Management and Production Engineering Review
Volume 11 • Number 3 • September 2020 • pp. 84–91
DOI: 10.24425/mper.2020.134935

IMPROVING SUPPLY CHAIN TRANSPARENCY BETWEEN A MANUFACTURER AND SUPPLIERS: A TRIADIC CASE STUDY

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Received: 29 August 2019
Accepted: 2 July 2020

Abstract

This paper addresses supply chain transparency improvement in a triadic manufacturer-supplier-supplier relationship. It investigates the problem of improving transparency using a set of interviews; then, a detailed problematization and a simulation model is formulated based on the results. The interview results show that there are two key issues to be considered: information systems issues related directly to transparency and capability issues related to utilizing transparency. The simulation results support developing capabilities by illustrating the effects of different options for coordinating material flow. The results of the study also indicate that while solutions to improve transparency can be relatively straightforward to implement, developing the capability to benefit from it can be more challenging, even in a well-established close partnership. In addition, suppliers may be hesitant to collaborate without active manufacturer involvement.

Keywords

Supply chain management, transparency, responsiveness, manufacturer, supplier, triad, simulation.

Introduction

Issues, such as transparency, responsiveness, real-time transfer of demand data, and just-in-time (JIT) delivery, are all interrelated and remain topical in the research field of supply chain management, e.g. [1–5]. In particular, transparency remains one of the main managerial challenges, even though information is ample and easier to share than ever before [6, 7]. However, scientific research on transparency still lacks a strong empirical basis [7, 8]. Barriers to transparency have been recognized, suggesting that supply chains could be smarter through information technology (IT) solutions as well as processes [6]. In this paper, we discuss this phenomenon through a detailed study of transparency improvement efforts in a selected manufacturer-supplier-supplier relationship. The purpose of the study is to identify the key issues related to supply chain transparency, development proposals and their potential impacts.

The triad under investigation consists of a leading machinery manufacturer, one of its key suppliers and another related supplier. The three companies are physically located near each other, enabling delivery in a short time span. It was found that improved transparency, with methods such as real-time availability of demand data, could further improve the timeliness of deliveries and reduce inventory levels in the supply chain.

Studies on supply chain triads have become increasingly popular since Choi & Wu [9] proposed that moving from dyads to triads would enable capturing the essence of a network. A large body of triad research has been accumulated since then, with a majority of it focusing on services, e.g. [10–12]; our standpoint of transparency in a production setting has not been exhaustively studied.

We utilized a mixed methods study design to investigate this practical problem; first the situation was investigated in more depth through interviews with all the stakeholders and by analyzing the data related to supply chain operations. A simulation model was created based on this understanding to illustrate the effects of some possible improvement efforts. A case study design with multiple methods allows for the investigation of practical behaviors and their effects, addressing the methodological gap noted by Fayezi et al. [13].

In the following sections, we first describe the case study situation and present the methods and materials we used. Next, the stakeholders' views of the situation are presented and some of the key differences are compared. This is followed by a discussion of the simulation results. In the conclusion, we discuss potential opportunities for improvement in the studied case, as well as the implications and limitations of our results.

The case study situation and research methods

The starting point for the study was the manufacturing company's interest in improving information transparency, and, consequently, the responsiveness and material flow in its supply chain. In initial discussions, it was also decided that choosing a local key supplier (Supplier A) as a pilot case would be a good way to begin these efforts. The choice was also influenced by experiences from earlier co-development projects, and by perceived open information sharing and mutual trust. During the initial analysis, another supplier (Supplier B) was included in the study, because it welds and paints some of Supplier A's products into sub-assemblies for the manufacturer. These three businesses are located within 1 km of each other. This triad is illustrated in Fig. 1.

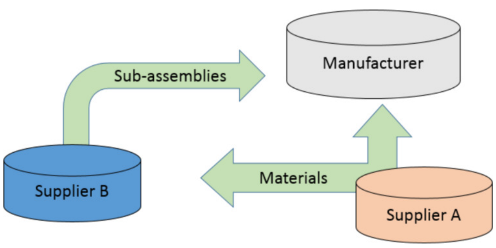

Fig. 1. The case environment.

The manufacturer produces configured machines for customers worldwide; it is one of the market leaders in its niche with a turnover of around 500 M€. Its production and factory are built around JIT concepts. Roughly half of the materials used in production are sourced from local suppliers, a vast majority of which are from domestic suppliers.

Supplier A is a medium-sized subcontracting partner for machine building companies and other companies in the metal industry. It focuses on system and component deliveries as well as various cutting methods. Supplier A delivers different sheet metal parts and machined parts to the manufacturer.

Supplier B is a small short-run contract manufacturer of metal products and their sub-assemblies. It produces welded and painted sub-assemblies for the manufacturer's products.

To further understand the current situation from the viewpoint of these three companies, interviews were conducted in February 2019. Additionally, the courier responsible for the logistics between the three companies was interviewed. A summary of the interviewees is presented in Table 1.

Table 1
The interviewees.

Company	Role
Manufacturer	IT project manager; buyer; logistics engineer; director, supply chain; country director; production planner; development engineer
Supplier A	Development manager, production planner
Supplier B	Factory manager
The courier	Logistics operator

The interviewees received a short list of topics that will be discussed in this paper; these topics varied depending on the person's title/position/working area. The interviews lasted between 45 minutes and 1.5 hours. A total of 10 interviews were conducted with 13 participants. All the interviews were recorded, except for the telephone interview with the courier. The manufacturer and supplier A also shared supporting materials, such as inventory, order, and production data, via email.

A more detailed view of the problem was obtained based on that information, and it is presented after the description of the current situation. A simulation model was created, using the AnyLogic simulation software, to further analyze and illustrate the coordination of materials between the manufacturer and Supplier A. The assumptions for this model were based on the collected data.

The current situation from all perspectives

The manufacturer

The order-to-delivery process begins when a customer confirms the order and a bill of sale and the machine configuration chosen by the customer are sent to order processing. The order is entered into the factory's production system and scheduled according to the agreed upon delivery date. This information is also visible to the suppliers through the Extranet. After the sale, the customer can change the order up to three months before the shipping date. Typically, the 12-week production schedule is only subject to minor changes.

Fixed four-week production plans are generated based on the 12-week plan, and they include detailed production plans that are scheduled backwards using the target shipping dates. After an order is entered into the four-week plan, orders for the suppliers' parts are generated automatically. The four-week plan is changed only in special conditions, such as material shortages. For example, the production sequence can be changed to avoid idle time. Suppliers can view the 12-week and four-week production plans via the Extranet.

The manufacturer purchases components from Supplier A in two ways. Cut parts for welding form 80% of the quantitative order volume. These are ordered through the Extranet as automated orders, and the system provides shipping documents that the supplier attaches to an order. If the supplier meets the required quantity and delivery date, no further communication with the manufacturer is needed. The courier visits the suppliers' premises four times daily, so the suppliers do not have to order deliveries; they only prepare them for pick-up. Bulk items are ordered manually via the Extranet based on their re-order points; they have to be manually processed by the supplier's buyers. In terms of order lines, the volume of these orders is very small in comparison to automatic orders.

The four-week production plan can fall behind the target date, for instance due to a sequence of particularly demanding machines, breakdowns, material shortages, or faulty materials. Weekend shifts are scheduled to catch up. This provides a significant temporary boost to the weekly capacity. These fluctuations are not visible in the Extranet, so suppliers are unaware of manufacturer's current demand; they follow the orders from the four-week plan. This problem is caused by the interface between the manufacturer's and the supplier's IT systems; schedule changes do not update existing requests; instead, they create new material requests without removing the now outdated ones. Deliveries arriving earlier than needed create extra inventory. This is particularly troublesome because the production facilities are designed for JIT deliveries, and there is no dedicated inventory space in all of the production line steps. Moreover, this requires extra manual work for coordinating production and communicating changes to the suppliers.

Supplier A

Supplier A reads the automated orders from the manufacturer seven workdays in advance from the Extranet using an automatic order-reading tool. The orders are scheduled in line with the logistics arrangement (date and time of delivery) between the manufacturer and Supplier A. A large percentage of A's parts are needed for early production stages, meaning that deliveries are scheduled for 1.5 weeks before a machine is finished. For the four-week plan, this means that Supplier A's effective planning window is 2.5 weeks. In practice, Supplier A has chosen to use the first week from that window because accuracy decreases as the number of weeks increases. The delivery capability is managed with safety stocks to allow timely delivery and reaction to fluctuations in demand. Because Supplier A's lead times, including order processing and production planning, vary from four to nine days, this is seen as a necessity. Safety stocks usually accommodate six days of estimated average demand.

Even in a one-week planning window, schedule or quantity changes in orders are sometimes needed. The more changes are required, the more challenging it is for a supplier to schedule production and manage inventories. Every day, Supplier A receives 400 to 500 new order lines. A line is a specific item for a specific machine, and the quantity varies depending on how many units is required for a product. The production planner relies on the automated order-reading system to determine if a line is not in stock or if it will drop the stock level below the re-order point. Consequently, roughly 50 to 80 lines need to be scheduled for production/day. The time required for the planner to process these orders is about one hour/day. The manual orders are handled by sales; these require a similar amount of work.

Supplier B

The manufacturer orders sub-assemblies from Supplier B via the Extranet; these orders are also processed using an automated order-reading tool. As with Supplier A, these are scheduled so the date and time of delivery are indicated. The materials that Supplier B needs to produce the sub-assemblies come from Supplier A. Their lead times can be up to 2.5 weeks, including Supplier A's lead times; however, Supplier A keeps safety stocks to expedite the lead times. Supplier A can see the manufacturer's demand for Supplier B's sub-assemblies in the Extranet. This view is offered by the manufacturer, but it does not include a bill of materials for Supplier A's parts. Consequently, Supplier B orders parts from Supplier A via e-mail, and the orders must be processed manually.

Logistics

Logistics between the manufacturer and the suppliers are handled by a local logistics operator. Deliveries to the manufacturer are made four times/day; deliveries between supplies are made twice daily. The courier picks up materials at Supplier A, then at Supplier B, before driving to the manufacturer's receiving dock.

When a supplier prints out the packing list to pack an automatically generated delivery, the manufacturer's buyer can see the status of the order as "Packing list generated". Once orders are packed, the courier picks them up during the supply runs. The delivery pick-up times are color-coded. Delivered orders are signed in at the manufacturer's receiving dock, and entered into the inventory system. However, this information is not visible to the buyer. If a delivery is missing from production, emails and phone calls are required to determine its location.

A more detailed problematization

Based on the interviews and auxiliary data, we were able to summarize the key issues affecting transparency, responsiveness, and material flow in this case. Some of the issues are not strictly about transparency; rather, they are about the prerequisites for extracting value out of improved transparency. A summary of these key points is presented in Table 2.

Table 2
Key issues.

	Issue
Manufacturer	Production falls behind schedule Limited room for inventory in the production facilities Buyers cannot access the delivery information from the IT systems
Supplier A	Cannot exploit medium- or long-term visibility of demand Safety stock ties up working capital Long production lead time
Manufacturer-Supplier A interface	Schedule status cannot be relayed due to IT system limitations Supplier A delivering according to the production plan causes excess inventory for the manufacturer
Supplier A-Supplier B interface	Demand for Supplier A's parts going through Supplier B is not automatically relayed, resulting in a need for manual order processing work

As seen from Table 2, the key issues are related to IT systems and production capabilities. The IT-related issues relate directly to transparency and indirectly to operations. The production capability issues hinder the utilization of transparency.

Simulation modelling

A simulation model was constructed to support additional analysis of the information and material flows between the manufacturer and Supplier A. The model was based on the available data and discussions with the manufacturer and Supplier A. It addresses several of the issues listed in Table 2: transfer of real-time production status, production rate variability, lead times, and stock levels. The focus was on the Manufacturer-Supplier A interface, as it represents a majority of the volume, and it was found out that many relevant issues are located there. The simulation interface is presented in Fig. 2.

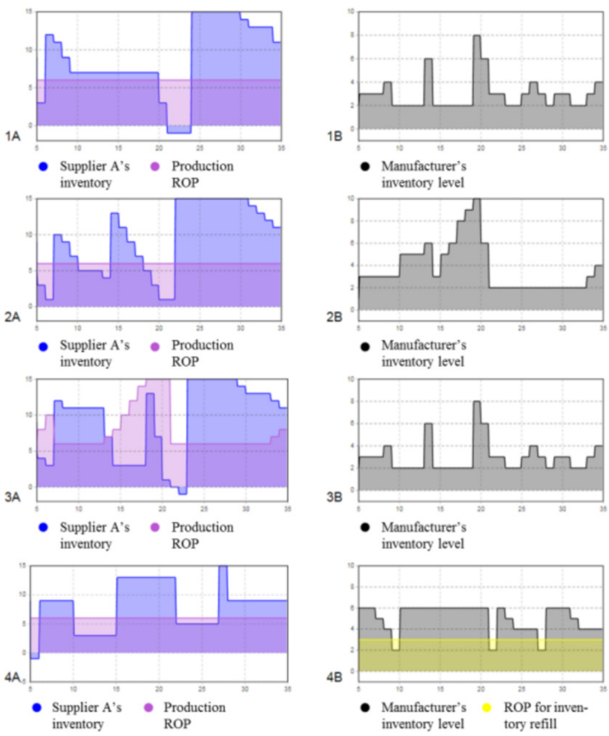

Fig. 2. The simulation interface.

In the model, the manufacturer has a demand that is relayed to the supplier. The supplier's operations are defined by three parameters, production lead time, re-order point (ROP), and a re-order quantity, which can be interactively varied. The resulting view compares four different scenarios of how supply and demand is coordinated with the supplier's inventory levels on the left (xA) and the manufacturer's inventory levels on the right (xB).

Scenario 1 has the supplier delivering according to the manufacturer's next-day demand. The one-day delay is based on an actual situation; the time required for picking and packing makes it too challenging to pack and deliver on the same day.

Scenario 2 shows the supplier delivering according to the production plan, without knowing if the manufacturer is on schedule.

Scenario 3 is Scenario 1 with the addition of the supplier accounting for backlog in the manufacturer's production. If backlog exists, the supplier's ROP increases with the amount of backlog.

Scenario 4 features a ROP at the manufacturer's end; the supplier delivers an order with a one-day delay when the manufacturer's inventory falls below the ROP. The amount delivered will increase the manufacturer's inventory level to the target level. A comparison of these four scenarios is presented in Fig. 3.

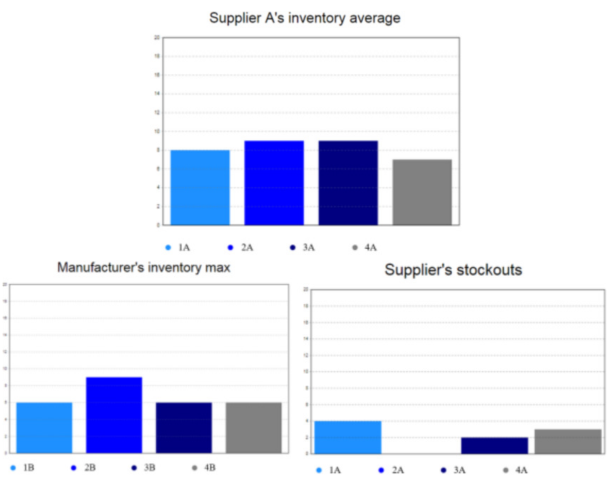

Fig. 3. Comparison of the four scenarios.

When only the inventory levels are considered, Scenario 4 is optimal for both the supplier and the manufacturer. For the manufacturer, the maximum inventory level in Scenario 4 will be equal to the target level. Scenario 2 is the least optimal because it has the highest maximum and average inventories.

Considering stockouts, Scenario 2 is the best option with zero stockouts. Scenario 1 is the worst scenario with the highest stockout rate. Scenario 3 has four stockouts, but that is less than the stockouts in Scenario 1.

The simulation model results suggest that if the supplier delivers according to the manufacturer's estimated demand for the next day (Scenario 1 and Scenario 3), counting the backlog decreases the stockout risk at the supplier's end. Although this leads to increased inventory at the supplier's end, it is needed to respond to the demand peak that occurs when the manufacturer produces the machines in the backlog during an extra shift. If the supplier only follows the production plan and the manufacturer does not share its actual demand, this causes high inventories at the manufacturer's end if production is not on schedule (Scenario 2). Scenario 4 is the best solution; the supplier delivers based on real-time information about the manufacturer's inventory level. However, if the delivery delay increases from one to two days in Scenario 4, the supplier's stockouts decrease but the manufacturer faces a stockout (Fig. 4). It is also important to note that changes in the parameters will cause different outcomes. Moreover, it is easy to implement additional scenarios in the model, such as a hybrid of Scenario 3 and Scenario 4.

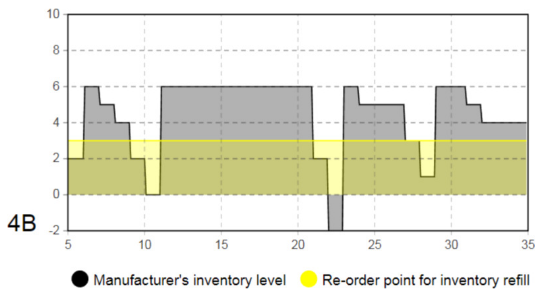

Fig. 4. Outcomes of longer delivery delay in Scenario 4.

Discussion and conclusions

Based on the results, actions can be proposed to improve transparency and the readiness to benefit from transparency. These proposals are presented in Table 3.

As seen in the results and the proposed solutions, transparency is already at a reasonably good level in this case study, apart from some gaps in the systems. Transparency could be further improved by enabling the relay of the current production status, improving the visibility for Supplier A for the bills of materials required through Supplier B, and integrating the inventory system. Solving these issues would primarily be work related to systems; thus, it would not require major changes in policy or processes. Solving the IT-related issues would be the proverbial low hanging fruit, with some immediate effects related to reducing the amount of manual work.

However, moving towards better responsiveness and JIT deliveries is more complex. As the adage goes, inventories are used to cover up issues in the supply chain; this also applies to our case study, at least to some extent. The supply chain works very

Table 3
Development proposals and possible outcomes.

	Action	Impact
Manufacturer	Decrease production variability	Deliveries arrive JIT Suppliers can rely on the production plan No need for extra shifts Reduces the need for manual coordination due to being behind schedule Decreases manufacturer's inventory issues
	Integrate warehouse inventory management with the buyers' IT system	Reduces the manual work of locating deliveries
Supplier A	Shorten production lead times	Increases responsiveness Safety stocks can be decreased
	Reduce safety stock	Frees up working capital Reduces risks of obsolete items (end-of-life parts)
Manufacturer-Supplier A interface	Create visibility for real-time inventory levels/demand	Enables pull Reduces the need of manual coordination due to being behind schedule
	Deliveries based on real-time production status	Decreases manufacturer's inventory issues
	Provide a clearer view of demand for the entire range of parts ordered	Eases medium- and long-term planning Supplier A can decrease safety stocks
Supplier A-Supplier B interface	Create an IT solution between Supplier A and Supplier B to relay order information	Lead times are shortened Responsiveness is increased Supplier A can reduce safety stocks Decreases the amount of manual order processing work

well as is, and the process is well established. However, Supplier A's inventory is an important link in the chain. It serves both the manufacturer and Supplier B, allowing them to keep little or no inventory, and it safeguards the supply chain from issues, such as not being able to respond to fluctuations in demand due to the lengths of the lead times.

The interface between Supplier A and Supplier B is an interesting target of study, and the results offer micro-level insight related to the findings of Wu et al. [14]. Engaging the suppliers in co-opetition instead of competition requires buyer attention. The IT systems issues between the suppliers are an example of a practical issue that most likely won't be solved unless the manufacturer actively participates in solving it.

To exploit the full potential of improved transparency, the responsiveness of the supply chain should be improved according to JIT and lean principles. This includes, for example, the reduction of production setup and lead times, e.g., [15, 16]. A key challenge is how to motivate the suppliers to improve their performance in this area. This issue is related to the larger concept of supplier development, which should be of interest to the manufacturer and the supplier if they want to invest in their collaboration. One practical approach would be to explore the utilization of comprehensive collaboration frameworks, such as collaborative, planning, forecasting, and replenishment (CPFR). However, using CPFR also requires supply chain members to have shared targets, interoperable IT systems, and mutual trust [17].

This study addresses a methodological gap indicated by [13]; it provides insight on how transparency and responsiveness issues manifest in a fairly mature supply chain partnership. It also contributes to the literature, e.g., [18, 19], on using supply chain simulations as "a communicative means between the analyst between the analyst and stakeholders" [20, p. 66]. The results confirm some challenges related to taking advantage of transparency, such as IT system limitations, internal capabilities, and motivation. These are in line with previous findings, e.g. [6, 21–23].

In regards to managerial implications, the results are a good reminder that transparency may have limited value, and it does not necessarily directly result in improved responsiveness, as noted by e.g. [24]. While it has some direct positive effects, such as a reduction in the amount of manual work, to maximize its benefits, the supply chain must be capable of utilizing transparency. For interfaces between suppliers, it cannot be assumed that collaboration will take place without an active role by the buying company. Managerial tools to achieve this include strategic supplier development [25] and collaboration frameworks, such as CPFR [17]. This is similar to the current hype around digitalization, Industry 4.0, and the Internet of Things (IoT): the fundamentals must be in place. However, under the right conditions transparency can improve the supply chain performance [26]. Furthermore, the use of new technologies and concepts, such as RFID, IoT and Blockchain can have positive influence on the supply chain transparency [27].

The use of digital twins is a recurring topic in the Industry 4.0 discussion; a simulation model could be seen as a digital twin, albeit a simplified one. Simulation can be a powerful tool for analyzing the effects of different collaboration models, such as changes in inventory levels and stockout risks in different scenarios. This is applicable to short-term demand and supply management, as well as long-term planning in cases where significant changes in demand are expected over a longer period of time. The use of simulation can be an important stimulus to motivate improvement.

This paper presents a single case study utilizing mixed methods to investigate a practical supply chain problem. We discussed a set of practical issues related to transparency, and we presented a case example using simulation models in development work. In a single-case study, the findings are naturally context-related, with limitations on generalizability. Further studies using a similar approach would allow for a comparison between cases and providing the ability to draw more generalized conclusions. The simulation model created in the study focused on the interface between the manufacturer and supplier A. Developing a triadic simulation model would increase the complexity of the model, but could provide new and interesting insight on supply chain triads.

An earlier version of this paper was presented in 26th EUROMA conference "Operations adding value to the society" in Helsinki, Finland, 17–19.6.2019. We thank the reviewers and the conference audience for valuable ideas and feedback. This study is a part of the Reboot IoT Factory project, and we thank Business Finland and other project funders.

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