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Efficient Design of Distribution Logistics by Using a Model-Based Decision Support System

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***Abstract*—**The design of distribution logistics has a decisive impact on a company's logistics costs and performance. Hence, such solutions make an essential contribution to corporate success. This article describes a decision support system for analyzing the potential of distribution logistics in terms of logistics costs and performance. In contrast to previous procedures of business process re-engineering (BPR), this method maps distribution logistics holistically under variable distribution structures. Combined with qualitative measures the decision support system will contribute to a more efficient design of distribution logistics.

***Keywords*—**Decision support system distribution logistics, potential analyses, supply chain management.

I. Introduction

COMPANIES spend about 7.7% of their total costs on logistics [1]. Besides the reduction of these logistics costs, businesses most frequently cite boosts in their logistics performance as a goal they aim to attain over the next few years [2]. Given that customers no longer make their purchasing decisions based on product price and quality alone, expeditious delivery times and high delivery reliability rates are establishing themselves as increasingly important aspects [2], [3]. Consequently, logistics performance has evolved into a deciding competitive factor for a company's success in the international markets. In this context, distribution logistics play a key role given that they link manufacturing to its target sales markets and are directly observed by customers. Nonetheless, many enterprises do not place sufficient focus on distribution logistics. For instance, 14% of all companies surveyed do not even know how their own logistics costs. [3]. Hence, businesses find themselves confronted with the challenge of determining their own logistics costs and of identifying the cost reduction and performance improvement potential inherent in their distribution logistics. Existing BPR methods aim at the attainment of principally significant cost, service and speed optimizations [4]–[6]. However, the existing approaches were not explicitly developed for distribution logistics. As a result, they do not sufficiently reflect the interactions between logistics costs and logistics performance, which have to be taken into account. This article introduces a method based on the logistics decision support system called "Distribution Logistics Decision Support System" (DLDSS). Besides the determination of the actual logistics costs and logistics performance, this tool also allows users to conduct distribution logistics potential analyses based on quantitative and qualitative objectives. The logistics support system is implemented in MS-Excel and offers the option to conduct the evaluation for a single warehouse or the entire distribution structure.

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II. Literature Review

A. The Elements, Tasks and Objectives of Distribution Logistics

Distribution logistics provide the direct link between manufacturing and sales market. It can be divided into the following three elements:

- Order processing
- Warehousing and
- Transportation

The term 'order processing' comprises the acceptance, preparation, implementation, passing on and documentation of customer orders from the moment the order is placed until the customer receives the goods as well as the invoice. These activities also include the sharing of information and the communication with customers as well as the in-house departments in charge of handling the order, e.g. production [7]. In distribution logistics, the term warehousing refers to all tasks affiliated with inbound and outbound inventory management, the storage of goods, transshipment and the finished product order picking and packaging [7]. Transportation plays a geographically equalizing function in distribution logistics, i.e. it uses suitable transportation resources and carriers [7] to geographically distribute the goods within the logistics system. The term 'distribution structure' refers to the physical layout of a distribution system defined by the geographic distribution and number of warehousing facilities, as well as the distinction between and the allocation of delivery territories [7]. Two fundamental variants are centralized distribution structures (each item stored in just one warehouse) and decentralized distribution structures (all items stored at all warehouses).

Given that the importance of delivery reliability and short delivery times continues to grow; this report utilizes both criteria to evaluate logistics performance. Distribution logistics costs are modeled on the basis of process costs and capital tie-up costs. Besides these clearly measurable quantitative benchmarks, qualitatively measureable benchmarks, such as green logistics, robustness or sustainability play increasingly important roles in practical industrial applications [8]. Hence, the aim is to also integrate these qualitative criteria into a holistic potential analysis.

B. Distribution Logistics Potential Evaluation Methods

The idea of BPR covers the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in the critical, contemporary performance measuring, such as costs, quality, service, and speed [4]. In this manner, BPR is a mind-set of continual change with a large range of business improvement techniques that have similarities to change management, supply chain management or total quality management [9]–[11]. In a case study, [5] described the re-engineering of a supply chain system. The estimated savings in inventory level and lead-time are specified but a repeatable approach to calculating the potentials is missing. With regard to the supply chain problem, [6] discuss several other models for supply chain re-engineering. All these models do not particularly focus on distribution logistics and do not contain consistent techniques to re-design and to evaluate its cause-effect-relationships quantitatively. Therefore, methods for assessing potentials in distribution logistics are needed to re-design and evaluate possible improvements quantitatively.

The already existing distribution logistics potential evaluation methods can be divided into the following procedural categories:

(1) Analytical procedures for individual issues
(2) Simulation-based potential analysis,
(3) Model-based potential analysis.

Analytical procedures for individual issues evaluate parts of the distribution logistics aspects. They optimize one of the three elements without taking the remaining two into account. This focus may also occur within one segment. One familiar example in the transport segment is the so-called traveling salesman problem with its numerous solution options from the operations research segment aiming at the identification of the optimum materials flow location sequence [12], [13]. The application of this method appears to be particularly expedient for tour planning in the transportation segment. Another scope of application in element warehousing is - for instance – inventory management within the supply chain [14]–[17]. Analytical procedures for individual issues are limited to a certain part of the distribution logistics aspects. Hence, their consideration of upstream or downstream interactions is insignificant. If the general conditions under which the model is valid are complied with, these processes can deliver detailed results and precise solutions. However, due to the exclusion of other aspects, there is a risk that the generated solution attains only optimum results only locally.

Simulation-based potential analyses aim at generating insights into the underlying system through a model-based analysis [18], within which its model parameters and variables are altered and the resulting system statuses are recorded by way of simulation. A large number of computations take place in conjunction with this process. Partial models, all of which support decisions parts of the distribution logistics system, for instance for the optimization of transports and warehouse management, are frequently utilized in distribution logistics [19]–[22]. In theory, the individual models used for each part could be consolidated into an overall model so that the interactions between the parts can also be taken into account. However, the compilation and application of this option would be costly, complex and time-consuming. Consequently, this approach is usually averted in practical applications [23]. As a result, this process does not meet the standards of a fast, low cost and effort application.

Similar to simulation-based potential analyses, model-based potential analyses are based on the model depiction of reality. However, its usability is largely independent from specific application scenarios [24]. Consequently, these applications are more complex to set up than simulation approaches; however, their practical use is less costly and takes less effort [25]. In practical application, the adjustments are frequently limited to the collection of company specific data. Fronia was the first to develop a model-based potential analysis for distribution logistics [26]. Other solutions were developed to complement it [27]. This model was used as the basis for the support system introduced in this article.

To conduct a potential analysis of distribution logistics, all relevant objectives have to be modeled and all of their correlations have to be depicted. This is the only option that makes it possible to not only depict the actual situation, but also to evaluate the effects of measures on the objectives. The aim of this article is to place the focus on the support system-based utilization of the potential analysis. Readers interested in a comprehensive description of the mathematical relations and models are encouraged to refer to [26], [27].

III. The Model-Based Potential Analysis Process

Fig. 1 provides an easy-to-understand overview of the fundamental model-based potential analysis process, which is divided into the main steps of the system engineering problem resolution cycle [28]: Setting objectives, finding solutions und selecting a solution.

A situation analysis of the company is conducted along with a distribution logistics target formulation in conjunction with the objectives search. As part of the situation analysis, the market environment as well as the strengths and weaknesses of the company itself are first identified on the basis of defined criteria. The distribution logistics objectives can subsequently be derived from this foundation. Possible objectives could cost reductions by a specified percentage or a boost of the logistics performance e.g. through reduced delivery times. Once the data has been gathered, the quantitative examination of the actual situation is divided into the analysis of the logistics costs (in this case process and capital costs) and of the logistics performance (in this case delivery time and delivery reliability). The logistics costs or logistics performance are modeled on the basis of process steps order processing, warehousing and transportation. The process costs for order processing and warehousing are modeled as a process cost calculation.

The capital costs are computed on the basis of the capital tied up within the individual process steps. The delivery time for all processes is modeled through the process time computation via delivery time determining sub-processes. Delivery time determining sub-processes are sub-processes that have a direct impact on the delivery time perceived by the customer. In the model, the computation of the delivery reliability rates is implemented through a service level-oriented safety stock formula. An overview of the individual modeling processes is provided in Fig. 2.

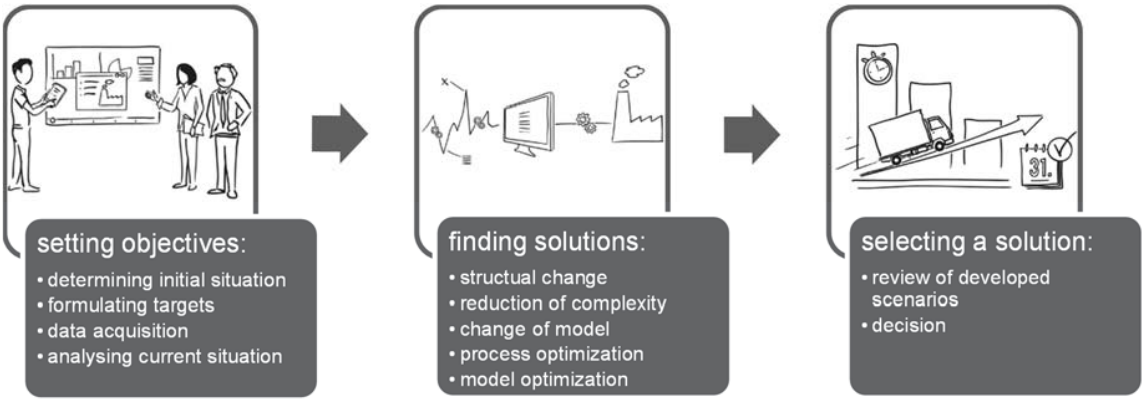

Fig. 1 The model-based potential analysis process

		order processing	warehousing	transport
logistic costs	process costs	process costing	process costing	cargo rate costing
	capital tie up costs	• unbilled receivables • outst. receivables • payment defaults	inventory costs = costs of safety stock + mean stock-level	costs of mean inventory during transport
logistic performance	delivery time	process time calculation	process time calculation	process time calculation
	delivery reliability	consistency of process times	servicelevel-oriented safety stock	consistency of transport times

Fig. 2 Distribution logistics modeling [27]

The next step in the model-based potential analysis – the solutions selection – is divided into sub-points structural change, reduction of complexity, change of model, process optimization and model optimization. The supreme goal of the solution selection is the creation of valid scenarios based on which the existing monetary and logistical potential can be identified. The number of items and the net sales that are processed through the respective distribution models and the specific characteristics of the model parameters define a scenario.

The first sub-point – structural change – offers the opportunity to question the distribution structure in place to date. It is, for instance, possible to analyze the current customer structure or the distribution models in use. One of the potential feasible results would be that a change in the distribution model to a consignment concept would make sense for strategically important customers. The updates that would have to be made to the distribution structures can subsequently be analyzed more concretely in steps reduction of complexity and change of model. A reduction of complexity may for example be achieved through the reduction of the item variants, a creation of parts batches or the consolidation of customers and delivery via wholesalers [29]. The term change of model pertains to the six standard distribution models shown in Fig. 3. What differentiates the standard distribution models from each other are the title transfer and the storage venue. A change of model results in the relocation of customers or net sales to other distribution models. The required order processing, warehousing and transportation process steps change accordingly.

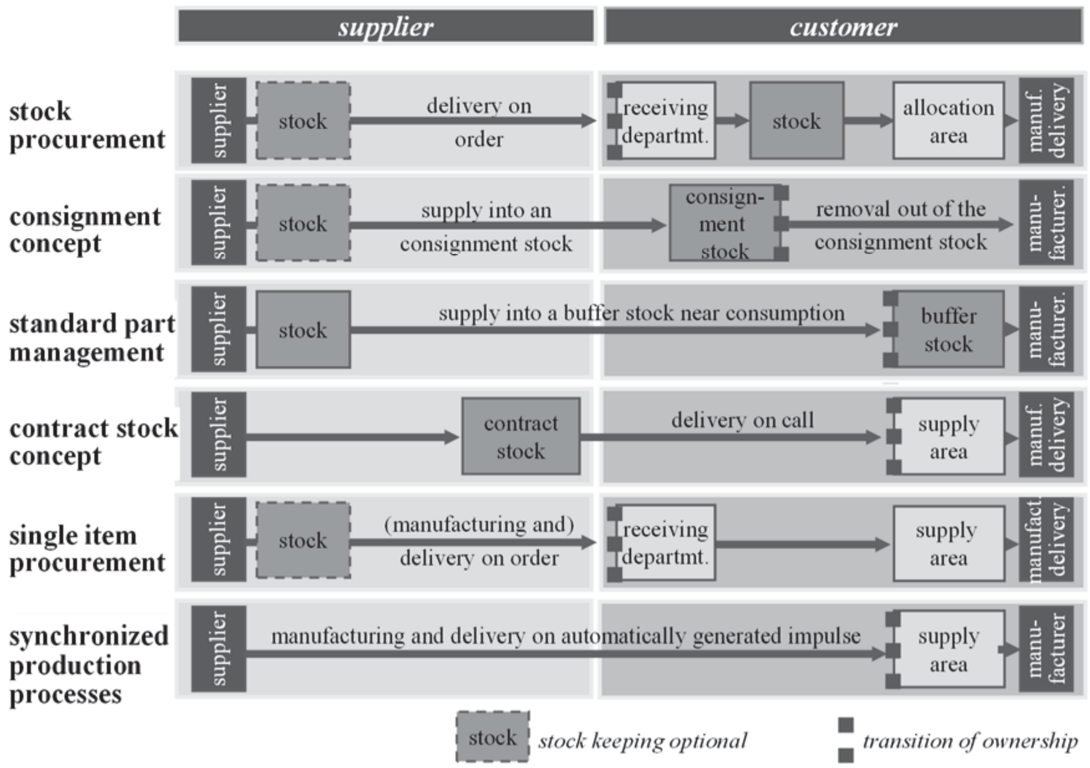

Fig. 3 Six standard distribution models [29]

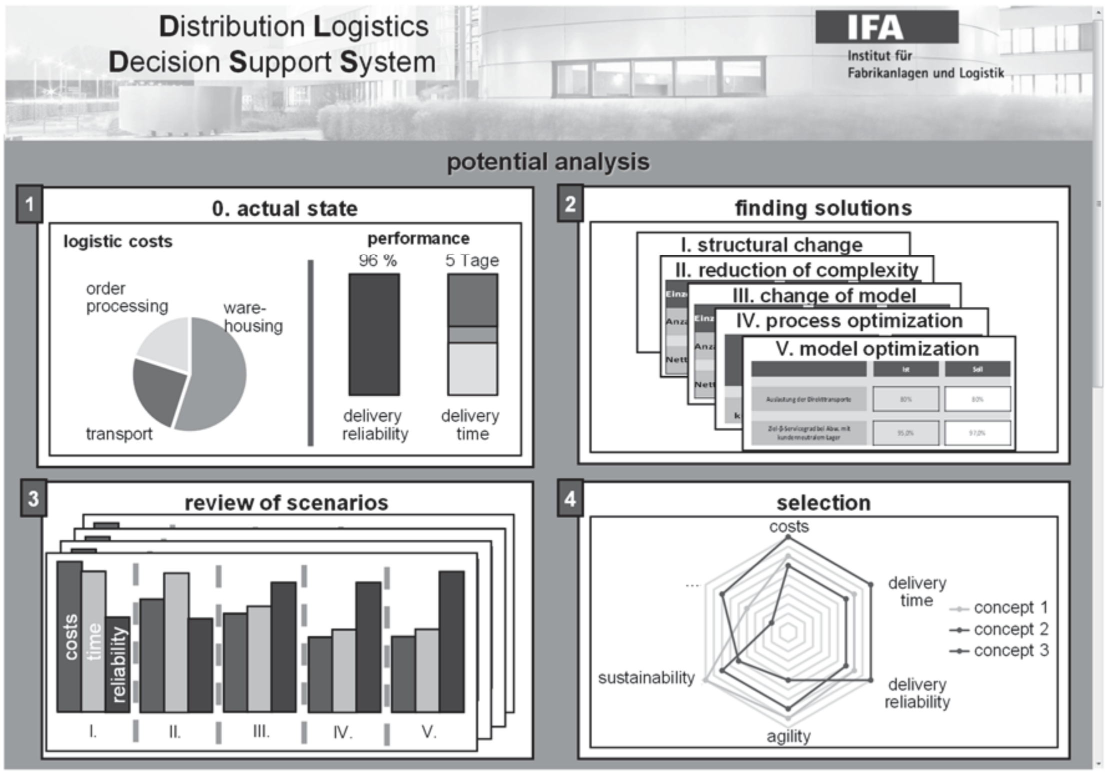

Fig. 4 The model-based potential analysis process

Through adjustments of information, material and value flows, potential estimates are made during the subsequent process optimization. This impacts primarily the process costs. The aim of the final model optimization is to uncover further potential through the regulation of parameters contained in the process. Parameter “target service level,” for example, directly affects the required safety stock level.

The final step of the potential analysis – the selection – is divided into the scenario assessment and the decision. The scenarios generated in conjunction with the solution selection are evaluated during the scenario assessment. Besides the quantitative evaluation based on logistics costs and logistics performance this also allows for an evaluation based on strategic objectives. This comprehensive basis of information allows companies to make transparent and target-oriented decisions.

IV. Utilizing Distribution Logistics Potential with the DLDSS

The DLDSS is based on the model-based potential analysis and completes the individual steps in the above-described sequence. The model-based potential analysis process aided by the logistics support system is shown in Fig. 4. To that end, the recording of the actual state, the five scenario creation steps and the scenario evaluation have to be recursively completed as often as necessary until the generated scenarios can be consolidated into one concept so that step four – the concept selection – can be executed. The concrete process based on the logistic support system is described in more detail below.

A. Recording of the Actual State

The DLDSS offers two different application options. The first option is the analysis of individual warehouses and the creation of multiple scenarios for these warehouses.

One tenable example would be to complete the recursive loop for a specific warehouse four times and to choose one of the four scenarios generated as a result. For instance, in the first round one could evaluate the impact of a model change; in the second round the impact of a model change combined with a service level change and in the third and fourth round a variety of other effects. Each of the four scenarios would yield an autonomous concept. It is also possible to define the entire distribution structure as a concept, so that all stock levels combined from a concept that is considered in the concept selection.

The required database for the use of the DLDSS can be accessed in a required data list (checklist). The respective data entered is divided into the recorded process costs, capital costs and logistics performance for the individual process steps order processing, warehousing and transportation. Users are first asked to enter data for the computation of the process costs based on entry fields. For instance, for order processing and warehousing, users have to enter the number of employees, the median hourly pay rate per person and the average work hours required for each sub-process step. To analyze the actual capital costs for e.g. each standard distribution model, the user is asked to enter the net annual sales, the capital cost rate, the warehousing cost rate and the median transportation time to the point of title transfer. For the analysis of the actual logistics performance, the actual on-time delivery rate of the transport or the actual service level of the respective distribution model have to be entered for each sub-process besides the process times for each sub-process. Information as to whether it is delivery-time relevant, i.e. whether it has an impact on the delivery time perception of the customer, also has to be provided for each sub-process.

Next, the DLDSS automatically visualizes a compact depiction of the actual situation based on indices and diagrams. The result is a transparent overview of the current logistics costs and logistics performance of the company.

B. Five Scenario-Creating Steps

The creation of scenarios begins with the structural change. This is a step that has to be completed beforehand – in workshops or expert sessions. During this step, the current stock level or distribution structure of the company must be reviewed. Next, the potential changes or adaptations have to be defined. This step must not be neglected since the targeted, valid result producing application of the logistics support system is contingent upon the company's knowledge of its own distribution structure. The resulting effects of the structural change are examined afterwards as part of the subsequent reduction of complexity and the change of model.

The number of customers or item numbers can be varied within the reduction of complexity process for each of the six standard distribution models. One feasible implementation option would be the handling of deliveries through regional wholesalers or the elimination of customers who do not generate a profit. With the change of model, it is possible to re-categorize customers and the respective net annual sales with the assistance of the unprofitable DLDSS. For instance, if a change from stock procurement to a consignment warehouse is being considered, the actual customers, the actual net annual sales of the stock procurement have to be transferred into the target column of the consignment concept. Such a change would have direct effects on the delivery time, since a consignment warehouse would eliminate the delivery time thanks to the geographic proximity to the customer.

The next step is process optimization, which examines the effects of improvements of individual sub-processes. It is possible to enter the respective improvement factors for each sub-process of any distribution model. Process optimization by the customer may for instance be achieved through a consistent order processing system or electronic order tracking.

Model optimization is the final step in the creation of scenarios. At this point the DLDSS can be used to examine the effects of adjustments of various model parameters on the logistics costs and the logistics performance. The interactions between these two aspects are particularly evident during this step. If for instance the target service level value is increased, this does not only boost the logistics performance, but also results in a direct increase of the required safety stock.

C. Scenario Evaluation

The overall result and an action plan are issued in conjunction with the scenario evaluation. The overall result shows the actual costs and the actual logistics performance at a glance along with all of the effects on the logistics costs and performance generated by the five scenario creation steps. The results are centrally visualized in index tables and diagrams. The automatically generated action plan subsequently allows users to present the actions that have to be taken to attain the overall result in a compact manner.

D. Concept Selection

The previously defined concepts are evaluated in a cost-utility analysis during the concept selection process. The cost-utility analysis makes it possible to not only consider the determined quantitative criteria (logistics costs and performance), but also include qualitative criteria in the decision-making process. The agility or sustainability of distribution logistics [30] have established themselves as relevant criteria. In this context, the term agility describes the change flexibility of the distribution structure to be evaluated within a complex and dynamic corporate environment. The contributions the compiled concepts make to the company's lasting success should be evaluated on the basis of the three pillars economy, ecology and social issues. Moreover, business could also add e.g. company specific criteria to the evaluation process. The result of this evaluation is subsequently visualized in a radar chart, an example of which is shown in Fig. 5.

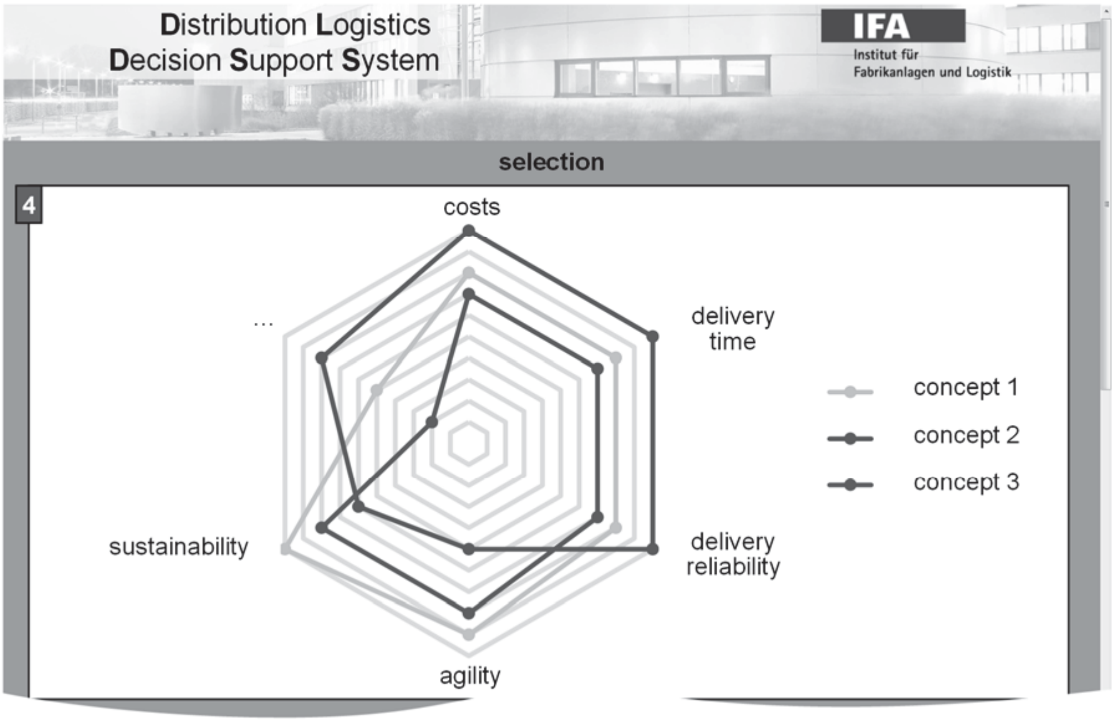

Fig. 5 Concept evaluation

V. Summary and Outlook

As part of a company's logistics system, distribution logistics significantly affect both, a business' logistics costs and logistics performance. Hence, it should be the objective of every company to position itself in this discipline, which is prone to friction.

The DLDSS development presented herein makes it possible to identify logistics cost reduction and logistics performance boost potentials as well as other qualitative criteria. The process begins with an analysis of the actual state – the status quo. During this step, the current logistics costs and logistics performance are computed on the basis of the company's indices (e.g. service level, annual net sales). The actual situation – the status quo – is evaluated on the basis of qualitative criteria (e.g. agility). The five scenario creation steps, during which the potentials of the change of the distribution structure unleashed by the reduction of the complexity or a model change are determined, are completed next. It is also possible to identify the potential generated by a process and model optimization.

The overall result the DLDSS can deliver for every warehousing stage reflects the determined actual costs, the actual logistics performance as well as the respective values post the reduction of complexities, a change of model, a process optimization and a model optimization. This procedure makes it possible to directly identify the potential of each individual step. Moreover, with the assistance of the DLDSS it is possible to generate an action plan for each warehousing stage, which reflects the changed defined during the solution selection. This action plan serves as an overview of the criteria that have to be met to attain the overall result for the respective warehousing stage. Besides the monetary evaluation, the logistics support system also offers the option of performing a cost-value analysis, in which additional criteria can be defined and evaluated. As a result, it is also possible to integrate strategically important criteria, such as sustainability and adaptability/flexibility.

The DLDSS enables companies to quantitatively determine their current logistics costs and logistics performance. It is also possible to efficiently identify cost reduction and performance boosting potential. Scenarios that lead to the establishment of agile and sustainable distribution logistics can be selected in combination with additional qualitative criteria.

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