Cost Sensitive Analysis of Production Logistics Measures
A Decision Making Support System for Evaluating Measures in the Production

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Abstract—Due to the volatile global economy, enterprises are increasingly focusing on logistics. By investing in suitable measures a company can increase their logistic performance and assert themselves over the competition. However, enterprises are also faced with the challenge of investing available capital for maximum profits. In order to be able to create an informed and quantifiably comprehensible basis for a decision, enterprises need a suitable model for logistically and monetarily evaluating measures in production. Previously, within the frame of Collaborate Research Centre 489 (SFB 489) at the Institute for Production Systems and Logistics, (IFA) a Logistic Information System was developed specifically for providing enterprises in the forging industry with support when making decisions. Based on this research, a new initiative referred to as 'Transfer Project T7', aims to develop a universal approach for logistically and monetarily evaluating production measures. This paper focuses on the structural measure echelon storage and their impact on the entire production system.

I. INTRODUCTION

IN the course of globalizing productions and the tremendous competition accompanying it, enterprises are now confronted with new challenges. With the aid of selected logistic measures, enterprises are in the position to counter this competitive pressure. Whereas at the start of the economic boom, enterprises drastically increased their investments, today, within a difficult market environment, they are faced with the challenging of investing existing capital in logistics to maximize their gains. Companies thus need a model suitable for creating a well-founded decision making basis for monetarily and logistically evaluating measures in the production.

At the Institute for Production Systems and Logistics (IFA), numerous research projects have shown that the logistic performance of an enterprise can be significantly improved already with a minimum of investment. For example, by

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harmonizing the variance of the work content, throughput times can be reduced and due date reliability improved from the perspective of downstream processes or customers [1].

Nevertheless, up until today no approach can be found, either in national or international publications, which allow measures in the production to be universally and quantitatively evaluated with regards to their monetary and logistical impact. So far, the only approaches that can be found are focused only on a monetary evaluation of measures [2], [3].

Within the frame of Collaborate Research Center 489 (SFB489) a Logistic Information System (LIS) was developed specifically for the forging industry. This monitoring and decision model is based on Microsoft Excel© and allows users to evaluate selected logistic measures based on monetary and logistic objectives (e.g., residual gains or delivery performance). The basis for this decision logic is a driver-tree for determining residual gains (RG), the production Logistic Operating Curves and so-called "transfer functions", which for example, along with the sales-delivery performance function, allow improvements in the logistic performance to be monetarily evaluated [1]. Now, in a transfer project based on this collaborate research center, a universal model for evaluating measures in the production from a monetary and logistics perspective is being developed.

II. A SUPPORTING FOR EVALUATING PRODUCTION LOGISTICS MEASURES

A. User Environment

The LIS is based on a decision logic that evaluates selected logistic measure through logistic (e.g., delivery time) as well as monetary (e.g., RG) objectives. Logistic and monetary goals are to be set by the enterprise so that targets can subsequently be evaluated based on a comparison of target and actual values after the logistic measures are selected.

The RG is a fundamental element in the LIS's structure and allows the value of an investment to be evaluated for the enterprise. This parameter is well established in the industry and is a proven approach [4], [5]. The RG (1) is defined from the earnings before interest and taxes ($EBIT_t$) at the end of a period minus the product of the average weighted cost of

World Academy of Science, Engineering and Technology
International Journal of Economics and Management Engineering
Vol:7, No:5, 2013

capital (CC_{mw}) and the total capital ($TC_{(t-1)}$) at the start of the period [6]:

$$RG = EBIT_t(1-s) - CC_{mw}TC_{(t-1)} \qquad (1)$$

After the target values are set, monetary parameters (e.g., material/manufacturing and inventory costs) for determining the RG as well as feedback data from the production are entered into the LIS. The feedback data from the production refer to input and output data as well as work contents in order to be able to model the Logistic Operating Curves. So that the transfer function can be modeled, the minimum sales increase that is attainable by improving the delivery performance has to be entered. In a further step, logistic measures are selected either individually or in combination with one another in order to improve the logistic performance.

The LIS has a cockpit in which the most important variables are listed. The cockpit is comprised of selected logistic and monetary variables as well as the Output Rate and Range Operating Curves. Based on the operating curves, the operating points – calculated before and after the measures are introduced – are displayed in order to visually indicate a possible WIP potential. The LIS thus supports the user in efficiently selecting production measures suitable for increasing the logistic performance [6].

B. Basic Structure of the LIS

A driver tree (see Fig. 1) is used to model the relationship between measures in the production and the RG [7], [8]. The driver tree is connected to a logic, which for example, produces a link between the logistic objective 'due date reliability' and the RG. In comparison to the already existing EVA driver tree, interactions between the logistic and monetary objectives are depicted in the LIS the by means of so-called 'transfer functions' [7]. First and foremost, a transfer function depicts the relationship between the delivery performance, the delivery time and the sales volume in respect to the company's sales. Due to the various influences (e.g., customer requirements, market strategy, the competition's delivery performance), the practical derivation of the curve progression for a transfer function proves to be complex [9]. As a result of these complex interactions, a method for considering a number of influences and restrictions is implemented as part of the LIS.
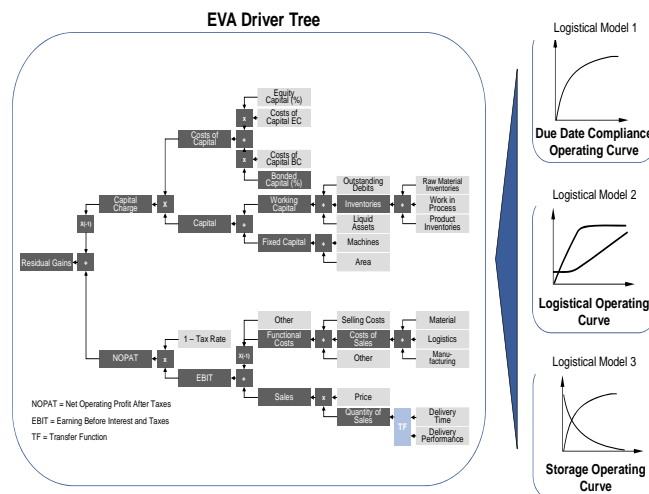

Fig. 1 Exemplary EVA Driver tree (cp. [6])

Besides the transfer function, further interactions between the different drivers are modeled. For example, within the LIS the relation between the sales volume and the material consumed is depicted. In the case of the existing LIS, material costs increase linearly with the sales volume. Moreover, the sales volume is restricted by the machine's prevailing capacities (less the setup times and downtimes), which in turn is subject to a limited machine area. Through planning measures, such as harmonizing the work contents however, more capacity has to be provided due to the greater number of setup operations. This is depicted in Fig. 2, using the Logistic Operating Curves [10]. The above examples illustrate the complex interactions.

The correlations described in the preceding are modeled by the Logistic Operating Curves, which are also integrated in the LIS. Based on the entered feedback (input and output dates as well as work content) the impact on the logistic objectives such as the due date reliability can be quantified. The improvement in the due date reliability thus flows indirectly into the RG via the delivery performance/sales function, while the reduction in the WIP within the production flows directly into it via the tied up capital costs [11], [12]. On the other hand, the drivers in the LIS influence the position of the operating curves, in that for example, increasing the number of machines and thus the capacities will shift the Output Rate and Range Operating Curves [10].

Within a sub-project of the Collaborate Research Center SFB 489, referred to as 'C2' or "Logistic Operating Curves", the LIS was oriented on a rigidly linked forgery line, which does not allow it to be adapted to another type of manufacturing. In doing so, measures specific to forging and which influence the monetary and logistic parameters differently were saved in the LIS. Besides the measure for harmonizing work content, other logistic measures such as strengthening a forging machine's die are saved [7].

World Academy of Science, Engineering and Technology
International Journal of Economics and Management Engineering
Vol:7, No:5, 2013

III. IMPLEMENTING A STORAGE ECHELON ALONG THE SUPPLY CHAIN

Within the frame of the current research project, additional measures are being implemented in the model [7]. In addition to the already implemented measures for harmonizing manufacturing lots or the invest in optimal machine equipment reducing cycle time, this research project is primarily focusing on some other logistical measures as the changing the position of a decoupling store and reducing the production complexity.

A storage echelon within a production represents a quantitative decoupling of orders [13]. A quantitative decoupling within the production has significant advantages with regards to the logistic performance of the entire system. At the same time, implementing a storage echelon results in increased costs, since for example the tied-up capital within the store increases due to the product refining. Not only capital tie-up costs are impacted; process dependent costs also increase when implementing the storage echelon. However, an improvement in the logistic performance can also be observed, through which there is a strong probability that new market potential can be created. A user-oriented depiction of these complex correlations is implemented within the tool.
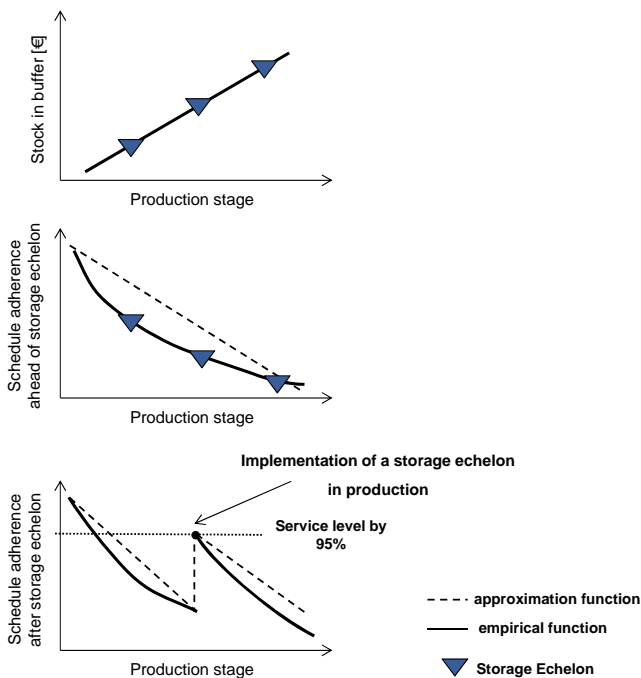

Fig. 2 Logistical Interactions between the schedule adherence and production stages

The structural measure of positioning or shifting the buffer along the supply chain including the resulting effects on the EVA driver tree can be depicted with the developed tool. With respect to all of the downstream processes, implementing a storage echelon improves the due date compliance at the end of the supply chain. These logistical interactions are depicted within the model using a transfer function, exemplarily presented in Fig. 2. The approximation function is subject to the assumption that with consecutive/on-going production steps, a reduction in the due date compliance can be observed. The weighting of the coefficient of the transfer function is dependent on various influences such as the total availability of the workstation or the inter-operation times and is entered by the user.

Based on the improved due date compliance and the available due date distribution, a WIP reduction with a fixed delivery time buffer can be proven with the aid of the Due Date Compliance Operating Curve integrated in the model [14]. Along with that, the reduction in the capital tied-up in the finished goods store can be evaluated, presented in Fig. 3. Besides the costs of the capital tied-up in the finished goods store, the WIP along the supply chain should also be examined. A buffer in a manufacturing stage also improves the due date compliance in the downstream processes. This effect can be observed in the form of a WIP reduction in the supply chain with a defined service level within the storage echelon, which in the EVA driver tree, positively influences the capital costs tied into semi- finished goods. In addition to the improved total due date compliance along the supply chain and an increase in capital costs due to the shifting of the decoupling store at the end of the supply chain, the changes in the process costs also need to be investigated.
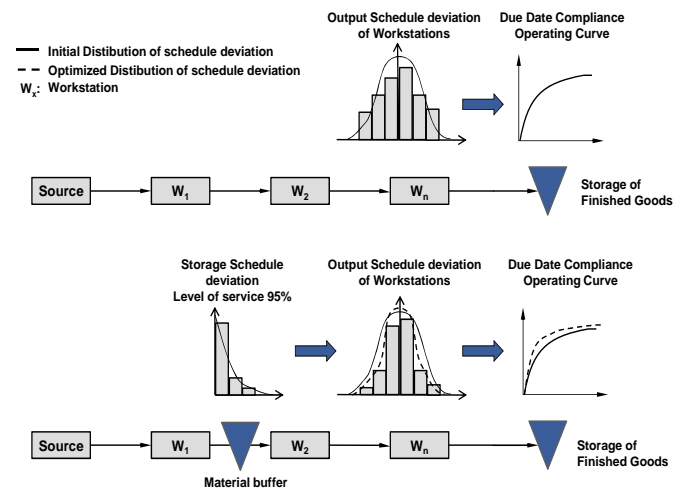

Fig. 3 The results of a better schedule adherence within the storage for finished goods

The process costs increase according to the positioning of the storage echelon within the supply chain. Based on the transfer functions the relation between the mean WIP and the process costs (e.g., for materials, manufacturing and personnel) are modeled and integrated into the tool. By implementing a storage echelon within the supply chain the process costs change significantly. Personnel costs in particular increase due to processes necessary for providing materials within the buffer. This correlation between the WIP and personnel costs is modeled using a staircase function, so that each new hiring of a stock keeper causes a jump in costs. The relation between the WIP buffer and the

World Academy of Science, Engineering and Technology
International Journal of Economics and Management Engineering
Vol:7, No:5, 2013

transportation/handling costs is modeled as a linear function. Process costs are also increased by shifting the buffer towards the end of the supply chain i.e., closer to the customer. By improving the due date compliance and maintaining the same lead time buffer, lower stock levels can be observed in the finished goods store. At the same time, this means that personnel and handling costs are reduced in the store.

In addition to increased processing costs, due to a storage echelon being implemented within a supply chain, the range of assets in the EVA driver tree is cost sensitive. Should the buffer area need to be expanded, the storage area itself increases and thus plant costs; this relationship is thus also modeled as a staircase function.

Based on the different parameters for the process costs, a cost-piece analysis for the current products can be conducted. With the aid of the different process costs and material costs parameters it should also be possible for the user to select logistic measures in view of their impact on the piece-costs of the product. Moreover, within this piece-costs analysis, the extent to which the logistic performance and thus the sales positively develop also needs to be considered. Furthermore, the number of products sold is highly relevant with regards to process costs. Thus the model offers users the possibility to examine changes in the piece-costs when selecting logistic measures (see Fig. 4).
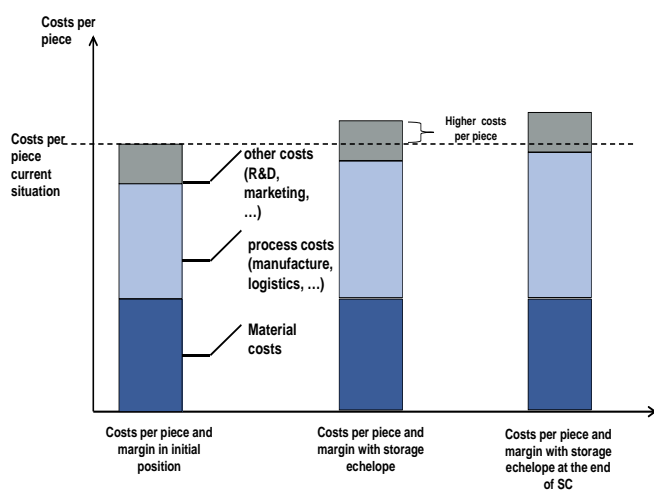

Fig. 4 Costs per piece analysis concerning the position of a storage echelon

In Fig. 4, an increase in piece-costs can be observed when implementing the described measure to shift the storage echelon along the supply chain. The tied-up capital costs increase due to storing refined products in a farther back manufacturing stage, the logistic performance of the entire system still significantly improves so that greater sales lead to larger profits despite higher piece-costs. Just by shifting the buffer one manufacturing stage closer to the end of a supply chain in a simple line production, the piece-costs are increased significantly because of more handling in the storage echelon. The effects of the changed process and storage costs as well as

the increased sales volume due to the improved logistic performance are ultimately reflected in the EVA, which can then be used as a support in making the decision about the measures.

IV. SUMMARY AND OUTLOOK

The former Logistic Information Systems allows the user to evaluate measures in the production based on logistic and monetary objectives. However, this model has only been developed for rigidly linked processing chains in the forging industry, which prevents it from being applied in other industry branches. For this reason a universal LIS is currently being developed within the frame of a transfer project. In the course of the project, the different logistical interactions will be converted into transfer functions. Implementing a storage echelon creates significant potential for improvement with regards to the EVA values. Shifting the storage echelon just one manufacturing stage closer to the customer uncovers a row of potentials in view of cost reductions and increased logistic performance. Currently, additional measures similar to those mentioned above are being modeled via different transfer functions and evaluated with the aid of existing IFA models. Ultimately the tool should enable every user in make-to-order, serial or mixed productions to evaluate selected measures in the production from a monetary and logistics perspective and thus to make a well-founded investment decision.

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