Framework for Delivery Reliability in European Machinery and Equipment Industry

G. Schuh, A. Kampker, A. Hoeschen and T. Jasinski

Abstract—Today's manufacturing companies are facing multiple and dynamic customer-supplier-relationships embedded in non-hierarchical production networks. This complex environment leads to problems with delivery reliability and wasteful turbulences throughout the entire network.

This paper describes an operational model based on a theoretical framework which improves delivery reliability of each individual customer-supplier-relationship within non-hierarchical production networks of the European machinery and equipment industry. By developing a non-centralized coordination mechanism based on determining the value of delivery reliability and derivation of an incentive system for suppliers the number of in time deliveries can be increased and thus the turbulences in the production network smoothened. Comparable to an electronic stock exchange the coordination mechanism will transform the manual and non-transparent process of determining penalties for delivery delays into an automated and transparent market mechanism creating delivery reliability.

Keywords—delivery reliability, machinery and equipment industry, non-hierarchical production networks, supply chain management

I. INTRODUCTION

NON-HIERARCHICAL production networks describe a today's common business environment of the machinery and equipment industry which forms the backbone of the European economy. 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 [1]-[3].

G. Schuh is head of the Chair of Production Engineering, RWTH Aachen University, 52074 Aachen, Germany (e-mail: g.schuh@wzl.rwth-aachen.de).

A. Kampker is head of the Chair of Production Management, RWTH Aachen University, 52074 Aachen, Germany (e-mail: a.kampker@wzl.rwth-aachen.de).

A. Hoeschen is with the Chair of Production Management, RWTH Aachen University, 52074 Aachen, Germany (e-mail: a.hoeschen@wzl.rwth-aachen.de).

T. Jasinski is with the Chair of Production Management, RWTH Aachen University, 52074 Aachen, Germany (corresponding author, phone: +49-241-8026267; fax: +49-241-8022293; e-mail: t.jasinski@wzl.rwth-aachen.de).

II. CHALLENGES OF PURCHASING IN THE EUROPEAN MACHINERY AND EQUIPMENT INDUSTRY

The concept described in this paper addresses the industry of European machinery and equipment manufacturers. This highly specialized industrial sector accounts for 10.9% of value-added in European manufacturing (178 billion €) and employs about 3.5 million people [4]. The typical machine manufacturer acts as a prime contractor for his customer and coordinates all relevant activities from development of specific parts or components to coordinating order specific networks of several hundreds suppliers and partners worldwide in order to create a highly specialized and complex product consisting of thousands of parts, components, and modules [5].

The logistic performance of enterprises in machinery and equipment industry has to adapt permanently to changing market conditions. Whereas in times of oversupply a quick delivery is the successive factor, during high market demands the ability to deliver is critical for the business [6]. For example, finding suppliers in other European regions in times of high market demands will not be that easy, as due to the highly interlinked markets within Europe, order entries (as the economy itself) within individual countries rise and fall simultaneously. Furthermore bottlenecks regarding specific supplier goods are not concerning only one producer but generally occur as a phenomenon of the entire European network (e.g. delivery problems with cast parts just before the current crisis). Therefore general market information delivers important indicators for the supply chain coordination of a manufacturer in this industry.

Hence coordination occurs as the big challenge. This handicap is being hampered by a very heterogenic IT-landscape with approximately 250 different enterprise resource planning systems (ERP-Systems) within Europe [7]. That is the main reason why most ordering or purchasing processes are conducted manually via fax, telephone or email [8]. With regard to the number of components of a machine it takes enormous effort for the purchase department to place and negotiate orders. Thus parts are usually ordered without validation of individual standard replacement times. Only a small number of components (usually the A-parts) is monitored and tracked manually by agreeing on delivery dates with suppliers, negotiating of penalties and bonus for differing delivery dates and manually monitoring the order status on a regular basis via telephone, fax or email. Usually this procedure leads to a successful delivery fulfillment. However,

this approach is very time consuming and can only be applied to a limited number of parts (normally less than 5%) with regard to limited resource capacity. Thus parts with invalidated standard replacement times can become very critical as delays are usually not identified in advance. Consequently the supplier decides autonomously on the sequence of assembly or assembly completion which might lead to failed delivery times on the manufacturer's side.

The manufacture's problem originates in missing participation in the decision making process. Usually the manufacturer has no information about the current order status which gives him the role of a reacting authority (e.g. re-scheduling). Therefore only one missing component, regardless to its value or importance, can be responsible for a total assembly stop. This leads to turbulences within the production process as quick countermeasures in a fire-fighting mentality have to be identified, usually delaying subsequent orders. Delay will first propagate to the consecutive partner/ customer and then to the internal company network due to strong cross-linkage and mutual time dependencies. This is the focal point for initiation of turbulences to the network.

III. DELIVERY RELIABILITY AND DELIVERY VALUE IN NON-HIERARCHICAL NETWORKS

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 adopted. Even more the financial impact related to missing delivery reliability 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 are not. Studies and internal industry cases[1] state that machine manufacturers e.g. have to pay 0.5% of the project budget per delayed week [9]. 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.

Applying those 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.

A. Failure of approved coordination mechanisms

There are several reasons why coordination mechanisms known and successfully implemented in other industrial sectors have failed in machinery and equipment industry [10].

---

[1] The author has extensive experience in the machinery and equipment industry due to numerous consulting projects.

The main reason for the failure 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 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 [11, 12]. 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 [13].

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 [14].

B. Necessity of a non-centralized coordination mechanism

The only known and successfully exercised approach to reach a pareto-efficient allocation of resources in a non-hierarchical network is exemplified by creating market mechanisms with its pricing functions [15]. Thus the poor resource allocation within machinery and equipment industry can only be traced back to a market failure due to information asymmetry – the unknown value of delivery reliability. In order to overcome this failure, delivery reliability has to become a commonly traded good. Therefore one central research question has to be answered: Can delivery reliability be priced as a commonly traded good?

IV. FRAMEWORK FOR DELIVERY RELIABILITY

In order to answer the question posed above positively, a theoretical framework is introduced, which is based on the idea of a market-driven, non-centralized coordination mechanism (see Fig. 1). By enabling communication, setting up transparency, creating a market-driven coordination mechanism and thus facilitating pareto-efficient allocation, the framework can be seen as an enabling model for improving delivery reliability in non-hierarchical production networks of machinery and equipment industry.
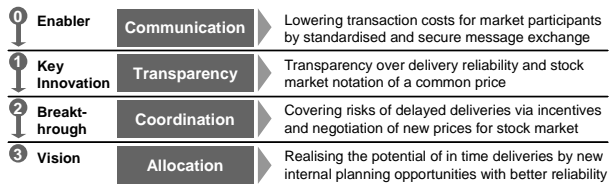
Fig. 1 Theoretical framework for delivery reliability

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. Otherwise the information required for bilateral communication and negotiation functions would exceed the value proposition of increased delivery reliability.

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.

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.

Simultaneously, the pricing and coordination function enables higher network performance by pareto-efficient *allocation*. 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.

V. CONTROL LOOP FOR DELIVERY RELIABILITY IMPROVEMENT

The theoretical framework presented above can be transformed into an operational model by applying a control loop's logic to a certain customer-supplier-relationship respectively a purchasing process in general (see Fig. 2). 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.

Here, a purchasing process represents the control path of the control loop and is to be improved. *Communication* is enabled by an IT-based B2B-platform named myOpenFactory. External *transparency* is created by a supplier's and purchasing process' performance evaluation and internal *transparency* if facilitated by monetarily quantifying the value of an in time delivery. Both correspond to the control loop's feed-back path. Evaluated supplier information 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. By applying this control loop to the non-hierarchical production network of the machinery and equipment industry, a pareto-efficient *allocation* is reached.
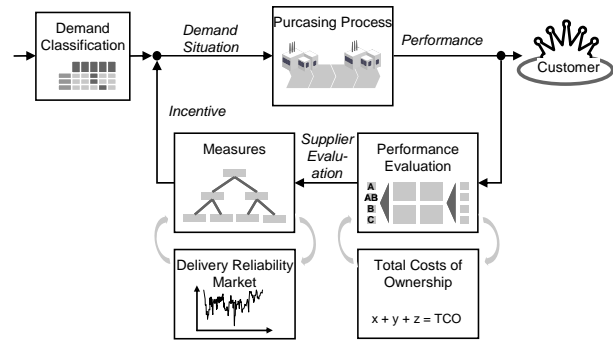

Fig. 2 Control loop for delivery reliability

The control loop's key elements demand classification, purchasing process, performance evaluation, total costs of ownership, measures, and delivery reliability market are detailed in the following paragraphs.

A. Demand classification

The input variable of the control loop is represented by a certain demand situation. A manufacturer needs to initiate and conduct a number of purchasing processes in order to fulfill his customer's order. Each of those purchasing processes can be described and classified by a morphological box. The parameters used for the classification have to clearly characterize each ordering process by means of integrity, differentiability, and comparability.

The parameters used to describe an ordering process are sub-divided into four groups, each being related to different influencing entities/ factors:
1) Customer-related parameters,
2) Manufacturer-related parameters,
3) Supplier-related parameters, and
4) Order-related parameters.

The *customer-related parameters* describe the purchasing process related to the manufacturer's customer. Relevant issues to be regarded are the power or impact of the customer's order as well as the customer itself (A-, B-, or C-customer), and the probability of change of the order's specification (deviation due to quantity, construction, time etc.). In order to regard the manufacturer's point of view, the *manufacturer-related parameters* cover issues like the critical path of the order or the way of conducting the order (make-to-stock, assemble-to-order, engineer-to-order etc.). The *supplier-related parameters* record subjects like the replacement time respectively the possibility to substitute a supplier for a specific order, the supplier's way of conducting the order (make-to-stock, assemble-to-order, engineer-to-order etc.), the supplier's signification or classification (A-, B-, or

C-supplier) or the general framework of the transaction (frame contract, project-related or spot market contract etc.). To enable a comparability of all the variables mentioned the *order-related parameters* clearly describe the purchased parts by means of a general classification of parts (e.g. scrubs, cast parts, bearings etc.) and a monetary valuation of the items (A-, B-, or C-part).

B. Purchasing Process

The purchasing process itself remains on one hand as simple as possible to allow comparability, on the other hand as configurable as necessary to cover all order types possible. To reduce complexity concerning the control loop an established and approved approach is being used. The myOpenFactory approach represents a B2B-plattform enabling the exchange of business information like orders, invoices, quotes etc. between multiple enterprises and creating a situation in which enterprises are interconnected, applying a common data model [7]. A multiplicity of companies of the machinery and equipment industry is connected to this platform already thus myOpenFactory provides an adequate IT-based fundament for the control loop, covering all basic interactions in an ordering process, from the initial query, to an offer and acceptance ending with a receipt of goods.

C. Performance Evaluation

Once the purchasing process is completed data and relevant information is being gripped and stored automatically (by making use of a server) according to the main principle of a control loop. The necessary data (e.g. delivery date, adherence to delivery date, quality measures etc.) can be uploaded from any ERP-system or an integrated myOpenFactory module (in the case the company does not use IT-based ERP). The data uploaded exhibits the basis for evaluating the performance of the purchasing process and the associated supplier.

The biggest challenge of the performance evaluation is guaranteeing comparability among different suppliers. Supplying different parts or goods in differing purchasing constellations might lead to miscellaneous performances. The basis for setting up comparability was formed by clearly describing the purchasing process in the demand classification including a visible assignment to a product group (e.g. cast parts). In addition the performance has to be evaluated in an as generic way as possible. Therefore well-known and established key performance indicators (KPI) are selected to enable a comparable performance evaluation. These performance measures can be aggregated from the data uploaded before.

The KPIs represent traditional performance evaluation sectors. In a time dimension, time-related measures like delivery date or adherence to delivery date are aggregated and calculated. In a quality dimension the most important quality aspects like quality rate etc. are measured. A value dimension is used to evaluate all relevant financial indicators like price, price stability or monetary penalties.

According to these three dimensions each purchasing process and each supplier can be evaluated. With each new purchasing process new data is generated and stored creating a huge database which is used to create transparency and comparability among suppliers within non-hierarchical production networks.

D. Total Costs of Ownership

While the performance evaluation basically represents an external transparency the total costs of ownership account for internal transparency. Most companies are not aware of the negative effects of a delayed delivery. Mainly standardized penalties are contracted representing a minor project's budget share not covering all delay-related impacts at all.

A delayed delivery of the manufacturer's supplier causes many losses beside a possible financial penalty of his own customer if his delivery is not in time. 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. Thus in order to get an idea about the value of an in time delivery, these figures have to be taken into account. If all relevant financial measures mentioned can be aggregated to the total costs of ownership, delivery reliability respectively an in time delivery can be quantified monetarily and be used e.g. to financially stimulate a supplier to deliver in time.

E. Incentive System

Based on the performance evaluation and the transparency over the value of delivery reliability an incentive system can be implemented acting as a central coordination mechanism. If the manufacturer is aware of the costs of a delayed delivery he explicitly knows the range of his financial margin to foster an in time delivery. For example, if a delayed delivery might cause costs of e.g. 15% of the project's budget, the manufacturer could add an amount of up to 15% of the project's share to the price agreed on with his supplier in order to guarantee a delivery in time.

An incentive system also might be based on non-financial measures. An effective way to stimulate suppliers is to dangle e.g. frame contracts, a long-term relationship or partnership. This maximizes the supplier's interest in an in time delivery resulting in a prioritization of a specific delivery.

This kind of incentive system takes the role of a non-centralized coordination mechanism within the non-hierarchical network of the machinery and equipment industry. Each order in any customer-supplier-relationship is coordinated bilaterally by making use of an automated incentive mechanism. Therefore a methodology is used which assigns a certain incentive (financial or non-financial) to a specific demand classification as introduced above.

F. Market for delivery reliability

According to the financial incentives a market for delivery reliability can be established. This market is based on the knowledge about the monetary value of delivery reliability as well as the current demand situation in the market respectively

within the production network and runs analogously to a common stock market. A manufacturer is 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 becomes a commonly traded good. It is to be expected that the value of delivery reliability will significantly be higher in times of high demand than in times of an economic downturn.

VI. Technical Implementation

The technical implementation of the control loop is presented in Fig. 3. The left side represents the customer and his ERP-system. The communication with the supplier's ERP-system is conducted via the myOpenFactory server covering the entire purchasing process. In addition the customer's and supplier's ERP-systems are linked to a transparency server which is responsible for any market functions necessary. Via secured communication channels the ERP-systems is updated with information about the current value of delivery reliability enabling an automated negotiation process between the customer's and supplier's ERP-systems resulting in a final order price including a possible monetary incentive.
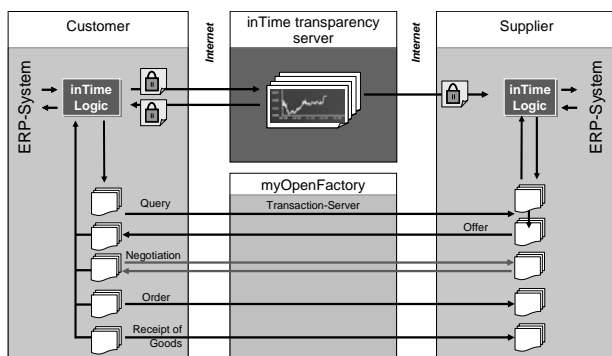

Fig. 3 Technical implementation of the control loop

VII. Conclusion

Delivery reliability is a very important success factor in non-hierarchical markets. The impact of delayed supplies impedes the competitiveness of the European machinery and equipment industry. Based on a theoretical framework picking the value of delivery reliability out as a central competitive advantage, this paper introduces an approach to improve delivery reliability in non-hierarchical production networks within the European machinery and equipment industry by applying the basic principle of a control loop to a common purchasing process, thus creating a non-centralized, market-driven coordination mechanism.

The control loop describes an applicable model for the machinery and equipment industry which helps overcoming the information asymmetry (the unknown monetary value of delivery reliability) of the industry's non-hierarchical production networks. Thus on the one hand a basis for the industry's decisive improvement is created and on the other hand scientific advancement is achieved. However,

implementing the control loop and making all functions work in collaboration with a company's ERP-system each of the control loop's key elements as well as their interfaces have to be further specified and detailed, making advanced research and development necessary.

Thus, the European research project "inTime" coordinated by the author is developing all functionalities, methodologies and tools necessary to make the control loop applicable in the environment of European machinery and equipment industry.

References

[1] A. Gunasekaran, L. Forker, and B. Kobu "Improving operations performance in small company," *International Journal of Operations & Production Management*, vol. 20, no. 3, pp. 316-335, 2000.
[2] A. Ghobadian, and D. Gallear, "Total quality management in SMEs," *OMEGA*, vol. 24, no. 1, pp. 83-100, 1996.
[3] G. Reinhart, and M. Bredow, "Kooperationsgestaltung in Productionsnetzwerken," in *5th Conference Vernetzt planen und produzieren*, Chemnitz, 2006, pp. 241-244.
[4] Eurostat. (2008 March 01) Industrial turnover – Manufacturing [Online]. Available: ec.europa.eu/eurostat/
[5] Verband deutscher Maschinen- und Anlagenbauer (VDMA), *Maschinenbau in Zahl und Bild*. Frankfurt: VDMA Verlag, 2008
[6] D. Jones, "Creating lean solutions (Published Conference Proceedings style)," in *2nd Lean Management Summit*, Aachen, 2005, pp. 17-28.
[7] G. Schuh, A. Kampker, C. Narr, T. Potente, and P. Attig, "myOpenFactory," *International Journal of Computer Integrated Manufacturing*, 2nd ed. vol. 21, no. 2, p. 215, 2007.
[8] A. R. Voegle, and M. P. Zeuch, *Supply network management*. Wiesbaden: Gabler-Verlag, 2001, ch. 2.
[9] G. Schuh et al., *Effizient, schnell und erfolgreich*. Frankfurt: VDMA Verlag, 2007, pp. 60-62.
[10] H. P. Wiendahl, G. Cleminskfa, and C. Begemanna, "A systematic approach for ensuring the logistic process reliability of supply chains," *CIRP Annals - Manufacturing Technology*, vol. 52, no. 1, pp. 375-380, 2003.
[11] G. E. Akerlof, "The market for lemons: Quality uncertainty and the market mechanism," *Journal of Economics*, vol. 84, no. 3, pp. 488-500, 1970.
[12] K. Johansen, M. Comstocka, and M. Winroth, "Coordination in collaborative manufacturing meganetworks: A case study," *Journal of Engineering and Technology Management*, vol. 22, no. 3, pp. 226-244, 2005.
[13] M. He, A. Rogers, X. Luo, and N.R. Jennings, "Designing a successful trading agent for supply chain management," in 5th International Joint Conference on Autonomous Agents and Multiagent Systems, Hakodate, 2006, pp. 1159-1166.
[14] G. Schuh et al., *Effiziente Auftragsabwicklung mit myOpenFactory*. München: Carl Hanser Verlag, 2008, ch. 2.
[15] N. G. Mankiw, *Principles of economics*. South-Western: Thomson Learning, 2004.