World Academy of Science, Engineering and Technology
International Journal of Industrial and Manufacturing Engineering
Vol:3, No:11, 2009

Efficient Supplies to Assembly Areas from Storage Stages

Matthias Schmidt, Steffen C. Eickemeyer, Prof. Peter Nyhuis

Open Science Index, Industrial and Manufacturing Engineering Vol:3, No:11, 2009 publications.waset.org/3898/pdf

***Abstract*—**Guaranteeing the availability of the required parts at the scheduled time represents a key logistical challenge. This is especially important when several parts are required together. This article describes a tool that supports the positioning in the area of conflict between low stock costs and a high service level for a consumer.

***Keywords*—**Systems Modeling, Manufacturing Systems, Simulation & Control, logistics and supply chain management

I. Introduction

OVER the last 20 years the logistical performance attributes of manufacturing companies have become established as criteria that are just as important to purchasing decisions as the price and quality of the products. The tendency for the key variables of the logistical performance to be considered among the quality attributes of a company or product has asserted itself in international markets. In this development the logistical targets "short delivery times" and "high delivery reliability" have taken on a special meaning [1], [2].

Industry has responded to the changing competitive conditions by introducing new strategic concepts. Above all, we have seen a marked reduction in the manufacturing depth over recent years. Driven by the approaches of the network economy and supply chain management, the manufacturers of mass customization products, primarily in the automotive industry, have transferred large parts of the value creation chain to multi-level supplier hierarchies [3]. This development has continued in the ensuing supplier pyramids: the system suppliers on the first level often assemble parts or subassemblies that they themselves have obtained from several suppliers.

But reducing a company's internal complexity by outsourcing selected parts of the production is matched by an increase in the procurement depth. In the automotive industry and parts of the electrical engineering industry this procurement depth now accounts for more than 70% of the value creation. The manufacturers themselves only carry out the assembly of subassemblies and the branding [4]. For the manufacturer, the full availability of all the parts required for an assembly order at the scheduled time becomes a prerequisite for the fulfillment of customer requests regarding short delivery times and high delivery reliability. Therefore, guaranteeing the availability of parts is the key challenge when planning the logistics for an assembly area.

Matthias Schmidt is research associate at the Institute of Production Systems and Logistics, Leibniz University of Hanover, Garbsen, 30823 Germany (corresponding author to provide phone: 0049-511-762-18130; fax: 0049-511-762-3814; e-mail: schmidt@ifa.uni-hannover.de).

Steffen C. Eickemeyer is research associate at the Institute of Production Systems and Logistics, Leibniz University of Hanover, Garbsen, 30823 Germany (corresponding author to provide phone: 0049-511-762-18188; fax: 0049-511-762-3814; e-mail: eickemeyer@ifa.uni-hannover.de).

Prof. Peter Nyhuis is director of the Institute of Production Systems and Logistics, Leibniz University of Hanover, Garbsen, 30823 Germany (e-mail: nyhuis@ifa.uni-hannover.de).

II. The Significance of Providing Materials on Time for Assembly Areas

The full availability of parts in assembly is an important prerequisite for the logistical quality and performance of the assembly itself. However, from the customer's viewpoint, whether the assembly is supplied with parts from the company's own production or from an external supplier is irrelevant (see Fig. 1). But crucial in every case is the quality of the supply to the assembly area. Although we must distinguish between two classes of provision, both make-to-order production and buy-to-order procurement on the one hand, and make-to-stock production and buy-to-stock procurement on the other, involve the specific problem of the logistical coordination of internal company processes. We shall not explore this any further below because the focus here is on the provision of materials from storage areas. More information on this subject can be found in [5], [6].

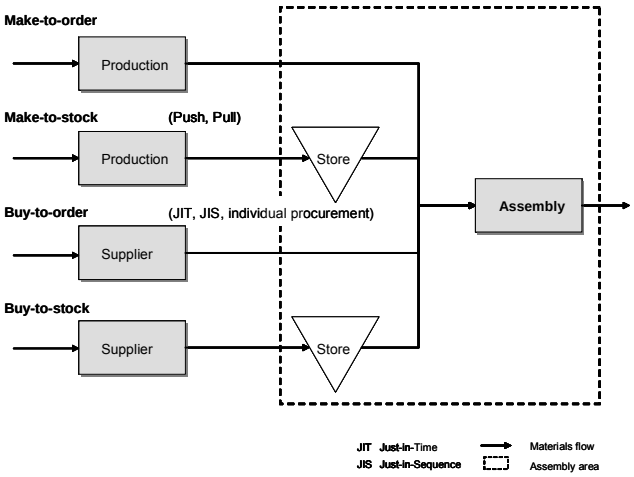


Fig. 1 Overview of assembly supply chains

The aforementioned growing significance of the inter-company division of work into supply chains means that buy-

Open Science Index, Industrial and Manufacturing Engineering Vol:3, No:11, 2009 publications.waset.org/3898/pdf

to-order and buy-to-stock procurement from a supplier become key elements in our deliberations.

A key feature of make-to-order production is that the production work is initiated by the customer order. As a result, the quantities produced are managed directly for the individual customer order, and, accordingly, cannot be interchanged among individual customer orders. Decoupling the process by introducing a storage stage does not take place in this case, nor in the case of buy-to-order procurement. Buy-to-order procurement by means of just-in-time or just-in-sequence concepts is one option for organizing the provision of parts in close cooperation with the suppliers. The aim of both concepts is to eliminate the traditional stages of the customer's materials flow from checking of incoming goods via storage right up to commissioning and to replace all this by the direct provision of the parts in the assembly area. However, these methods increase the risks of a possible bottleneck in the supply of materials: the lack of one component can bring the entire downstream process chain to a stop because the materials flow dries up. Consequently, in these methods the importance of providing materials at the right time is even more significant. Furthermore, such concepts can only be implemented advantageously when high-quality and low-variant parts (A-parts) are procured in large numbers over a longer period of time with a high planning reliability [7].

In the case of an upstream make-to-stock production, the production work is initiated by a demand forecast. The production order is subsequently buffered in a storage stage. Similarly, with buy-to-stock procurement the provision of parts in assembly is decoupled from the actual procurement process. In these cases the parts required in assembly are provided from a storage stage. Therefore, this results in the need for target-oriented logistical storage management. The term "storage management" includes all the planning and control tasks that concern the storage of goods [8]. The targets for the planning and control activities of storage management for an assembly area must support customer requests for short delivery times and high delivery reliability and at the same time keep stocks at an economic level.

The adequate sizing of stocks is one of the key tasks of operative planning. The problem of sizing of stocks has to be considered here in the sense of an overall view irrespective of the transfer of ownership of the stocked parts and the spatial arrangement of the storage. Focusing on the problem of the sizing of stocks is carried out here initially against the background of buy-to-stock procurement with the provision of parts from a store (in make-to-stock production the replenishment time should be replaced adequately by the throughput time).

Consequently, the main task of inventory management in procurement and distribution consists of guaranteeing an economic supply to the customer on a high and stable level in the area of conflict between the flexibility requirements of the consumer and the logistical capacity of the source. Sizing of stocks therefore becomes very important. Fluctuations in the ordering behavior of the customer and deviations in the delivery dates of suppliers must be buffered by stocks.

In order to achieve efficient inventory management it is necessary to describe the mutual dependencies between the aforementioned target variables taking into account the operational boundary conditions and the influencing options. Only in this way can a company position itself in the aforementioned area of conflict and influence the procurement and stockkeeping processes in line with its objectives. Therefore, the storage throughput diagram was developed as a descriptive model. This model enables the relevant logistical key variables such as stocks, delivery delay, service level, stock holding time and inventory capacity to be depicted quantitatively and with a dynamic timescale, and enable a detailed evaluation of the stockkeeping process on the basis of operational data [9]. In order to describe fully the conflict of aims between the lowest possible stock level and a high supply reliability, service level curves were developed to supplement the storage throughput diagrams; these curves represent the service level and the delivery delay as a function of the inventory [10].

III. Provision from Storage Stages

A. Service level Curve

The consumer-oriented service level describes the degree of fulfillment of the demands of a consumer (and the demand can consist of more than one product). For example, if a supply order involves several products, the consumer-oriented service level is the product of the individual service levels. Fig. 2 shows an example of the calculation of the consumer-oriented service level. However, this relationship only applies when the individual products, subassemblies and parts involved are independent from each other in terms of their logistical behavior [5].

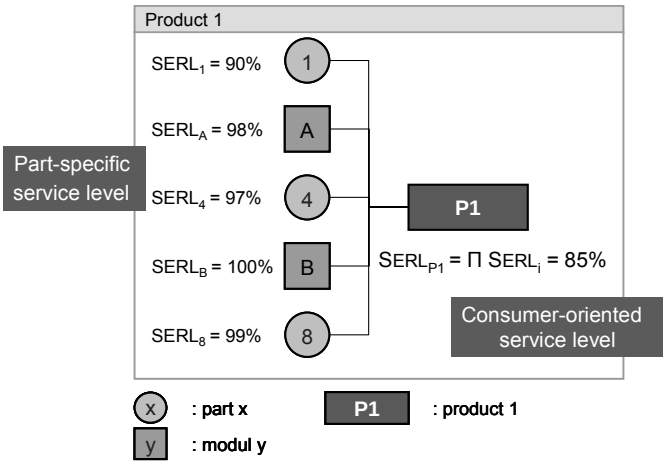


Fig. 2 How an individual stocked part influences logistical customer satisfaction

This sample calculation for the consumer-oriented service level shows that this can deviate considerably from the part-specific service levels. The reason for this can be found in the multiplicative connection of the part-specific service levels ($SERL_i$). This means that a single low service level (in this case $SERL_1$) has a significant influence on the consumer-

Open Science Index, Industrial and Manufacturing Engineering Vol:3, No:11, 2009 publications.waset.org/3898/pdf

oriented service level ($SERL_{P1}$). This is also shown by the equation for calculating the consumer-oriented service level (1):

$$SERL_{P1} = \prod SERL_i \quad (1)$$

The service level is a key parameter for describing the quality of supplies from a storage stage. It can be described by a logistical service level curve depending on the given stock level (Fig. 3). This so-called service level curve describes the dependence of the mean service level ($SERL_m$) on the mean stock level (SL_m) for a part. In the case of a low $SERL_m$, a small increase in the SL_m leads to a relatively large increase in the $SERL_m$. Accordingly, a large rise in the service level curve can be seen in this area. The gradient flattens out as SL_m increases and changes to a horizontal line at $SERL_m$ = 100%. As a result, small increases in $SERL_m$ when $SERL_m$ is already relatively high cause a disproportionate rise in SL_m [10].

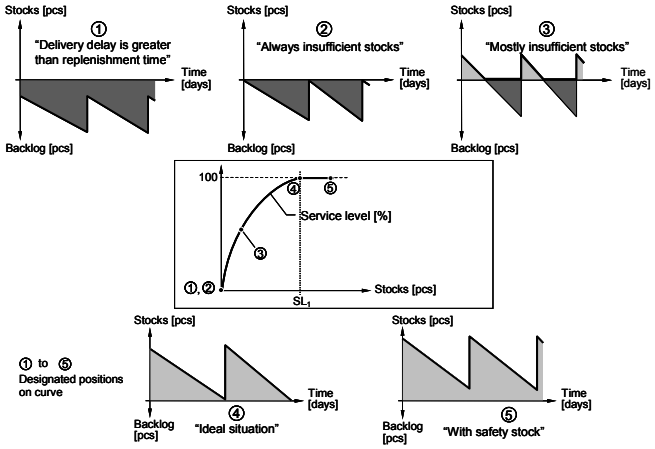


Fig. 3 Development of the service level curve depending on inventory

The point SL_1 on the curve determines the practical minimal stock level at which the delivery capability of the store is guaranteed at all times [10]. Based on the known equations for the safety stock and the mean batch stock, SL_1 can be calculated as follows (2):

$$SL_1 = \frac{X_{in,m}}{2} + \sqrt{\left(PDD^{+}_{\max} * DR_m\right)^2 + \left(NQD^{-}_{\max}\right)^2 + \left((DR_{\max} - DR_m) * RT\right)^2} \quad (2)$$

SL_1	practical minimal stock level [units]
$X_{in,m}$	mean incoming stocks (batch size) per incoming event [units]
PDD^{+}_{max}	maximum positive date deviation (delay) [SCD]
DR_m	mean demand rate [units/SCD]
NQD^{-}_{max}	maximum negative quantity deviation (undersupply) [units]
DR_{max}	maximum demand rate [units/SCD]
RT	replenishment time [SCD] / [TT] for make-to stock throughput time [SCD]

On the whole, the service level curves can be used in a number of ways. One application for the curves is the evaluation of processes and possible process variants. The input variables for determining the curves are always the parameters of the upstream processes; different curve progressions ensue depending on their productivity. If the process upstream of the storage is a procurement process involving external suppliers, these can be given a logistical evaluation. Individual curves can be drawn up for every supplier involved with the part concerned on the basis of his deviations from the plan. This provides the chance of evaluating the quality of suppliers. The supplier with the more favorable curve progression should be preferred. This method can also be used for upstream production processes.

By varying the input parameters for the curves there is the chance of assessing the effects of changes to a process, e.g. improving the date reliability and hence reducing the incoming date deviations. The necessary service levels or stocks resulting for a process state can be compared with each other. This permits the analysis of the effects of changes to processes and current optimization options.

Service level curves are assigned two tasks within the scope of considering the target variables: the evaluation of targets with respect to their compatibility with the logistical target variables and the establishment of new, more consistent target values. By comparing the mean stock level of an operating unit with the target value for the inventory, it is possible to determine the potential for adapting the stocks.

Summing up, we can say that service level curves are ideal for logistical inventory and storage controlling. The curves can be easily calculated by using approximation equations [10]. To do this, essentially quantifiable data and merely one empirical value are required.

B. Consumer-Oriented Service Level

The service level curves represent one approach that renders possible statements regarding an individual part. However, only limited statements can be made regarding the interactions that ensue when several parts have to be taken into account, e.g. in the provision for assembly [5].

As shown above, when sizing stocks it is also necessary to consider the effects on the stock costs in addition to considering how the part-related service level influences the consumer-oriented service level. Fig. 4 shows an example in which the influence of the part-related stock sizing on the consumer-oriented service level and the stock costs can be seen.

The example chosen for the graphic is one in which an assembly product is a combination of six different parts. The assembly orders for a product are to be provided from a storage stage. The product consists of one A-, two B- and three C-parts. The C-parts that have to be incorporated into the products constitute an annual value of € 10,000. The total cost of the three product groups amounts to € 1 million and the capital tie-up cost rate is 15%. If the C-parts are provided one day too late, additional capital tie-up costs of about € 400 ensue for the other parts that have to be provided. This is because the A- and B-parts must wait to be completed and tie

up capital in this time. On the other hand, if the provision is on average one day too early, the capital tie-up costs are only about € 4 for the parts provided too early.

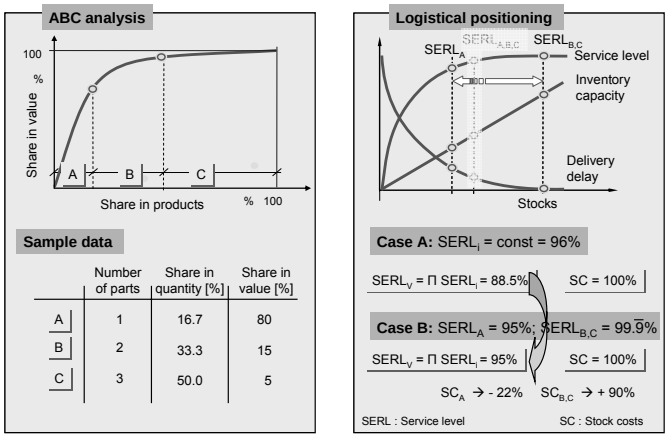


Fig. 4 Optimization of service level and stocks (example)

In the case of provision from storage stages, adhering to the required date is directly influenced by the service levels for the individual parts. Following the logic of the example (C-parts should have a high service level because this is paid for with a comparatively low capital tie-up), an optimum capital allocation approach is shown below for the desired consumer-oriented service level.

The quantity and value shares are shown on the left. If we now assume that the service level is 96% for every part, the resulting consumer-oriented service level is approx. 78%. So although each individual part has a relatively high service level, we face an unsatisfactory supply situation on the consumer side.

If in this example we alter the service level for the individual parts, we can create totally different operational situations. For example, if we assume that the service level is increased to almost 100% for the B- and C-parts, and on the other hand reduces the service level for the A-part to 95%, results in a consumer-oriented service level of 95%. This vastly improved supply situation does not involve an increase in the stock costs here because the higher stock costs for the B- and C-parts are fully compensated for by the lower stock costs for the A-part.

IV. A Tool for Practical Applications

In order to be able to exploit in practice the depicted potential for increasing the supply reliability and at the same time reducing stocks, a computer program was developed at the Institute of Production Systems & Logistics (IFA), part of the Leibniz University of Hannover, within the scope of a research project. This will be described below.

The algorithm in the software (Fig. 5) is based on the analysis of part-related data that has to be input into the tool. The data required includes the batch stock, the mean replenishment time, the mean demand rate, the maximum demand rate, the maximum positive date deviation, the maximum negative quantity deviation and the unit price. Some of these data can be obtained from master data files, other data are easily determined from inventory movements data.

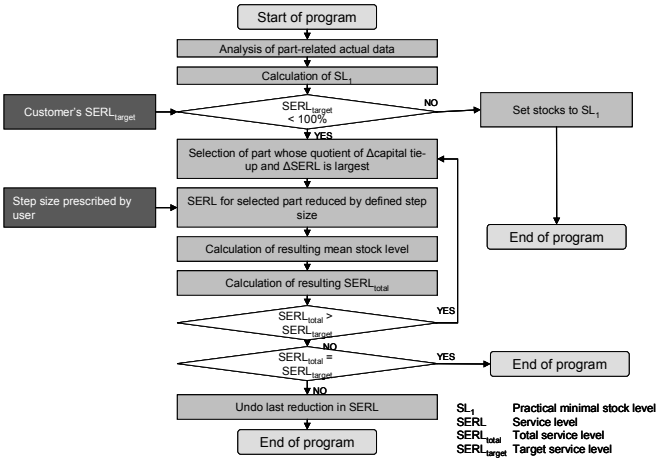


Fig. 5 Algorithm for economic stock sizing in assembly

Based on the input data, the mean stock level that just guarantees a service level of 100% is first determined for each part. However, for the consumer it is not the service level of an individual part that is critical, but rather the consumer-oriented service level. The tool guarantees this by allocating the parts to consumers.

Normally, the service levels tolerated by individual consumers are less than 100%, e.g. a company demands a service level of 95% from its suppliers. In order to guarantee the service level that is just permissible, the service levels of the individual parts must be dimensioned accordingly. On the other hand, the service level for a given stock costs level can also be optimized (see Fig. 4).

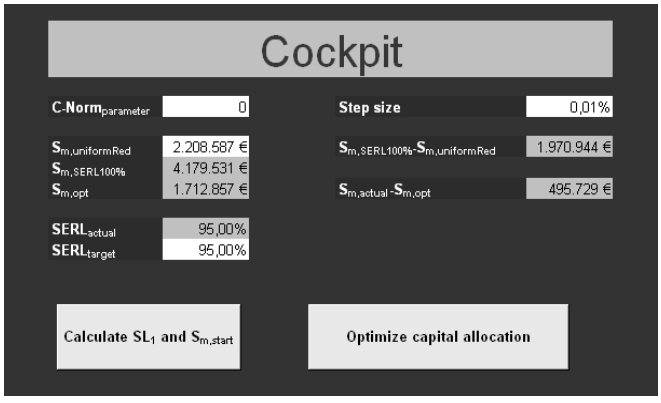


Fig. 6 Software interface

A more economic option for approaching the service level just permissible (95% in this example), and developed within the scope of the research project, is firstly to reduce the stocks for those parts for which the quotient of capital tie-up reduction and service level change is largest. In order to achieve this with minimum effort, the tool calculates mean stocks for individual parts after a lower limit for the service

Open Science Index, Industrial and Manufacturing Engineering Vol:3, No:11, 2009 publications.waset.org/3898/pdf

level has been entered. These mean stocks can be compared both with the stocks necessary for a service level of 100% ($S_{m, SERL100\%}$) and with the stocks that would ensue with a uniform reduction of all part service levels ($S_{m,uniformRed}$). Fig. 6 shows an evaluation of the data with the tool for this example.

A service level of 100% is just reached with the data given in Fig. 7 for a stock value of € 4,179,531. A uniform reduction in the service level to 99.49% per part results in a stock value of € 2,208,587 (approx. 53% of the stock value necessary for 100%). A targeted reduction of individual service levels with the algorithm in the Excel tool permits an additional reduction in stocks of € 495,729, to € 1,712,857. This corresponds to approx. 41% of the original stock level and an additional potential of approx. 25% related to the potential for a uniform reduction in stocks.

The method in the software for the economic increase in the availability of parts in the supply to a consumer enables the mean stock values and the corresponding safety stock to be determined, which lead to the attainment of a target service level for all the parts to be incorporated into a product to be assembled. This means that the optimum capital allocation for achieving a desired target service level can be determined.

Part No. [-]	Consumer [-]	Batch stock$_{opt}$ [pcs]	RT$_m$ [SCD]	DR$_m$ [pcs/SCD]	DR$_{max}$ [pcs/SCD]	PDD$^+_{max}$ [SCD]	NQD$^-_{max}$ [pcs]	Price [€ each]
1	1	3	60	2	4	2	1	20000
2	1	7	70	4	5	3	1	6000
3	1	22	40	7	9	2	1	1200
4	1	31	30	9	11	4	2	800
5	1	32	35	9	9	3	1	700
6	1	236	12	100	107	1	2	150
7	1	1080	7	1400	1409	3	1	100
8	1	1021	5	1000	1002	4	5	80
9	1	1000	3	600	612	1	2	50
10	1	1443	5	1000	1008	2	1	40

Fig. 7 Part-specific data in the Excel tool

V. Summary and Outlook

This article describes an approach for the economic sizing of storage stages in order to supply an assembly area efficiently from storage areas while taking into account an optimum capital allocation. The consumer-oriented service level represents a model that can be used for analyzing and optimizing the supplies of materials from storage stages taking into account the various, contradictory storage logistics target variables. One of the model's uses is the sizing of stocks for individual stocked parts while minimizing the capital tie-up costs with respect to a consumer-oriented service level demanded by the customer.

This approach supplies excellent results for the applications described, a fact that has been corroborated within the scope of simulation studies. The future work required essentially results in two research paths, which are based on the research findings given here and can be worked on concurrently:

Firstly, the results up until now confirm that the findings apply when the individual products to be incorporated are independent of each other. As a result, further research is required into the consumer-oriented service level with correlating part-specific service levels. Accordingly, up until now the tool could not be used with products that are dependent on each other. However, initial simulations confirm that a correlation between parts to be incorporated has an effect on the consumer-oriented service level. But this influence can be ignored in practical applications because of its low significance, and so this research issue is more of an academic nature. Nevertheless, the theoretical relationship will be explored at the IFA in the near future.

Secondly, the findings described in this article are limited to several individual products that are incorporated into a "final product". However, the consumer-oriented service level for the case of, for example, 30 "blanks" incorporated into two "final products", or multiples thereof built into both, has not been investigated so far. Owing to the ongoing rise in the complexity of networking within the scope of globalization, this point is very important. A corresponding research project is currently at the application stage. The software will be continually updated based on the results generated from this.

References

[1] Hon, K. K. B.: Performance and Evaluation of Manufacturing Systems. CIRP Annals 54 (2005) 2. pp. 675-690.
[2] Boston Consulting Group: Steering Carmaking into the 21st Century, From today's best practices to the transformed plants of 2020, Boston, 2001.
[3] Freudenberg, T., Klenk, U.: Strategische Veränderungen in der Zulieferpyramide der Automobilindustrie. In: Hahn, D.; Kaufmann, L. (Hrsg.): Handbuch Industrielles Beschaffungsmanagement, Gabler Verlag, Wiesbaden, 1999, S. 123-134.
[4] Corsten, D., Felde, J.: Supplier Collaboration: Eine Erfolgsstrategie? Ergebnisse einer empirischen Studie. In: HMD – Praxis der Wirtschaftsinformatik, No. 228, dpunkt.verlag, Heidelberg, 2002.
[5] Nyhuis, P., Schmidt, M., Wriggers, F. S.: Reduction of Capital Tie Up for Assembly Processes. CIRP Annals 57 (2008) 1, pp. 481-484.
[6] Schmidt, M., Berkholz, D., Nyhuis, P.: Modeling of Logistic Processes in Assembly Areas. In: Ao, S. I. et al. (Eds.): Proceedings of the World Congress of Engineering and Computer Science, Newswood Limited, Hong Kong, 2008, pp. 1067-1072.
[7] Boutellier, R.; Wagner, S. M.: Beschaffungslogistik. In: Koether, R. (Hrsg.): Taschenbuch der Logistik, 2. Aufl. Fachbuchverlag Leipzig im Carl Hanser Verlag, München, Wien, 2006, S. 406-423.
[8] Schönsleben, P.: Integral logistics management: operations and supply chain management in comprehensive value-added networks . 3. ed., CRC Press, Boca Raton, 2007.
[9] Gläßner, J. (1995). Modellgestütztes Controlling der beschaffungslogistischen Prozesskette. VDI, Düsseldorf.
[10] Nyhuis, P., Wiendahl, H.-P.: Fundamentals of Production Logistics. Springer, New York, 2009.

Authors

Dipl.-Wirtsch.-Ing. Matthias Schmidt, Dipl.-Wirtsch.-Ing. Steffen C. Eickemeyer, Prof. Dr.-Ing. habil. Peter Nyhuis
Institut für Fabrikanlagen und Logistik (IFA)
An der Universität 2, 30823 Garbsen, Germany
Tel. +49 (0)511 762-18130 or 18188
Fax +49 (0)511 762-3814
E-mail: schmidt@ifa.uni-hannover.de (M. Schmidt) or eickemeyer@ifa.uni-hannover.de (S.C. Eickemeyer)
Internet: www.ifa.uni-hannover.de

Open Science Index, Industrial and Manufacturing Engineering Vol:3, No:11, 2009 publications.waset.org/3898/pdf