Decentralized, Market-Driven Coordination Mechanism Based on the Monetary Value of in Time Deliveries

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OEMs in machinery industry face multiple logistical challenges in their daily business. Interacting in complex non-hierarchical production networks and thus living with the consequences of a lack of transparency, temporal instability or imbalanced share of market power finally leads to a missing delivery adherence which in many cases can be traced back to the suppliers’ late deliveries. These unpunctual deliveries cause a number of unplanned costs which very often imperil a project’s profitability. However, nowadays machine manufacturers are not able to quantify these extra costs. In addition, no theoretical model is provided in literature in order to support calculating or estimating this kind of additional costs. This paper provides a framework illustrating a methodology to monetarily quantify delivery reliability. Furthermore a possible application of this specific knowledge is demonstrated – the financial incentive of suppliers to motivate delivery reliability.

JEL Codes (Field of Research): E23, L64 and M11

1. Introduction

Non-hierarchical production networks describe a today’s common business environment of the machinery and equipment industry. Each company faces multiple and dynamic customer-supplier-relationships within its production network. These highly volatile, instable and non-transparent market conditions lead to high turbulences within the non-hierarchical network resulting in missed delivery promises (delivery reliability within machinery and equipment industry is usually below 65%). The loss of efficiency is estimated to be about one billion Euros, thus the competitiveness of individual companies as well as the entire machinery and equipment industry in Europe is compromised (Gunasekaran et al., 2000; Ghobadian et al., 1996; Reinhart et al., 2006).

2. Delivery Reliability in Machinery and Equipment Industry

The evolution of industrial production was always characterized through differing visions, specific success factors and management theories. Starting in late 18th century with the industrial revolution, industry has been subject to a continuous development permanently adjusting to an ever changing environment and newest scientific approaches (Womack et al., 1991). Whereas increasing efficiency and minimizing prices was the ultimate goal of production management in the beginning of the 19th century, delivery reliability is the paramount target in today’s competitive business (Schuh et al., 2007).

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Being able to keep delivery promises is an indicator of stable and reliable processes creating a strategic excellence position in today’s global markets (Wiendahl, 1997). Thus delivery reliability becomes a company’s decisive strength to maintain competitiveness (Figure 1). Consequently meeting external as well as internal dates becomes a substantial demand towards production logistics influencing on one hand the customers satisfaction but on the other hand also impacting financial measures like liquidity or earnings potential (Böge, 2007). As a result, a positive correlation between delivery reliability and business success is not surprising (Dehler, 2001). The importance of delivery reliability is even boosted in times of strong market demand and overflown order books as appearing right now, two years after the global financial crisis (Lödding, 2008).

2.1. Effects of Missing Delivery Reliability

Highly inter-connected dynamic networks characterize the European machinery and equipment industry. Strong market and technology cycles foster the stated dynamic behavior. Models, simulations or forecasts can hardly be applied resulting in bad delivery reliability in the entire industry causing an enormous amount of additional, unplanned costs. This financial impact related to missing delivery reliability in addition cannot be quantified to a satisfying degree. Most enterprises are only able to estimate their correlative losses. Basically penalties for delayed deliveries, extended assembly times, and expensive short-term logistical counter-measures are quantifiable factors; opportunity costs for example are not. Studies and internal industry cases state that machine manufacturers have to pay 0.5% of the project budget per delayed week (Schuh et al., 2007). Others express their losses in terms of uncounted hours of additional work and thus high efficiency losses (e.g. 600 hours of additional work in a project resulting in 15% efficiency loss). As reaction manufacturers try to stabilize their production and internal planning by making use of stocks which only can be applied in cases of make to stock. Applying these numbers to the European machinery and equipment industry, missing delivery reliability accounts for one billion Euros within the entire non-hierarchical network. Thus improvements in coordination can lead to enormous effects for each individual company and the production network itself. However, there are reasons why this has not been achieved yet.
Zooming into one of many heterogenic customer-supplier-relationships representing a company’s daily business underlines the challenges OEMs in machinery and equipment industry are facing. As mentioned before OEMs tend to have poor delivery reliability. Asking why this is the case, the last step of value-adding, the final assembly is analyzed. 60% of the companies claim to deal with missing parts in the final assembly leading to belated fulfillment of the customer orders (Schuh et al., 2009). Asking why these missing parts occur, nearly half of the companies name a missing delivery reliability of their suppliers as the main cause (Figure 2).

The supplier’s missing delivery reliability can usually be tracked down to multiple causes, a high diversity of parts, the failure of hierarchical coordination principals, an opportunistic behavior on supplier’s side, missing transparency and communication and no information regarding criticality and value of an in time delivery. This leads to search times and efficiency losses on the OEMs side; in many cases even stopping the entire assembly process, followed by a transmission of turbulences into the entire network. This usually causes a high administration and communication demand and in worst case the own delivery performance is affected which usually is punished with penalties (Figure 3).
2.2. Failure of Approved Coordination Mechanisms – Literature Review

There are several reasons why coordination mechanisms known and successfully implemented in other industrial sectors have failed in machinery and equipment industry (Wiendahl et al., 2003). The main reason is the fact that principles of hierarchical coordination cannot be adapted. Production networks in machinery and equipment industry are highly non-hierarchical. Companies are involved in several customer-supplier-relationships simultaneously and big players like e.g. Siemens deliver products to tens of thousands of different customers every single day. Therefore any hierarchical coordination approaches analogue to automotive or commerce sector fail due to the complexity of each individual customer-supplier-relationship and its diverging targets.

In addition, a market-based coordination fails caused by a lack of transparency. Enterprises within non-hierarchical production networks show opportunistic market behaviors by following their own interest which creates local optima within the network (Akerlof, 2007; Johansen et al., 2005). The key element to optimize their profit is being seen in maximizing outputs (and not in delivery reliability). Mainly the value of an in time delivery respectively the losses due to a delayed delivery are not within the focus. This is the reason why the lack of transparency concerning the value of delivery reliability leads to market failure. This effect is strongly boosted in times of high demand and/ or shortage of goods. The missing incentive to deliver in time leads to permanent delays because manufacturers optimize their schedules according to their output rather than keeping their delivery promises (He et al., 2006).

Another reason for the failure of hierarchical coordination principles lies in a supplier’s lack of transparency over the criticality and value of an in time delivery to his customers. Despite the importance of delivery reliability most suppliers do not have the ability to prioritize between different customers or orders (Schuh et al., 2008).

Consequently OEMs face enormous extra costs due to a missing delivery reliability, costs they usually do not take into account calculating a project’s budget or products price. According to the companies’ estimation, stocks due to early deliveries increase costs by ca. 7% and handling costs due to early deliveries account for another 5% additional costs. These numbers imposingly underline that not only late deliveries have to be avoided but early deliveries shall remain on a company’s radar as well (Schuh et al., 2009).

Nevertheless late deliveries still have the higher impact on a company’s performance causing a cost increase of about 10 to 15% in overtime, production scheduling and handling costs, whereas the additional costs in stocks, transactions and lost sales are rated around 5 to 10% throughout the year. However those numbers still remain estimations. Even though having a mutual consensus about the effects of missing delivery reliability of their suppliers, companies usually are not able to exactly quantify the monetary effects of neither early nor late deliveries. Companies are basically not aware of the additional costs they are facing when a supplier is late. Indeed some cost positions (e.g. overtime or penalty costs) can be derived comparatively easy as they can be located directly. However, they account for only a part of the total extra costs and do not reflect the real situation thus endangering a project’s profitability (Figure 4).

The efficiency in assembly shrinks significantly caused by missing parts and search times, inventory and stocks create high working capital and costs of coordination and
administration rise highly due to re-scheduling, and monitoring or tracking. Especially those costs related to handling, costs for re-scheduling of the production or any transaction costs are by far more difficult to calculate or allocate. In addition, effects like efficiency losses due to a stop of assembly caused by missing parts, leading to incalculable opportunity costs are not being regarded as well. This difficulty of cost tracking in combination with the characteristics of the mid-sized companies within machinery and equipment industry (e.g. lack of resources and expertise) has the effect that almost 40% of the companies do not track the costs related to procurement problems at all (Schuh et al., 2009).

Figure 4: Branch view on delivery reliability in machinery and equipment industry

<table>
<thead>
<tr>
<th>How often do procurement problems lead to a delay of your own products?</th>
<th>How important do you rate the determination of the costs arising from...</th>
</tr>
</thead>
<tbody>
<tr>
<td>For core product orders</td>
<td>For spare part orders</td>
</tr>
<tr>
<td>Rating</td>
<td>Neuer: 1</td>
</tr>
<tr>
<td>3.0</td>
<td>3.2</td>
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3. Methodology for Quantifying the Monetary Value of in Time Deliveries

As shown above, a way to monetary quantify unpunctual deliveries is required from theoretical as well as practical point of view. This chapter introduces a methodology for calculating the value of in time deliveries. Specifically, this methodology seeks to estimate the additional costs which occur, when a supplier does not deliver in time. Being aware of the value of these costs on one hand increases the transparency in the order processing and on the other hand can be used for negotiation purposes as an opportunity to increase a supplier’s delivery reliability through financial incentives. The basic idea is to use a certain amount of the total costs which would occur when a supplier is late and use it as a financial incentive to rise in the supplier’s priority of scheduling his orders. In this case the OEM basically pays more for the purchased part but can expect a far higher probability of being supplied in time. The methodology is based on process costing related methodologies (Degraeve et al., 2004; Haindl, 1996; Ligget et al., 1992; Trippner, 2006). It consists of six main steps as shown in figure 5.
4. Detailing of the Methodology – The Findings

This chapter details the methodology presented above. Each individual step will be explained referring to the derivation and its application.

4.1. Step I – Definition of Main Processes

The first step of the methodology defines the main processes involved during processing a customer’s order from an OEM’s point of view involving sourcing from suppliers, making within the own facilities and delivering to the final customer (Figure 5, top). Once an OEM receives an order from the end customer he decides what to source and what to produce independently according to his resource capacities and technological capabilities. Once all parts are purchased and the final assembly is finished, the machine is delivered and set-up at the customer’s site.

4.2. Step II – Detailing into Sub-Processes

The main processes are detailed into sub-processes in the methodology’s second step. Finding an adequate aggregation respectively detailing level is crucial as the model attempts on one hand not to be too complex and on the other hand not to be too general. However, it still needs to remain generic and adjustable to a certain extent allowing application in industry.

The sourcing process consists of supplier controlling, sourcing & approval, specification and order, delivery & reception as well as invoice verification & payment (Figure 6, bottom). The main process “make” is subdivided into the major production functions including planning & controlling, storing, production (usually assembly only) and transportation. Reactive distribution management, delivery & reception, assembly & turnover as well as invoice verification & payment define the main process “deliver”.

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**Figure 5: Methodology for the Calculation of Costs of a Delivery Delay**

| I | Definition of main processes |
| II | Detailing into sub-processes |
| III | Identification of delivery reliability relevant sub-processes |
| IV | Identification of delivery reliability relevant cost drivers |
| V | Identification of the functional relation |
| VI | Aggregation to an overall cost curve |
| VII | **Calculation of costs of a delivery delay**

VALUE OF INTIME DELIVERY
4.3. Step III – Identification of Delivery Reliability Relevant Sub-Processes

The third step consists of the identification of delivery reliability relevant sub-processes, as not all previously defined sub-processes which describe an order processing procedure are affected by unreliable deliveries (Figure 7). In this context four differing cases can be distinguished. In case one the supplier delivers in time which gives the OEM the opportunity to stick to his initial schedule and assemble the machine as ordered by his customer. This case represents the ideal case, where the supplier’s delivery is reliable and in time. No additional costs are occurring. All following cases involve additional costs due to a supplier’s unpunctual deliveries which have not been planned in the initial project plan.

In the second case the supplier delivers too late. However, the late delivery can be compensated by the OEM’s additional effort (e.g. additional, unplanned extra work) so that the final delivery date promised to the final customer is not being affected.

In case three the supplier’s delayed delivery cannot be compensated through additional effort at the OEM’s site. The only chance to hold the promised delivery date is to choose alternative, faster delivering ways which cause additional costs. If for example the OEM is not able to finalize the assembly to the scheduled date, shipping of the machine via sea freight might take too long to meet the agreed delivery date at the final customer’s site. In this case the OEM has to choose a faster (and thus more expensive) way of delivering his product like e.g. via air freight.

Finally, in the fourth case the lost time due to a supplier’s delayed delivery cannot be recovered neither through extra work nor an alternative delivering way thus impacting the final customer’s due date. In this case the OEM has to fear penalties, another unplanned cost dimension.

To complete the picture, a fifth case is illustrated where the supplier delivers too early. Early deliveries might cause additional costs in storing and handling. However, this case will not be regarded in the following deliberations.
4.4. Step IV – Identification of Delivery Reliability Relevant Cost Drivers

The methodology’s fourth step is used for the identification of cost drivers within the chosen sub-processes caused by unreliable deliveries. A cost driver for example might be the additional expense of re-scheduling the assembly. In this case the production manager has to bring up additional time which initially was unplanned thus causing additional, unplanned costs. Another cost driver is unplanned overtime which has to be brought up to anticipate lost time due to late deliveries whereby overtime is usually more expensive than a standard shift. Following this idea, each sub-process has different forms of cost drivers. However, most cost drivers can be mapped through the cost position human resource.

4.5. Step V – Derivation of the Functional Relation between Delivery Delay and Additional Costs

Step five consists of finding a functional relation between cost and time. For each of the cost-relevant sub-processes a functional relation is derived. Such a mathematical relation might be of linear, exponential etc. nature. Figure 8 exemplarily illustrates the cost curve for production.

Usually a company schedules its supplier’s delivery date slightly earlier than the part is actually needed, anticipating a possible delay of the supplier. However, once a certain point of time (ϑ1) is exceeded, the assembly cannot be finished in time without additional efforts. A first countermeasure would be making use of an additional shift (if possible) to compensate the delay. This additional shift is unplanned and causes additional costs as indicted in the diagram. At a certain point of time (ϑ2) the available capacity of three shifts per day is not enough to compensate the supplier’s delay. Once this point is passed, additional Saturday shifts are required to be able to hold the delivery promise to the final customer. Accordingly passing the next milestone (ϑ3) Sunday shifts are necessary to hold the delivery date. At a definite point of time (ϑ4) any additional expenses including night shifts as well as three Saturday respectively Sunday shifts are not sufficient to even the suppliers delay. However, at this point of time the company keeps assembling at full capacity as penalties are usually more expensive than additional costs due to overwork. From this point of time onwards no additional costs arise as the company is assembly at full capacity already; accordingly this point of time represents the worst case and the maximal costs caused in the sub-process production.
4.6. Step VI – Aggregation to an Overall Cost Curve

Once the cost curves for all relevant sub-processes are derived accordingly to the presented cost curve of production, an overall cost curve can be aggregated. This is accomplished by adding up each single cost curve following the superposition principle (Figure 9). Having generated the overall cost curve, a company is able to quantify the monetary impact of a supplier’s belated delivery.

5. Decentralized, Market-Driven Coordination Mechanism

In order to address the challenges discussed above, a framework is introduced which is based on the idea of a market-driven, non-centralized coordination mechanism. By enabling communication, setting up transparency, creating a market-driven coordination mechanism the framework can be seen as an enabling model for improving delivery reliability in non-hierarchical production networks of machinery and equipment industry. The framework is based on preliminary shown cost model. The knowledge about the value of in time delivery respectively the additional costs caused by belated deliveries can be used to financially incentivize a supplier, aiming for a prioritization in his production
scheduling. Basically a higher amount is paid, but taking into account the supplier might be late, below the line the OEM benefits from a financial point of view.

The framework is made operational by applying a control loop’s logic to a certain customer-supplier-relationship respectively a purchasing process in general (Figure 10). The main characteristic of a control loop is to subsequently track information or measures (of the control path), derive adjustments out of this quasi-historical data and thus ultimately improve the original state.

Figure 10: Decentralized, Market-Driven Coordination Mechanism

Here, a purchasing process represents the control path of the control loop and is to be improved. Communication, respectively the purchasing process, is enabled by an IT-based B2B-platform. Numerous bilateral transactions in a permanently changing production network entail an automated and standardized communication between customers and suppliers in order to enable cost-efficient, continuous and transparent information exchange.

External transparency is created by a supplier’s performance evaluation and internal transparency is facilitated by monetarily quantifying the value of an in time delivery. Both correspond to the control loop’s feedback path. A market price for delivery reliability will create transparency to all production network participants by necessarily making delivery reliability monetarily quantifiable. Therefore a price equivalent to delivery reliability has to be identified. Even though delivery reliability itself cannot be made tradable independently, the value of reliability can be set into comparison with incentives given in percentage to the price of the product ordered.

The evaluated supplier information and the knowledge about the value of an in time delivery forms the input variable for the control loop’s controller panel which fulfills the task of deriving adequate incentive measures improving a subsequent purchasing process. Thus a non-centralized coordination mechanism is created. Both, customer and supplier will make use of this price information for bilateral incentive negotiation. The incentive of delivery date adherence becomes the central coordination mechanism to ensure a better planning reliability for the customer.
By applying this control loop to the non-hierarchical production network of the machinery and equipment industry, a pareto-efficient allocation is reached and the delivery reliability is being improved. Simultaneously, the pricing and coordination function enables higher network performance. Both, the negotiated delivery dates manifested by the delivery reliability incentive and consequently the higher delivery adherence will lead to new planning opportunities incorporated in advanced production planning functions enabling lower stocks as well as higher efficiency in assembly and maximizing the network’s overall performance.

6. Summary and Conclusions

This paper pointed out the importance of delivery reliability in today’s competitive business and analysed the causes of missing delivery adherence in machinery and equipment industry. The analysis was supported by findings derived from a survey in European machinery and equipment industry illustrating the necessity to find a way to monetarily quantify the effects of unpunctual deliveries. Subsequently a framework was motivated which helps estimating the financial value of delivery reliability.

Delivery reliability is one of the most important success factors in non-hierarchical markets. The impact of delayed supplies impedes the competitiveness of the entire machinery and equipment industry. Based on the assumption that the knowledge about the financial value of delivery reliability is a central competitive advantage, this paper introduced an approach to overcome the information asymmetry – the unknown financial value of delivery reliability. This valuable information can be used to monetarily incentivise suppliers, increasing the chance being preferred in their delivery scheduling.

Applying this logic in each customer-supplier-relation improves delivery reliability in the entire non-hierarchical production network. Through this approach a non-centralized market-oriented coordination mechanism is being created. Companies which are in strong need of certain parts, components or sub-assemblies for instance due to time restrictions are in favour to pay a higher monetary incentive than companies which do not need the part/ component etc. as bad as its competitor. This mechanism indirectly creates transparency about urgency of deliveries within non-hierarchical production networks of machinery and equipment industry. The generated higher delivery adherence will lead to new planning opportunities incorporated in advanced production planning functions enabling lower stocks as well as higher efficiency in assembly and maximizing the network’s overall performance.
The findings of this paper create the basis for further research. According to the financial incentives, a market for delivery reliability could be established. This market would be based on the knowledge about the monetary value of delivery reliability as well as the current demand situation in the market respectively within the non-hierarchical production network of machinery and equipment industry and would run analogously to a common stock market. Therefore a manufacturer would need to be able to access data which provides the information about the amount of money he has to add to a certain order to guarantee a delivery in time. Thus delivery reliability would become a commonly traded good. It is to be expected that the value of delivery reliability would significantly be higher in times of high demand than in times of an economic downturn. The other way round, this kind of stock market for delivery reliability would be an appropriate indicator for the economic situation in a market (Figure 11). Getting all European machine and equipment manufacturers on such a virtual platform would make the current financial value for delivery reliability becoming a real time indicator for the European economic situation as the machinery and equipment industry producing machine tools represents the backbone of European economy and is strongly related to all other industrial sectors.

The results presented in this paper are not meant to be exhaustive; they should be considered as a step forward in the production management research field to support practitioners in managing important business processes.

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References


