4th International DAAAM Conference
"INDUSTRIAL ENGINEERING – INNOVATION AS COMPETITIVE EDGE FOR SME"
29 - 30th April 2004, Tallinn, Estonia

FACTORS INFLUENCING THE RELIABILITY OF DELIVERY PROMISES IN CASE OF PRODUCTION

Zschorn, L.; Jähn, H. & Härtig, M.

Abstract: *The reliability of delivery promises is determined by various influence factors. It is important to know those factors because the reliability of the deliveries strongly influences the competitive environment of the enterprises. Therefore, deliveries later then promised should be avoided if possible. For that reason, this article contains a contribution to the investigation of the influence and disturbance variables of the reliability of delivery. This has the objective to make usage of those factors for the calculation of a parameter for quantifying the reliability of delivery of a concrete order. Thereby, the work concentrates particularly on the case of a make-to-order environment which leads to the fact that the delivery cannot be guaranteed by existing stocks.*
Key words: Delivery promise, reliability of delivery, uncertainty, Probability of Delivery, Capability of Production.

1. INTRODUCTION

Today especially producing enterprises have to assert themselves on markets which are characterised by an oversaturation. The consequence of this is an increasing power of the customers and a very strong stress of competition because of the other applicants. Because of the trend of the globalisation forced by the abolition of tariff regulations and the internationalisation of the big enterprises, so called global players, this situation intensifies. The small and medium-sized enterprises (SME) can only survive in that market environment if they exploit their advantage of the proximity to customers and concentrate increasingly on customer-individual orders. This trend might also be referred to as an increase of their orientation towards the customers. That situation often leads to the fact that it in many cases is impossible to establish a stock of finished products for certain products (make-to-stock) because those customer-specific parts are only produced after the arrival of a manufacturing order. Thus, a so-called make-to-order manufacture dominates in the SME. As a consequence of that, the manufacture of smaller lots and thus a widespread production programme is predominant within producing SME.
The increase in the orientation towards customers for strengthening the competitiveness of the enterprises – besides further competition factors (Spring & Boaden, 1997; Palcic et al., 2003) – however only leads to success for a medium term, if the enterprises keep the given delivery promises to a high degree. Thus, the demand arises for the enterprises for clear and objective information concerning the reliability of their delivery promise already before preparing a committing order. The customer expects that his order is completed at the agreed date in the predetermined quantity and quality. The former approach to evaluate the reliability of delivery by the delay in relation to the promised date of delivery in a make-to-order production (New, 1992; Palcic et al., 2003) resulted from that. This work however presents an alternative for the evaluation of the reliability of delivery in a make-to-stock environment. That second possibility for a quantification of the reliability of delivery is based on the evaluation of the uncertainty of a deviation between a promised and the actual date of delivery for a concrete production order. The advantage consists in the fact that the reliability of delivery can be estimated dependent on the marginal conditions individually for every order and that it is not exclusively based on the statistic analysis of data of the past.
In the following, the influences and factors are analysed which might lead to a delay of the delivery. It is the objective of that investigation to be able to ascertain an impartial parameter based on the data existing in the enterprise during the generation of the offer. That parameter is called Probability of Delivery P_D (Teich & Zschorn 2002; Teich et al., 2002). For example it might be used for the decision support and for the negotiation about contractual penalties in the stage of the preparation of an offer.

2. UNCERTAINTIES CONCERNING THE ADHERENCE TO DELIVERY PROMISES

2.1 Delimitation of the Field of Research

By the acceptation of a customer order, the enterprise commits itself to the delivery at the predetermined date. In most cases, the fixed date of delivery is based on the offer of the enterprise. This commitment causes the necessity of further information for a human decision maker in the enterprise. He wants especially to improve his knowledge concerning the existing uncertainty of a possible non-compliance of the delivery promises and thus of direct and indirect costs related to that before preparing an offer and determination of contractual agreements. According to *Hirshleifer* and *Riley* (1992), the preparation of an offer might be interpreted as a terminal move which however presumes the informational action for the evaluation of the uncertainty.
As oppose to the risk, in case of the uncertainty, there is no possibility to objectively quantify the probabilities of the occurrence of incidents (Knight, 1921). According to that statement, this paper deals with the *uncertainty* of a non-compliance of delivery promises. The reason for that is in spite of objectively and quantitatively measurable input data, there is no objective possibility for the calculation of the probability of a disturbance. This article rather introduces a subjective estimation of the uncertainties. In that sense, the parameter that has to be calculated indicates the probability of a disturbance as a subjective degree of belief (with reference to Savage, 1954; Hirshleifer & Riley, 1992). Furthermore, the confidence in the correct estimation of the uncertainty is an important influence for actions and decisions (Knight, 1921; Hirshleifer & Riley, 1992). That confidence has to guarantee the analysis of the influence factors and the measurable input data to make sure that the parameter can be interpreted as a “hard” probability in the sense of *Hirshleifer* and *Riley* (1992).
The investigation about which factors influence the reliability of delivery thereby restricts to the field of production. As mentioned above, the fulfilment of a customer order is not only made visible by the compliance to the promised date of delivery and quantity. However, if the goods are delivered to a wrong

place or wrong parts are delivered, the reason for that in most cases is a disturbance of the information flow. Those disturbances do not represent uncertainties in the sense of this article, but they have got avoidable reasons of faults. The uncertainty of disturbances in logistics, which means during the transportation from the enterprise to the customer, is as well not taken into consideration in those reflections. The reason for that is that those uncertainties are not relevant for fixing the date of delivery in the preparation of the offer. Often, the responsibility of the transport is outside the producing enterprise, e. g. the customer or external transportation service providers might be responsible for that. It can be assumed that the logistic enterprises have their “own” Probability of Delivery. Otherwise, that uncertainty can be collateralised by insurances.

2.2 Classification of the Uncertainties

Because of the assumptions made, the uncertainty of a delayed date of delivery restricts to disturbances in the production system of the producing enterprise while manufacturing the required parts. During the manufacture of products, several disturbance and influence factors influence the reliable procedure of the production process and might restrict it. Those factors first of all can be divided into internal and external impacts. The external factors influence the production system from outside and effect disturbances within the system. Therefore, they are mostly not in the responsibility of the enterprise. For example the availability of the supplied parts at the time they are needed is one of those uncertainties. The internal factors represent the inherent uncertainties of non-compliance of the production programme and of disturbances within the production system.

The second distinguishing feature refers to their temporal relation. The static uncertainties are based on existence factors and for example characterise the probability of breakdown in production (Teich et al., 2002a). They can be considered constant for a medium term and their size does not depend on a concrete order. The static probability of breakdown can only be calculated in a difficult way and in most cases has a considerably lower amount than the probability of a disturbance by dynamic uncertainties. The dynamic uncertainties depend on a specific order as well as the current situation in the producing enterprise and the predominant environmental respectively marginal conditions. Dynamic uncertainties for example result from not secure information at the time of delivery promises, for example concerning available resources, so that there are disturbances because of lacking available resources in the temporal process.

uncertainties	influence	
	internal	external
static	I	II
dynamic	III	IV

Fig.1. Classification of Uncertainties within Production Processes

According to the differentiation made, figure 1 illustrates the four different kinds of the uncertainty in the production process.

2.3 Effects of the Uncertainties on the Reliability of Delivery

It results from that mentioned classification of the uncertainties that not all kinds of uncertainties need to be considered in the evaluation of the reliability of delivery of a single order. The static uncertainties of type I and II might be neglected. Their causes are mostly not known or cannot be influenced and their evaluation with regard to the probability that it is called upon by a disturbance is very difficult. The peril of the breakdown of a machine is an example for a static uncertainty because of internal influences. Uncertainties of type II might for example illustrate breakdowns of the production system due to lightening strikes etc. Because of their static character, those uncertainties do not dispose of an expressiveness concerning the reliability of the compliance to a concrete order and thus they are not included in the definition of the reliability of delivery applied here. Therefore, the uncertainties are not longer considered in that place. However, enterprises need to aim at reducing such uncertainties on a long term or for example to assure themselves against their consequences.

The uncertainties of type III determine the variable of the Capability of Production C_P which quantifies the uncertainties within the production system of the enterprise. The Capability of Production concludes the internal influence and disturbance factors of an enterprise. This variable can be defined as a index for the compliance to a production plan and thus for the adherence to the planned production dates. Thus, that uncertainty is order-specific. That variable describes the probability of the production of a certain quantity until a certain date. The value is in an interval between 0 and 100. Thereby, 0 corresponds to an impossible production and 100 corresponds to a secure production. The reason for that determination is that the data can be quickly interpreted by human decision makers if the value is applied. It has to be mentioned that the term Capability of Production refers to the procedure of the production process. The general competence to manufacture the inquired parts – the required know-how and available machines – is presumed by a planned preparation of an offer (Teich & Zschorn, 2002).

By the help of that definition of the Capability of Production, it is possible to make statements concerning the reliability of delivery of a production order within the manufacturing enterprise. Thus, the focus of research is on the quantification of the uncertainties of type III. The third section illustrates an approach for the quantification as well as some reflections for the calculation of the Capability of Production.

The accurately timed completion of production orders furthermore depends on the duly availability of required supply parts and components. If the supply parts are belated, the production system of the producer might also be delayed. Those uncertainties are also order-specific and thus dynamic and they have an external origin. Thus, this problem can be classified according to figure 1 as uncertainty of type IV. For the assessment of a customer order it is necessary to quantify that uncertainty if the procurement of the supply parts is connected to the order. It is meant by that that the supply parts for the production of a customer order cannot be taken from the receiving storage location and thus no compensation is possible by shortfall of a minimum inventory level or other buffers. It has to be assumed that this case will be increasingly predominant in the operational practice because the increasing customer-specific manufacturing and the high number of variants connected with that also affects on the diversity of specific required input parts and components.

Besides the Capability of Production, the calculation of the parameter Probability of Delivery also has the uncertainties of type IV as input variables. Analogous to the theory of reliability, the probability for the function of the system can also be calculated from the single probabilities for the functions of the elements of the system (Birolini, 1985) whereby all the elements of the viewed system are necessary for its function. The logic AND-connection of these probabilities results from the claim for the function of all elements of the system. The breakdown calculations are valid if there is a stochastic independence. With regard to mathematics, an AND-connection means the multiplication of the probabilities (Birolini, 1985). That coherence can be transferred on the ascertainment of the Probability of Delivery because the supply of the components is independent of each other and all the supply parts need to be available at the required time for the manufacture of a product (Teich et al., 2002b). The unreliable provision of a supply part disturbs the whole production process. According to that, for supply components available in the receiving storage location of an enterprise, it is generally valid that their uncertainty concerning the availability in time equals to 0. Figure 2 includes an illustration of the connection between the reliability of delivery of the required supply parts and the reliability of delivery for the production order.

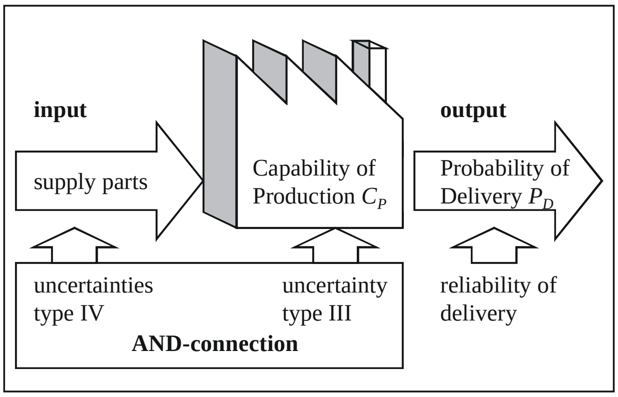

Fig. 2. Aggregation of the Reliability of Delivery from the Uncertainties of Type III and IV

The problem of an application of the multiplication of the assumed or respectively forecasted probability of a delay caused by uncertainties of type III and IV is, that a very small value results for the expected Probability of Delivery in case of a realistic large number of supply parts. For that reason, it is imaginable that the application of a minimum-function would dispose of a higher expressiveness for the decision support. This however needs to be further investigated.

3. ESTIMATION OF THE INTERNAL DYNAMIC UNCERTAINTIES OF A PRODUCTION SYSTEM

3.1 The Input Variables for the Quantification

The internal dynamic uncertainties for a possibly delayed date of delivery are based predominantly on the information deficit at the time of the preparation of the offer concerning the available resources at the time of the completion of the order. This has already been explained in subsection 2.2. It is one example for that deficit that all the possible production dates for an order can be determined by sequencing and scheduling. However, this is only possible if the reserved resources of earlier offers are taken into consideration. Nevertheless, not every given offer leads to a concrete production order which results in dynamic uncertainties concerning the available capacities. That is why those influences need to be reanalysed and recalculated for every preparation of an offer.

The introduced approach is based on the reflection that a delay in the manufacture of a customer order occurs when the capacities of a production system are not sufficient. Based on the available resources and other orders, a possible completion date for the considered order might be estimated by the help of the simulative dispatching in the production planning. The uncertainty of that estimation quantifies the Capability of Production. In principle, the Capability of Production depends on the required and the existing resources (Teich & Zschorn, 2002).

There is the possibility to determine the Capability of Production separately or in a generalised way for all the required resources, e. g. specified according to the kind of personnel, necessary machine types etc. That model is based on the simplification of a general consideration of the Capability of Production, which means that the required resources do not include a specification of the actually required resources (Teich & Zschorn, 2002). If investigations confirm the general suitability of the model for the estimation of the reliability of delivery or the Capability of Production, then it is imaginable to expand the model. However, a high complexity of the model results for realistic products and the record of the required data presumably require a high expenditure.

First of all, a closer look is taken on the input variables for the calculation of the Capability of Production which influence the required resources and thus characterise those.

The inquired quantity of an offer influences the resources necessary for the production of the current offer quantity. Because the developed model has to be specific for the enterprises, it is difficult to make a classification with regard to the quantities. Thereby, it is the problem that the quantities that have to be produced might be different for several products. For that reason, the required production time is applied instead of the inquired quantity. The ascertainment of that value is conditioned by an indication concerning the production time needed for a single part of the product. This value is fixed by the work planning and can thus it can be expected that this time is known. The required production time can be ascertained by a multiplication of that production time per part and the inquired quantity. An expressive input variable results from that procedure because not only the quantity is decisive for the utilisation of the resources; it is also the time needed for the production of the concerned order.

The required resources are also influenced by a further parameter which represents the experience of the enterprise in the manufacture of the inquired parts. As oppose to a variable for the complexity of a product (Teich & Zschorn, 2002), which among others took into consideration the temporal expenditure for the manufacture of parts dependent on their complexity, this is no longer required because that temporal parameter has already been included in the aforementioned required production time. A double consideration would only falsify the results. The suggested value experience can be generated automatically if the number of the former orders for a product (or for a very similar one) is applied as an indicator. Thereby, the intention is the consideration of learning effects. In case a product has already been manufactured several times, the temporal expenditure tends to decrease. Additionally, fewer problems must be expected in the manufacturing process than during the first production of completely new goods. Thus, that parameter also influences the necessary resources.

The first influence factor of the available resources is the actual usage rate of the production system. Thereby, the value needs to be ascertained based on a machine scheduling. It has to be aimed at achieving different values of the usage rate for different plans of the same order constellation. Because of the optimisation within the planning of the production programmes, several machine schedules are prepared. Thereby, the parameter Capability of Production is to serve as a decision criterion for a concrete plan. During the calculation, only the orders already included in the system and the order that still needs to be planned, have to be considered. Because of the inclusion of sequence-dependent setup times, it might result that also differing values of the usage rate can exist in case of the same orders. The procedure for the ascertainment of the current use of resources requires a detailed investigation and shall no longer be considered in the following. For that reason, it is assumed that that variable has a value between 0% and 100%. Thereby, 0% means that there are no orders and 100% implies that no free capacities are available.

The next considered influence parameter is the so-called offered production time. That variable is similar to the required production time on behalf of the required resources. It is composed of the unconfirmed offered production time multiplied with the acceptance rate. Thereby, the unconfirmed offered production time refers to the sum of all the required production times of all the other offers that have not been confirmed or refused yet. The ascertainment of that parameter is based on the production time per part of the offered products that has already been mentioned above. By multiplication with the quantities from the offers, the unconfirmed offered production times can be calculated.

The acceptance rate is the share of orders which result from the offers of the enterprise on the number of the given orders. By the help of the acceptance rate, the fact is considered that production orders do not result from every unconfirmed offers. Of course, the acceptance rate is enterprise-specific and can be ascertained via enterprise statistics.

The last parameter is the available time. It is composed of the difference between the offered date of delivery which also the reliability of delivery refers to and the time of the inquiry respectively during the stage of preparation of the offer. Thereby, it has to be considered that the date of delivery does not only depend on the machine scheduling, but also on the offer prepared based on that plan. According to that, not the planned date of completion of the order is the date of delivery, but it is the date determined within the offer. The available time is an index of the available resources which have the character that increasing available resources lead to a higher value of the Capability of Production. However, the Capability of Production is defined as an indirectly proportional index for the uncertainty type III and the uncertainties decrease if the time until the planned date of delivery decreases. Both opposite influences of the available time maybe not equalise each other that is why this variable have to be considered.

The mentioned influence parameters can be recorded in the enterprises and used for the estimation of the Capability of Production.

3.2 Ascertainment of the Capability of Production

For the calculation of the Capability of Production it is valid that there are no mathematically known coherences between the input variables and the output parameter introduced by that paper. Furthermore, it is a claim that the Capability of Production is to be in the defined interval. For that reason it presents itself to calculate that parameter by the help of a rule-based model, which means the usage of a corresponding fuzzy inference system (Teich & Zschorn, 2002). Because of the high adaptation expenditure of such systems within the scope of the introduction and the customising in the enterprises, e. g. the expenditure for the ascertainment of suitable affiliation functions of the terms, the implementation is based on an adaptive-network-based fuzzy inference system (ANFIS) according to Jang (1993). Those systems illustrate Takagi-Sugeno-controllers with a predetermined rule base they are able to approximate specific functions via free parameters. Thereby however, they dispose of fewer free parameters than neuronal networks. First investigations confirm the applicability of the system for the required task. Further works have to deal with optimisations of the learning algorithm. Those especially refer to the achievable quality of the approximation of the function, the running time for the training and the break off-criterion.

4. CONCLUSION

The described classification of the uncertainties is a pre-condition for the introduction of a new parameter for ascertaining the reliability of delivery. This is marked by the calculation of the binding agreement concerning a concrete date of delivery by the enterprise and therefore, as oppose to the former index as a statistic value, opens new fields of application for the reliability of delivery for example for the decision support in enterprises with the objective to increase the customer satisfaction and thus to strengthen the competitiveness of the enterprise.

An investigation concerning the availability of the input data in several enterprises as well as their values or domains and distributions in reality is planned for the near future. Those data are planned to be used for a simulation and refining of the former modelling and for the verification of the expressiveness of the presented approach.

Furthermore, it is important to check whether the expenditure for the identification of the training data for the ANFIS is smaller than a “manual” adaptation of fuzzy inference systems in enterprises. Where applicable those researches might fall back on other application fields of such systems. In this case the expressiveness for the reliability of delivery needs to be checked.

The current status of the work shows the dimensions of further investigations concerning the new parameter. However, the innovation and the potential for the management of enterprises and the increase of the customer orientation justify those investigations. The quantification of the reliability of delivery integrated into existing operational information systems might also be an objective.

5. REFERENCES

Birolini, A. (1985). On the use of stochastic processes in modeling reliability problems, Springer, ISBN 3-540-15699-2, Berlin.

Hirshleifer, J. & Riley, J. G. (1992). The Analytics of Uncertainty and Information, Cambridge University Press, ISBN 0-521-28369-8, Cambridge.

Jang, J.-S. R. (1993). ANFIS: Adaptive-Network-Based Fuzzy Inference Systems, IEEE Transactions on Systems, Man, and Cybernetics, vol. 23, no. 3, pp. 665–684.

Knight, F. H. (1921). Risk, Uncertainty and Profit, Augustus M Kelley Publications, reprint 1964, ISBN 067800031X, New York.

New, C. (1992). World-class Manufacturing versus strategic trade-offs, International Journal of Operations & Production Management, vol. 12, no. 4, pp. 19-31.

Palcic, I.; Polajnar, A.; Buchmeister, B. & Pandza, K. (2003). Competitiveness of the Companies with Order-Based Production, DAAAM International Scientific Book 2003, Katalinic, B. (Ed.), DAAAM International, ISBN 3-901509-36-4, Vienna (Austria), pp. 445-456.

Savage, L. J. (1954). The Foundations of Statistics, Wiley, New York, 2nd edition 1972, Dover, ISBN 0486623491.

Spring, M. & Boaden, R, (1997). “One more time: how do you win orders?”: a critical reappraisal the Hill manufacturing strategy framework, International Journal of Operations & Production Management, vol. 17, no. 8, pp. 757-779.

Teich, T. & Zschorn, L. (2002). Automatic procurement in production networks - Introducing the probabilities of delivery to quantify the uncertainties in supply and production processes, Proceedings of the 3rd CIRP International Seminar on Intelligent Computation in Manufacturing Engineering (ICME 2002), ISBN 88-87030-44-8, Ischia/Naples (Italy), July 03-05, 2002, pp. 37-42.

Teich, T.; Zschorn, L.; Neubert, R. & Görlitz, O. (2002a). Fuzzy-Logic in the Supply Chain Management - An approach to quantify the uncertainties in production and supply processes, Proceedings of the 2002 IEEE International Conference on Fuzzy Systems, ISBN 0-7803-7280-8, Honolulu (Hawaii), May 13-17, 2002, pp. 324-329.

Teich, T.; Zschorn, L. & Jähn, H. (2002b). Management of production networks - a new approach to work with Probabilities of Delivery, Proceedings of the 12th International Conference on Flexible Automation & Intelligent Manufacturing 2002, ISBN 3-486-27036-2, Dresden (Germany), July 15-17, 2002, pp. 762-771.