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# Using Real Options in ERP-Systems for Improving Delivery Reliability

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## ABSTRACT

Today's machinery and equipment industry is a highly volatile market, giving rise to frequently instable and inapprehensible buyer-supplier-relationships and to turbulences with respect to reliability of deliveries. With this paper we propose a minimal invasive approach how to overcome existing capability limitations in production planning, scheduling and procurement of ERP-systems by using real options as means for coordinating the divergent interest of buyers and suppliers. Following the design research paradigm, we first describe how real options can be integrated in a contemporary ERP-system. In a supplemental evaluation, the attitude toward using this approach is discussed. This final discussion provides insights whether companies in the machinery and equipment industry are willing to adopt our real options approach, or if they prefer the use of other, not necessarily IT-enabled, means for handling the poor delivery reliability.

## Keywords

Design science, enterprise resource planning, manufacturing and equipment industry, electronic procurement, real options theory.

## INTRODUCTION

Enterprise Resource Planning (ERP) systems are undergoing fundamental changes in both *business functionality*, *delivery*, and *target groups*. The evolution in the area of business functionality started with the so-called Material Requirements Planning (MRP) systems, which appeared for the first time during the 1960s. MRP had the purpose to find an effective method of ordering material and components needed for manufacturing. During time, MRP systems were gradually overcome by closed-loop MRP systems followed by Manufacturing Requirements Planning systems, which added further functionalities. This evolution led to the well known fully blown ERP systems such as SAP R/3 or BaanERP, which provided a seamless integration of data throughout the whole company using multiple modules, each encapsulating a single business functionality. According to Davenport (1998) the advent of ERP-systems presumed to be the "[...] most important development in the corporate use of information technology in the 1990s". Still the market for ERP-solutions is steadily growing. But before becoming a holistic solution for business integration, the origins of today's ERP-systems had to evolve over almost 50 years!

The evolution with respect to delivery started with the discussion of new computing paradigms such as *utility computing* or *cloud computing*, commoditizing and delivering ERP-systems in a manner similar to traditional services such as electricity, gas or water (Rappa 2004). In this sense vom Brocke et al. (2009) noted that, in contrast to former ERP, which were to be chosen and operated as self-contained systems of individual vendors, service-oriented ERP – often seen as equal with Software as a Service (SaaS) – will be hosted and maintained by the software vendor itself, delivering a set of common code and data definitions mainly on a pay-for-use or subscription basis. For both, software vendor and consumer this approach provides a dependable basis for calculating costs/revenues and planning service levels/capacity. An additional advantage arises, since the software vendor does not have to perpetuate a competition between present and future versions. According to Choudhary (2007) „[...] individual features can be released as soon as they are completed whereas the perpetual licensing model requires them to be withheld until a new version of the software is completed“.

Moreover, SaaS is an important driver for ERP vendors to win over new target groups. Whereas the large-scale ERP-systems were mostly adopted by large-scale enterprise, SaaS-based solutions offer a new possibility to also attract small and medium-sized enterprises (SME), which typically operate on limited budgets, human resources, and hardware capabilities, to adopt ERP-systems. In tightened economic times, SaaS is attractive because it is funded as an operational expense, not as a capital expenditure. Furthermore, SaaS can offer an 'instant on' capability for SME; that is, in some cases, it can be implemented with limited intervention or on shortened timescales, thereby allowing benefits to be gained sooner rather than later. In addition, this development fosters the ability to tailor next generation ERP-systems more easily in order to meet company or

industry specific requirements. We understand tailoring as actions that range from the configuration (refers to setting parameters in the package to reflect organizational features) until the modification (refers to changing package code to perform unique business processes) of ERP-systems (Brehm et al. 2001). The flexibility of today's ERP-systems allows for a great deal of tailoring by using minimal invasive configuration methods only.

A very specific but also a very interesting scenario for such a minimal invasive tailoring is given in the machinery and equipment industry. In this industry, the delivery reliability reaches only about 65%, constituting one of the industry's biggest challenges (Schuh et al. 2010). Such a poor delivery reliability is not the general case as the exemplary cases of automotive and retail industry prove by exhibiting a reliability of 95%. Reasons for this poor performance can be found in the characteristics of the manufacturing and equipment industry. Mainly small and medium sized enterprises (SMEs) engage in constantly changing, non-hierarchical, and volatile production networks with heterogeneous nature. Moreover, the industry's products represent highly specialized and complex items consisting of thousands of parts, components, and modules. Manufacturing enterprises therefore have to maintain relationships with several hundreds of suppliers and partners worldwide.

Manufacturing firms cannot fully quantify the losses related to missing delivery reliability. Though, they are aware of the correlative losses, which result from penalties for delayed delivery, extended assembly times and expensive short-term logistical actions. In order to improve delivery reliability in such non-hierarchical production networks, as it is the case for the machinery and equipment industry, suitable coordination mechanisms have to be employed. Kleinert and Stich (2009) propose to include delivery reliability as a commonly traded part of the ordered good's price. The value of delivery reliability has to be made comparable by representing it as a percentage of the price. In this way, the incentives for in time delivery become the central coordination mechanism. Regarding incentives in general, there are various approaches of how they can be realized (Pinto et al. 2011). Kleinert and Stich (2009) decided to choose the Real Option Approach (ROA) for calculating the incentives required for the coordination mechanism of non-hierarchical production networks. With the coordination framework at hand, we aim with this paper at answering the following research question: *How can ROA be implemented in ERP-systems in order to support SMEs of the machinery and equipment industry in improving overall delivery reliability?* To minimize the inevitable risks of changes to ERP-systems, the solution should be of a minimal invasive nature.

The paper is structured as follows: First, a short introduction to real options theory as well as contextualization with respect to our delivery reliability problem is given in the section that follows. Subsequently, we describe the applied research methodology, the means and framework for analysis as well as provide a short description of the generic business processes, which were analyzed in the course of this study. Based on the used business process framework, we then demonstrate how real options can be implemented in a contemporary ERP-system using a minimal invasive method. Finally in the last two sections, we present the results of a preliminary survey we conducted to estimate the acceptance of the proposed approach and conclude with a brief discussion related to managerial and research implications.

## **REAL OPTIONS IN THE CONTEXT OF DELIVERY RELIABILITY**

Originally, the real option approach is developed in the discipline of financial and decision-making science to adapt the evaluation of financial options to the investment in real assets (Myers 1977). The general idea was to evaluate investment possibilities according to changes in the project value through possible follow-on investments. Grounding on this idea, many delineations and areas of application were specified in literature (e.g. Amran and Kulatilaka 1999; Copeland and Antikarov 2003; McGrath 1997; Taudes et al. 2000; Trigeorgis 1996). With this paper we adopt the general definition of the Information Systems Theory website provided by the York University, which defines a real option as "the right, but not the obligation, to undertake some business decision, typically the option to make a capital investment" (Wade and Schneberger 2005).

In the context of our research question, this means that the possibility exists to adapt the suppliers' capacity to changing environmental conditions. Instead of deciding about the capacity of supplier on a certain date, an option allows the postponement of the decision. In order to have this option the supplier has to receive a certain incentive to keep his capacities open. This incentive can be rated as the price of a real option (cf. Figure 1).

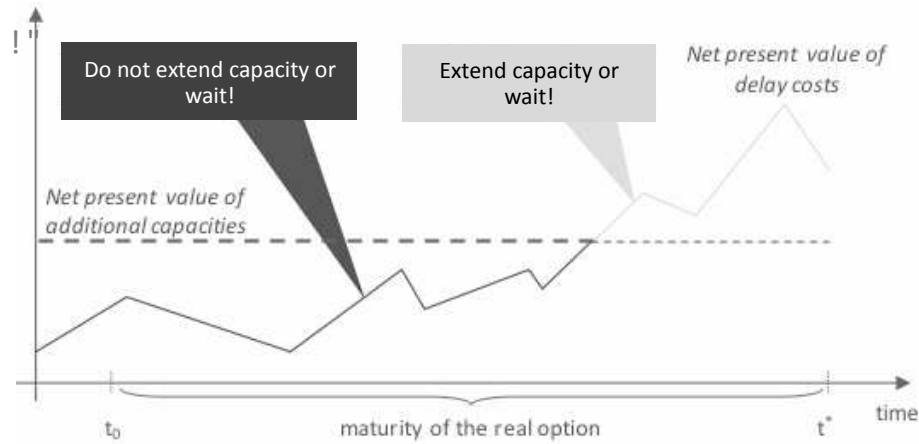


Figure 1. Real option approach for decision-making in procurement, based on (Trigeorgis 1996)

According to Kleinert and Stich (2009) the application of the real option theory to delivery reliability leads to exclusivity, flexibility, uncertainty, irreversibility and gradual investment: *Exclusiveness* arises from reservation of capacities insofar the supplier guarantees the reservation. This is because the reserved capacities are the right but not the obligation to access additional capacities flexibility. *Uncertainties* exist because benefit of delivery reliability is unpredictable in the phase of setting up the contract. The fee for reserving additional capacities is *irreversible*, in case of not accessing the additional capacities. It is necessary to record them as sunk cost. The fact that the investment in on time delivery outlines a *gradual investment* is because the investment in on time delivery is an investment in capacity reservation that constitutes an investment in an intangible asset. It starts with a payment to the supplier for capacity reservation and results in additive delivery reliability representing an advantage in terms of reduced setup times, rescheduling or delay costs, as well as possible follow-up orders.

## RESEARCH METHOD

Research which aims to design solutions to certain classes of practical problems requires a slightly different approach as to natural sciences, which rather try to explain and predict behavioral aspects of reality by developing and verifying theories (March and Smith 1995). Hence, in order to build and evaluate an 'artificial solution', the design science research (DSR) approach is applied in the context of this work (Hevner et al. 2004). Rather than theory-driven research, DSR can be seen as research towards systematical problem solving (Wieringa 2009). This understanding has been broadly adopted by other scholars (e.g. Hevner et al. 2004; Peffers et al. 2006; Vahidov 2006). However, there is not yet a general agreement on how a common design research process should look like. A comparison of different design research processes conducted by Offermann et al. (2009) suggests to differentiating three main phases, namely the problem identification, the solution design, and the evaluation of the design. Following this guideline, the research process can be outlined as follows: The research question to be addressed by the new IT-artifact, namely how can ROA be implemented in ERP-systems in order to support SMEs of the machinery and equipment industry in improving overall delivery reliability. The emergence of this research question has previously been identified by reviewing the current literature as well as by conducting expert interviews with three machine tool manufacturers (Mettler et al. 2011). With this paper we address the first iteration of our overall design research process, that is the description of how ROA can be implemented in ERP-systems by means of minimal invasive tailoring as well as the pre-evaluation of its conceptualization. We used use case analysis as method for representing and prototyping for practically showing how the ROA concept can be implemented in ERP-systems. For this, we will analyze the SaaS-based ERP-system SAP Business ByDesign, which is specifically suited for SMEs. As regards to tailoring types, we restrict ourselves to configuration (Brehm et al. 2001). In this way, implementation efforts as well as implementation risks and post-implementation risks involved, are minimized.

## Means and Framework for Analysis

As framework for the analysis the Supply Chain Operations Reference-model (SCOR) was applied (Supply Chain Council 2008). The framework differentiates three levels of analysis: top level, configuration level and process element level (cf. Figure 2).

At the top level, five distinct business processes are distinguished: plan, source, make, deliver and return. Business processes can be defined as sets of partially ordered and coordinated tasks and thereof deduced ‘atomic’ activities, often cutting across functional boundaries within organizations (Curtis et al. 1992; Leymann and Altenhuber 1994). The emphasis of this study has been placed on the sourcing processes. Other basic SCOR processes, such as plan, make and deliver were thus not reflected in much detail.

At the configuration level, the main tasks of the processes are defined. In order to investigate different production planning philosophies, the ordering routines of both engineer-to-order and make-to-order were part of the investigation (see section ‘analyzed business processes’). At the process element level, the respective activities were analyzed in more detail. This allowed the detection of integration points for ROA in current process steps or even entire workflows. Thus, the use case analysis mainly operated on this level of detail.

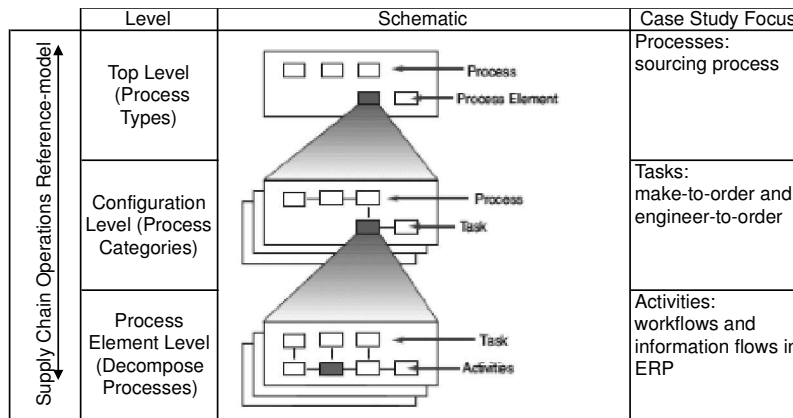


Figure 2. Framework for use case analysis

As means for documenting the use cases, the business process modeling notation (BPMN) was used. For testing the use cases in a real setting, we had access to an instance of SAP Business ByDesign, which represents an ERP-solution particularly designed for SME. It supports all key business areas of an enterprise like financial management, supply chain management, project management to name just a few. The architecture of SAP Business ByDesign is similar to most modern ERP-systems, however, it uses the SaaS deployment model, thus enabling the communication with a rich internet architecture client (RIA), web services, mobiles, mashups and office automation. The test system we had to our disposal was a SAP Business ByDesign feature pack 2.5, which was hosted by a computer center of the SAP AG on Linux 2.6. The underlying database was a MaxDB 7.9. Communication with SAP Business ByDesign was done via a Silverlight RIA-Client.

**Analyzed Business Processes**

Within the context of sourcing, we examined two specific tasks more thoroughly. First, based on the make-to-order (MTO) manufacturing logic as described by Ramakrishnan (2009), we analyzed six basic activities: sales order processing, production planning, production scheduling, manufacturing execution, shipment and billing (Figure 3). Production planning and production scheduling activities are of special importance for our analysis because offered incentives will impact planning and scheduling when adhering to ROA principles.

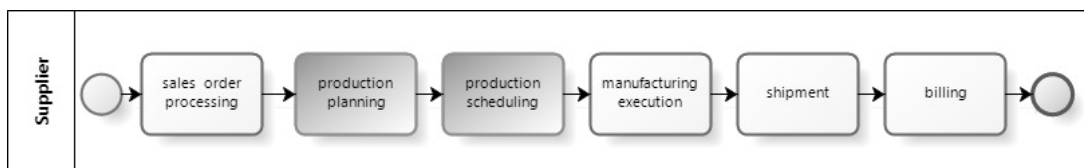


Figure 3. Schematic description of a MTO business process; relevant tasks are highlighted

Second, we analyzed the sourcing process, when the engineer-to-order (ETO) manufacturing logic is applied. In doing so, we examined seven basic activities: sales order processing, project planning, advanced procurement, engineering, production planning, manufacturing execution, and project billing (Figure 4). In this case, the most important activity for the analysis is advanced procurement, where incentives, calculated using ROA, are applied to purchase orders.

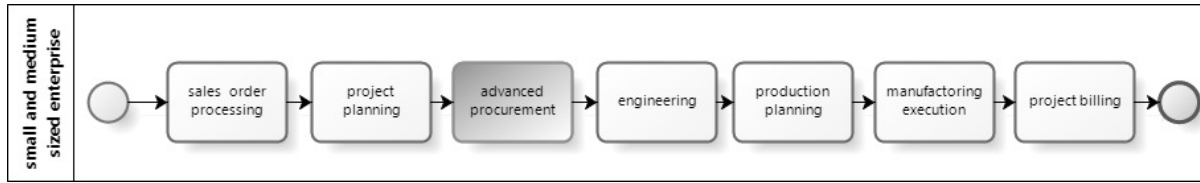


Figure 4. Schematic description of an ETO business process; relevant task is highlighted

**REAL OPTIONS IN ERP-BASED PRODUCTION PLANNING AND PROCUREMENT**

While executing the aforementioned business processes with the use case ERP-systems, possible integration points for ROA are identified. Special attention is required for the three activities that are highlighted in Figure 3 and Figure 4.

**Potential Changes in MTO Production Planning**

As to the ROA concept, real options offered by the customer should be used as fee for the reservation of additional capacities on supplier’s side (see section ‘background’). Already at this point a first challenge occurs: How can the reservation of additional capacities be handled? There are multiple strategies:

- *Ignore capacity reservations.* The supplier does not reserve any additional capacities during production planning. Consequently accepting the risk of not receiving the bonus, if delays occur during manufacturing execution.
- *Decide from case to case.* The supplier divides the production orders into those that are planned with slack times (additional reservation of capacities) and such that are planned without, maximizing the revenue.
- *Always reserve capacities.* Every production order that includes a real option is planned with slack times, to ensure more flexibility during production, hence increasing the probability of in time delivery.

For reasons of simplicity, we assume in the following analysis that the supplier company always tries to reserve additional capacities. Moreover, the concept of production planning is simplified in order to be able to better convey the general ideas of our approach. First of all, the amount of additional capacities or slack time has to be calculated for every production order that includes a real option. Then production planning can begin. In an ideal case, orders arrive successively and can be planned without any collisions. Production planning is performed as without the incentive approach, with the only difference being time of production consisting of the actual time of manufacturing including slack time. It gets challenging when a decision between two production orders has to be made. Figure 5 provides an overview of an example situation, assuming two production orders. The first one (PO I) has an order value of \$33.000 for which a real option of \$1.000 is offered. For the second one (PO II), a real option of \$6.000 was offered, having an order value of \$30.000. Both production orders overlap in the production schedule as regards to manufacturing time. Assuming that there is only one manufacturing facility and thus only one production order can be manufactured at a time, it is impossible to determine a production schedule for which both production orders are completed in time.

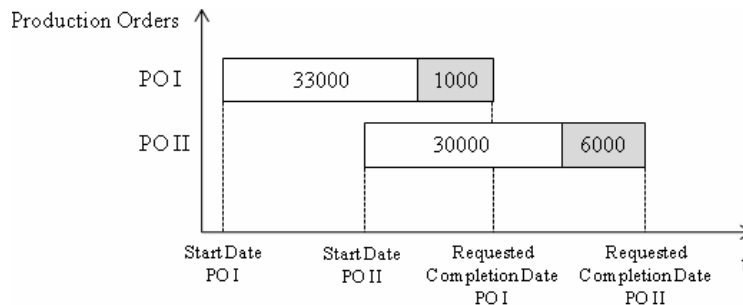
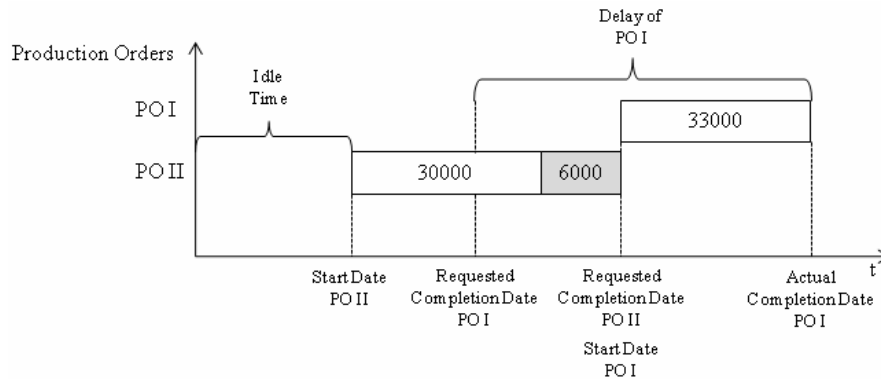


Figure 5. Overlapping Production Orders

This challenge can be addressed with two different approaches. The first one is to avoid such situations by checking if enough capacity is available for in time fulfillment of a production order. This check must be performed before an order confirmation is sent. Consequently, this procedure may lead to rejection of orders when not enough capacity is available, which will eventually result in lost sales for the company. From an entrepreneurial point of view, this option is not attractive. A more attractive approach is the following. Orders get accepted, even if there is not enough capacity to fulfill them in time. In the next step, a scheduling algorithm must be applied that maximizes revenue while considering the effects of real options

(if order is not violating any time constraints, the real option applies, otherwise not). For the sample case this would imply that production order two is preferred and production order one is scheduled with a lower priority which leads to idle times and a significant delay of production order one (cf. Figure 6).

In order to minimize consequences like idle times and severe delays, it is sometimes possible that the manufacturing process of goods can be split up in temporally separated steps. In fact, feasibility of such a manufacturing process depends heavily on the product, available machines and available equipment and cannot be regarded as a general case. Assuming feasibility for the sample scenario, production order one is then manufactured first until production order two is scheduled. After the completion of the second production order, the manufacturing of production order one will continue. This schedule will result in less idle times and less delay for production order one.



**Figure 6. Prioritized Production Schedule**

To use the described approaches it is first of all necessary to implement the described mechanisms to prioritize production orders and to determine slack times. In addition to this, it becomes necessary to use an adjusted production planning algorithm for mastering the new challenges arising from incorporation of ROA. As the adjustment of production planning algorithms of ERP-systems involves high risks and such adjustments tend to be very extensive by nature, the only way to stick to a minimal invasive strategy is to provide these special functionalities by applications external to the ERP-system. But reintegrating the output of these external applications into the manufacturing logic of the ERP-system represents a major challenge, which has to be solved.

#### **Potential Changes in MTO Production Scheduling**

Production scheduling is the process to adapt the production schedule to altered circumstances. With incorporating real options, it becomes necessary to adapt the production schedule when a production order that includes real options is processed and the planned slack time is not or only partially used. The production schedule has to be adjusted to avoid idle times between successive production orders. To enable this, it is necessary to compare the actual completion date and the planned completion date of a production order. If these dates are different, rescheduling of all succeeding production orders is required to avoid idle times. The basic mechanisms for rescheduling are provided by the considered ERP-systems.

#### **Potential Changes in ETO Advanced Procurement**

A suitable way to integrate real options into ETO advanced procurement activity is basically to add the amount of the real option as additional information to the purchase order. From a technical point of view, this can be realized by expanding the purchase order screen with an additional input field, which holds the amount of the real option. Moreover, to automate the calculation of the real options, a drop-down menu allows for choosing a means for calculation. Here various options can be provided, e.g. a percentage of the order value, calculation by an externally provided ROA algorithm or even manual input. For reasons of user convenience, these additional options will only be visible when toggling a check box. Figure 7 presents an impression of how a purchase order screen could look like after introducing real options.

The screenshot shows a Purchase Order form with the following details:

- Supplier:** S100400 - Omega
- Contact:** 24 - Linda Pitt (Main Contact), Phone: +44 1323 7654550
- Supplier Address:** State: [dropdown], Country: United Kingdom, City/Postal Code: Washington, NE38 8JH
- General Information:** Purchase Order ID: 81, Status: In Preparation, Purchasing Unit: A1110 - Finance, Buyer Responsible: E0005 - Janet Maxwell, Company: 1000 - Almika Inc.
- Financials:** Currency: GBP, Total Net Value: 80.00 GBP, Incoterms: EXW - Ex works, Incoterms Location: Company Site, Payment Terms: 14 days 3%, 30 days 2%, 60 days due net, Send By: e-mail
- Real Options Section (highlighted in red):**
  - Critical Delivery:
  - Amount of Incentive: 8.00 GBP
  - Calculation Base: 10% of order value (dropdown menu showing options: ROA, 5% of order value, 10% of order value, Free Text)

Figure 7. Purchase Order using Real Options

### Potential changes in other processes

The integration of the ROA concept has of course an impact to almost all activities summarized in MTO and ETO business processes. In the MTO process, sales order processing represents the point where orders that include real options are identified. From here onwards, information about the real option has to be propagated throughout all further activities. At the end, this information is required to bill the customer correctly, e.g. include value of real option in price if delivery was in time. In the ETO process, the use of real options for certain material requirements must be decided during the project planning activity such that advanced procurement can be based on these decisions.

### ATTITUDE TOWARDS USING REAL OPTIONS FOR INCENTIVIZING ON TIME DELIVERY

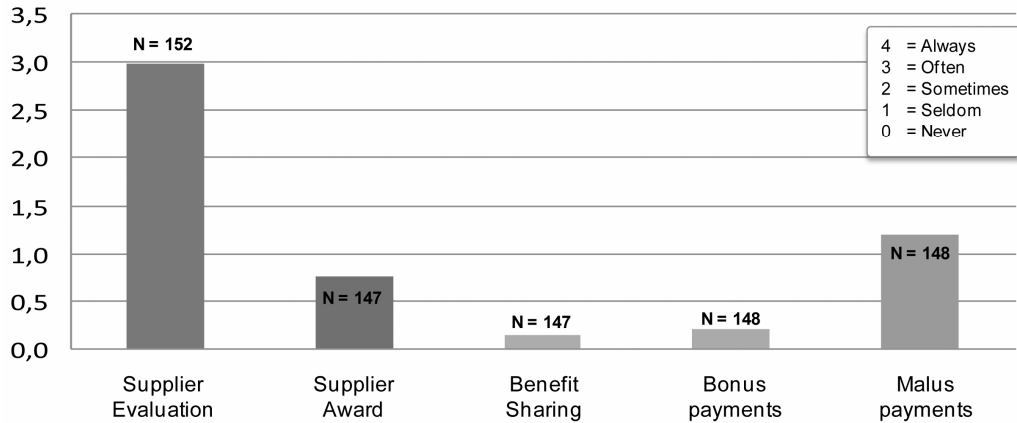
In order to test whether our propositions are welcome in practice (ex ante evaluation strategy as to Pries-Heje et al. (2008)), we conducted a web poll from November 2009 until April 2010, receiving a total of 163 responses. Around 17% were answered by enterprises with less than 50 employees, 33% by enterprises with 50-250 employees, 27% by companies with 251-1000 employees, and 23% by enterprises with more than 1000 employees. The average turnover of these companies is \$262m. With respect to the used manufacturing logic, around 43% apply project-based manufacturing (i.e. every customer order is manufactured differently), 31% exercise small series production, 17% big series production, and only 9% of the respondents employ assembly production.

With this web poll we asked a couple of general as well as very solution-specific questions relating to incentivization of on time delivery with real options (Mettler et al. 2011). As the main objective of this paper is to illustrate how to implement real options in ERP-systems, we can only provide a short recap of the most relevant answers in order to clarify the general attitude towards using real options in the context of an ERP-system and for the specific problem of delivery reliability.

First, it can be said that only about 40% of all surveyed companies could imagine using real options or other monetary incentives for reliable and flexible deliveries in the future. The highest agreement to use incentives for more reliable and more flexible delivery comes from big series production companies. Nevertheless, also more than 40% of project manufactures and small series producers could imagine applying other form of a monetary incentive to improve the reliability and flexibility of supplies. Insofar this shows that financial incentivization is not declined per se, however, attitude towards using incentives like real options is mean (cf. Figure 8).

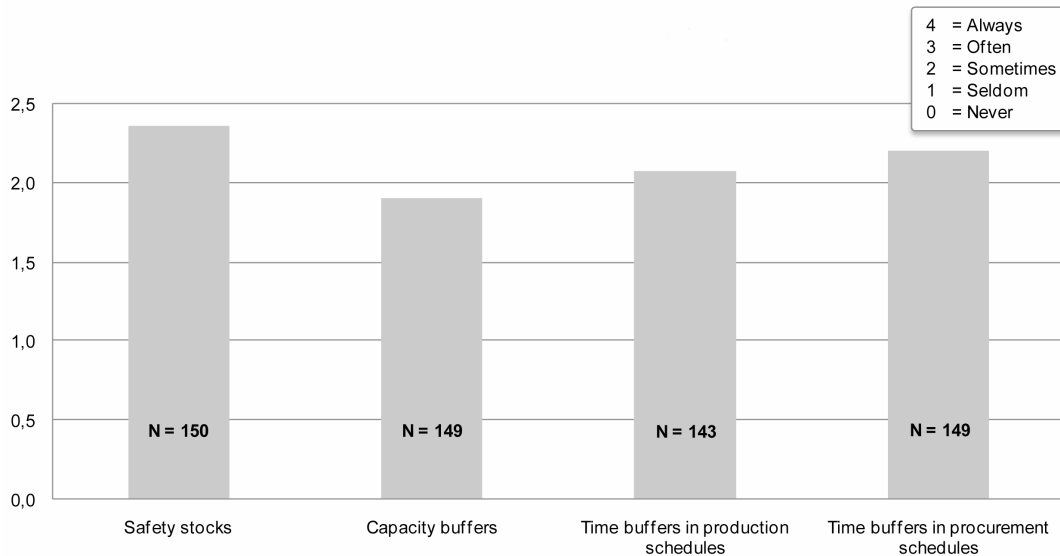
Given the low response rate with respect to financial incentivization (i.e. bonus and malus payments, benefit sharing), companies rather tend to use non-financial incentives such as supplier evaluation to motivate their suppliers of delivering the shipments on time.





**Figure 8: Proactive measures to motivate supplier to deliver on time**

Furthermore, companies complement the aforementioned proactive, motivational actions with more counteractive measures such as safety stocks, capacity and time buffers in both procurement and production (cf. Figure 9). As these actions can be performed independently from any “social binding”, the reactions to it were more positive. Anyway, it is harder to promote actions, which by the way not necessarily must be successful, in order to overcome current problems. However, it also can be said that counteractive measures – by nature – do not solve the root of the problem. Moreover, they also incur costs such as for stock keeping, idle-times, and re-scheduling. In this respect, the results of the web poll showed that a counteractive approach to handle late deliveries causes additional costs of around 10-15% in overtime, re-scheduling costs, and handling costs, whereas the additional costs in stocks, transactions and lost sales were rated around 5-10%.



**Figure 9: Counteractive measures to handle late deliveries**

**CONCLUSION**

In today’s highly competitive and dynamic markets such as the machinery and equipment industry, delivery reliability represents a key success factor for building and/or retaining competitive advantages. In this paper we therefore propose a minimal invasive approach how to overcome existing capability limitations in production planning, scheduling and procurement of ERP-systems by using real options as means for coordinating the divergent interest of buyers and suppliers.

A web poll was conducted as ex ante design evaluation strategy (Pries-Heje et al. 2008). The results drawn from this survey, however, indicate that the attitude towards using proactive means, such as the proposed real options approach for securing a supplier’s production capacity, is not widely accepted yet. Reasons for this are diverse. On the one hand, it seems that the companies still tend to extensively use time and capacity buffers to compensate poor delivery reliability. On the other hand, in this specific branch financial incentivization is not widely used as means for motivating suppliers. As competition and cost optimization will increase in future, we think that this behavior will not last forever. Besides, companies did not fully reject the idea either. As

pure counteractive measures such as safety stocks and buffers do not solve the root of the problem, continued research is needed to build and evaluate more convenient and accepted models, methods and instantiations for improving delivery reliability and coordinating interests (especially for those situations in which customers' orders are not clearly set and neither safety stocks nor capacity buffers work). Possibly, a combination of proactive as well as counteractive measures is more favorable.

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