppliers	Medium (2)
B.1 and B.2	86 → 86	57 (US, EU and CN) → 31 (EU, CN, and IN)	2 (EU and US) → 1 (IN)	2 (EU and US)	Medium → High	Capacity-constrained items and dependencies across factories. Long qualifications times and purchase commitments. Impact from transferring production across the globe	High (3)
C	164 → 1200	16 (CN and EU) → 1 (CN)	1 (CN) → 0	1 (CN)	Medium → Low	Large number of semi-manufactured items. Difficulty in validating costing data. Documentation and specification prepared for internal production	Medium (2)
D.1 and D.2	132 →	20 (IN, EU, CN) → 2 (EU, CN)	1 (IN) → 0	5 (EU, US, IN, CN, BR)	High	Interdependence between and impact on activities in technology, sourcing and manufacturing, and sales. Cost efficiency dependent on demand splits between key markets and movements in exchange rates. Difficulty in valuating future design improvements by suppliers. Uncertain future product design	High (3)
E	1 → 32	2 (EU) → 9 (EU & IN)	0 → 1 (IN)	2 (EU) and 1 (CN)	Low → High	Interdependence between and impact on activities in technology, sourcing and manufacturing, and sales	Medium (2)
F	4 → 2	1 (EU) → 1 (EU)	1 (EU) → 0	4 (EU) → 4 (EU)	Low	Well known supplier, already producing and supplying the same component to the focal firm. Separate production	Low (1)

(continued)

No.	Item numbers	Suppliers	Manufacturing locations	Downstream locations	Global connections	Codes for supply chain decision-making complexity	SC decision-making complexity
						area, enabling easy quantification of cost impact if closing production area	
G	37 → 1	24 (EU and CN) → 1 (CN)	3 (EU and CN) → 0	3 (EU and CN) → 3 (EU and CN)	Medium → High	Impact across multiple categories. Capacity-constrained items and local Chinese suppliers being developed. Negotiations with suppliers of key components. Shifting from existing European supply base to new Chinese. Product design as well as Documentation and specification prepared for internal and local assembly	Medium (2)
H	14 → 1	8 (EU and CN) → 1 (CN)	3 (EU and CN) → 0	3 (EU and CN) → 3 (EU and CN)	Medium → High	Shifting from existing European supply base to new Chinese. Product design as well as Documentation and specification prepared for local assembly	Medium (2)

Table AI.

Table AII.
Management attention for each supply chain design case

No.	Function	Management level S	M	D	VP	SVP	Form of interaction	Aspirational level for decision	Goals	Management attention
A	Procurement	1	1				Dedicated decision meetings	Historic cost when producing internally	Coherent	Low (1)
	Factory			1	1					
	Technology	1								
	Quality									
	Finance									
B.1	Procurement			1			Dedicated decision meetings	Historic cost when producing locally	Coherent among decision-makers involved	Low (1)
	Factory	2			2					
	Technology									
	Quality									
	Finance									
B.2	Procurement	2	2		2	1	Series of e-mail communication, and *ad hoc* meetings to discuss case	Future cost when producing internally	Conflict	High (3)
	Factory	2			2	1				
	Technology									
	Quality									
	Finance									
C	Procurement	1	1			1	Reporting within existing reporting structures. Specific decision meetings at manager and vice president level	Future cost when producing internally	Coherent	Medium (2)
	Factory	1	1		1	1				
	Technology									
	Quality									
	Finance	1								
D.1	Procurement		1	1			Part of new product development review meetings	Historic cost when procuring module	Coherent among decision-makers involved	Low (1)
	Factory	1								
	Technology	1		1						

(continued)

No.	Function	Management level S	M	D	VP	SVP	Form of interaction	Aspirational level for decision	Goals	Management attention
	Quality			1						
	Finance	1								
D.2	Procurement		1	1	1	1	Series of e-mail communications. Bi-weekly status meetings and series of dedicated meetings	Best future scenario	Conflict	High (3)
	Factory	2		1	1	1				
	Technology	1		1		1				
	Quality									
	Finance	2	1							
E	Procurement	1	1	1	1		Reporting within existing reporting structures	Best future scenario	Conflict	Medium (2)
	Factory		1	1	1	1				
	Technology		1							
	Quality		1							
	Finance	1								
F	Procurement		1				Dedicated decision meetings	Historic cost	Coherent	Low (1)
	Factory		1		1					
	Technology									
	Quality									
	Finance									
G	Procurement	1	1	1	2	1	Series of e-mail communications. Monthly meetings, and dedicated decision meetings	Historic cost	Coherent	High (3)
	Factory	1			3	1				
	Technology			2		1				
	Quality									
	Finance	1								
H	Procurement	1	1	1	2	1	Series of e-mail communications. Monthly meetings, and dedicated decision meetings. Spanning 6 months	Historic cost	Coherent	High (3)
	Factory	1			3	1				
	Technology			2		1				
	Quality									
	Finance	1								

Table AII.

Case	Descriptions	Error type	Consequence	Cost estimation error
A	Average inventory level expected to be reduced from index 100 to 10. Measured inventory levels showed increase to index 159	Estimated value	Capital cost of the associated increase in working capital, corresponding to approximately 30% of the predicted savings	Significant (2)
	Increase in resources spent on production planning and forecasting production at module suppliers	Scope	Not quantified	
	Implementation cost not considered	Scope	Not quantified	
B.1	Errors in sourcing master date used for cost estimation in the baseline	Estimated value	Corresponding to 60% of predicted savings	Critical (1) (Decision made to revert previous decision to offshore production)
	Cost baseline not reflecting sourcing split between suppliers of key items in baseline	Estimated value	Corresponding to 10% of predicted savings	
	Cost of offshore production not reflecting sourcing split and capacity constraints at inbound suppliers	Estimated value	Corresponding to 5% of predicted savings	
	Higher transport cost for importing items into offshored location	Estimated value	Corresponding to 2% of predicted savings	
	Movements in exchange rates	Estimated value	Corresponding to 50% of predicted savings	
B.2	Movements in exchange rates	Estimated value		Marginal (3)
	Shifts in local material prices	Estimated value	See note	
	Cost of maintaining logistics return loop not considered	Scope		
C	Deviation between predicted purchase price and realized purchase price less than 0.1%.	Estimated value	Corresponding to less than 3% of the predicted savings	Marginal (3)
	Realized inventory levels slightly lower than predicted	Estimated value	Corresponding to 6% of the predicted saving	
D.1	Financial benefits from locating production in India not considered	Scope	3-4% total cost saving for production in India.	Critical (1) (decision to outsource design and production reverted)
	Impact on internal activities from design outsourcing	Scope	Cost of internal activities estimated to 300.000–400.000 EUR not considered	
	Alternative option to redesign module and maintain production in India	Scope	Landed cost of modules delivered from Indian factory estimated to be approximately 10% lower than externally purchased	
D.2	Problems with qualifying the supplier of a critical component for the local assembly in India. Making it impossible to utilise the local manufacturing facility in India	Estimated value	Cost increase from relying solely on external suppliers for assembly	Significant (2)

Table AIII.
Overview of cost estimation errors for each supply chain design case

(*continued*)

Case	Descriptions	Error type	Consequence	Cost estimation error
E	Movement in exchange rates increased competitiveness of Indian supply	Estimated value	Increased cost competitiveness of production in India with 2–3%	Marginal (3)
F	No deviations observed	None (4)		
G	Capacity constraints at selected supplier limiting the volume to be sourced	Estimated value	Reduced scope of implementation from all global factories to a single factory	Significant (2)
	Issues with qualification of casted components in China increased cost of items supplied	Estimated value	20–30% of predicted savings	
	Transport solution not suitable for all factories.	Scope	Requiring investment in additional crane capacity in Chinese factory	
	Increase in transport costs.	Estimated value	10–20% of predicted savings	
H	Capacity constraints at selected supplier limiting the volume to be sourced	Estimated value	Reduced scope of implementation from all global factories to single factory	Marginal (3)
	Transport solution not suitable for all factories	Scope	Requiring investment in additional crane capacity in Chinese factory	

Notes: Case B.2, after the decision to revoke the decision to offshore production, alternative supply chain designs, such as offshoring, and outsourcing was continuously evaluated, for more than two years. The subsequent calculations showed slight differences in the competitiveness of local and offshore production. However, the conclusion remained unchanged and local production was cost optimal. Consequently, any cost estimation errors were found to be marginal

Table AIII.

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