ABSTRACT

In distribution systems, managers have to designate each article to its corresponding inventory level and location. This paper illustrates the need, the requirements, as well as a guidance for (in form of a system of objectives) a performance measurement system designed to advert to a suboptimal allocation and suboptimal inventory levels of articles in respect to logistic efficiency. It is necessary to reach changeability to cope with unpredictable dynamics on global markets.

1. PLANNING AND CONTROL PROBLEMS IN PRACTICE

Distribution systems of commercial enterprises consist of a multiplicity of different warehouse locations to cope with customers’ needs. Thereby, the assortment can be formed by up to several thousand different articles, permanently confronted with changing demands due to unpredictable dynamics on global markets (Hegmanns et al., 2012).
Competitive advantages in supply chains are gained through the ability to react to changing market conditions on a tactical or strategic level in an appropriate amount of time (changeability) (Lee, 2002, Saleh et al., 2001). Therefore, there is a continuous need to reorganize the stocking strategy in which decisions are made about the strategic article-warehouse allocation (at which warehouse to allocate which article) and the corresponding inventory levels (Hegmanns et al., 2012).

Nevertheless, in practice the stocking strategy is not adjusted promptly to changing market conditions (Hegmanns et al., 2012). Therefore, managers need to have a tool to handle the dynamic supply chain information and to be able to reduce the time of following suboptimal stocking strategies in the existing network of warehouses.

The aim of this paper is to present the need, the requirements, as well as a guidance for (in form of a system of objectives) a performance measurement system (PMS), which is designed to evaluate the current stocking strategy of commercial enterprises regarding logistic performance and logistic costs in such a way that changeability can be reached.

In section 2 of this paper, the current state of research in terms of changeability, methods related to stocking strategies as well as PMS related to logistics are presented. Thereby, what a PMS for a changeable stocking strategy in distribution systems of
commercial enterprises might constitute will be defined. Influencing factors on the
stocking strategy are illustrated in chapter 3 and requirements for a PMS for a
changeable stocking strategy are deduced. In section 4 the developed requirements are
matched to the existing logistical PMS. As a first step towards a PMS for a
changeable stocking strategy, a system of objectives is proposed in chapter 5. In
section 6 an example is presented how to use the developed system of objectives to
create a PMS for a changeable stocking strategy. The final section provides the main
conclusions of the paper.

2. CURRENT STATE OF RESEARCH

Overview of planning methods related to stocking strategies

There are many existing methods for the planning tasks of the strategic
article-warehouse allocation and the determination of inventory levels.

In e.g. (Magee et al., 1985, Boone, 2001, Botter et al., 2001) classification
methods are described with which one is able to determine the strategic
article-warehouse allocation in terms of whether the article should be stocked rather
decentralized or centralized.

To determine inventory levels well established methods are described in e.g.

Changeability

To reach changeability specific action-phases need to be passed in an appropriate
amount of time, which are systemized chronologically by (Hernández Morales, 2003, Kuhn et al., 2011) in a generic changeability process (fig.1).

In the first phase (monitoring) influencing factors need to be identified and permanently controlled. Furthermore they need to be analyzed in terms of their significance to the need to adjust the system under consideration. If the need to reorganize the adjustment is given, alternative adjustment-actions are considered in the planning phase, concluding in a decision. The last phase (change) of the changeability process is characterized by the implementation of the planned action as well as its impact.

In order to adjust the stocking strategy promptly according to changing market conditions and to reach changeability, the mentioned existing planning methods (planning phase) need to be used whenever there is a need for an adjustment. By doing this, the time of following suboptimal stocking strategies is in comparison to nowadays practice reduced.

Hence, within the prior monitoring phase a tool is required adverting to suboptimal stocking strategies and triggering a reorganization process of the stocking strategy.
The application of a PMS is a possible solution way since it is applicable to discover need for planning action (Zimmermann, 2005).

**Overview of PMS related to logistics**

Quantifying the effectiveness and efficiency of actions (Neely, 1998), a PMS is the composition of monetary and non-monetary measures complementing or supporting each other, being capable to measure an overall objective (Reichmann, 1995). PMS are able to give a fast and compact overview of the overall performance of complex logistic systems in terms of logistic costs and logistic performance.

In literature plenty of PMS are described, which are specially designed to measure actions related to logistics (Keller, 2010). In the following selected, often-cited, logistical PMS will be briefly described.

(Zimmermann, 2005) created a PMS to check the optimality of the structure of distribution systems in terms of e.g. the location of the facilities. He deduces indicators from influencing factors to the distribution system. Distribution costs and distribution performance are measured.

(Reichmann, 1995) developed a PMS, which consists of liquidity – and profitability oriented indicators selected to measure the achievement of a major objective. A part of this system is designed for logistic controlling in terms of logistic costs and logistic performance. Main indicators are turnover rate, total logistic costs per unit and the service level.
(Schulte, 2008) structures indicators to measure logistic performance in a matrix. This matrix is clustered in different types of indicators (structural-, productivity-, quality-, economical-, and framework-indicators) as well as logistical functions (procurement, material flow, transport, production planning and scheduling).

(Syska, 1990) developed a general PMS for logistics, which consists of two systems of objectives derived from the two objectives “increase service level” and “reduce logistic costs”. Corresponding indicators were developed in a deductive way.

The PMS in LogiBEST (Luczak et al., 2004) was built to benchmark the logistic performance and costs between different companies. The indicators are structured in a process oriented manner to the functions of procurement, production and distribution. They are assigned to a system of objectives derived from the objectives “high logistic performance” and “low logistic costs” which pursue the overall objective of a “high logistic efficiency”.

VDI 4400 (Verein Deutscher Ingenieure, 2000) provides a PMS similar to LogiBEST as it contains indicators which are assigned to a system of objectives with the overall objective of “a high logistic efficiency” which is in the next level divided up in the objectives of “high logistic performance” and “low logistic costs”. The PMS was built for internal controlling purposes as well as for benchmarking.

The logistic balanced scorecard (Brewer et al., 2000) can be seen as a PMS,
since it links the 4 different perspectives of the balanced scorecard approach (customer perspective, innovation and learning perspective, financial perspective, internal business perspectives) to 4 different kinds of objective classes (SCM goals, customer benefits, financial benefits, SCM improvement). Additionally, indicators are assigned to that system of objectives so that a PMS is formed.

(Weber, 1991) constructed a PMS with the overall objective of a high “logistic efficiency”, which is further divided up into “high logistic performance” as well as “low logistic costs”. He conceives the PMS as a calculation system, so that the logistic efficiency is an aggregated calculation out of the indicators of logistic performance and logistic costs which are also aggregated part values. The part value of “logistic performance” is an aggregated calculation of the three part values “performance volume”, “service” and “throughput time”. These three part values, as well as the part value of logistic costs are calculations of part values structured in a process-oriented functional manner (procurement, production, distribution). The calculation rules for and between the indicators are to be set individually by the companies.

(Konen, 1985) developed a PMS to analyze and control the functions of transport and warehousing of distribution systems in terms of logistic performance and logistic costs. Logistic performance is not measured out of the customer perspective, e.g.
measuring service level; it is rather measured by internal performance measures such as “degree of utilization of trucks”. Logistic costs are calculated through the transport costs as well as the inventory costs. The author developed basic indicators for each of the mentioned functions so that the user is able to do any kind of arithmetic calculation with those indicators.

The PMS presented in (Berg et al., 1980) was developed to control the performance as well as the costs of distribution systems. The performance is measured by the “service time” and the “service level”. The costs are divided between “transport costs”, “inventory costs”, “warehouse costs”, “labor costs” as well as “administrative costs”.

(Wicht, 2001) developed a PMS to control the performance and costs of distribution systems in international commercial enterprises. The indicators of costs as well as performance are structured among the supply chain (supplier, distribution center, store). Costs include transportation, handling, inventory as well as product costs. The performance dimension is measured by e.g. supplier reliability, volumes, out of stocks and delays in distribution.

In the following requirements to a PMS for a changeable stocking strategy (SSPMS) are developed and matched with the existing PMS.
3. REQUIREMENTS TO A PMS FOR A CHANGEABLE STOCKING STRATEGY

The SSPMS to be applied within the monitoring phase of the changeability process is supposed to identify the need for planning action to adjust the current stocking strategy and therefore to trigger the planning phase. To do so, the SSPMS needs to monitor all relevant variables of the stocking strategy and their influencing factors. Predefined boundaries of the measures enable one to identify significant changes as well as the need for planning action. By monitoring influencing factors, the SSPMS enables one to react as soon as possible to upcoming undesirable developments in terms of the stocking strategy. Hence, this increased speed is a further step to reach changeability.

In the following paragraph, factors influencing the optimal stocking strategy of commercial enterprises are listed. These factors have been deduced from the existing planning methods of stocking strategies mentioned in section 2. Additional indicators have been taken from (Zimmermann, 2005), who listed influencing factors on distribution systems.

Influencing Factors:

- Structure of suppliers:
  number and geographical position of suppliers
- Structure of customers:
- number, geographical location and mixture of customers
- Structure of orders:
  - mixture of orders (share of small and large quantities)
- Structure of articles:
  - number, mixture (share of high value, low value) articles
- Volatility of demand (frequency and deviation)
- Structure of distribution warehouses:
  - number, capacity, geographical position of warehouses
- Target delivery service
- Importance of customers to the company
- Delivery service expected by customers
- Suppliers delivery service
- Competitors delivery service
- Inventory costs:
  - variable inventory costs (inventory carrying costs)
- Process costs:
  - variable transport costs (freight rate)
  - variable handling costs
- Availability of articles on procurement market
- Order setup costs
- Procurement lead time
- Volatility of prices on procurement market
- Forecast accuracy
Changes within these factors result in changes of the overall

(1) logistic costs and/or

(2) logistic performance

and influence decisions on the article-warehouse allocation as well as the inventory levels at the same time.

The omnipresent trade-off between low logistic costs and high logistic performance leads to the need to measure both dimensions and choose adequate measures within the SSPMS.

This approach is in line with all in section 2 presented logistical PMS, as all of them analyze logistic costs as well as logistic performance. Not all influencing factors are equally important in each company. Companies should decide which factors are the most important to them in order to create a SSPMS in an economical and lucid way.

In the following, requirements to indicators for a SSPMS for a changeable stocking strategy are deduced from the illustrated influencing factors and assigned to the mentioned dimensions (1), (2). In addition, measures of actual logistic costs and actual logistic performance need to be monitored to provide information about the actual performance of the distribution system, as well as to enable target-actual comparisons. By doing this a further differentiation between output measures,
measuring the resulting logistic costs and logistic performance as well as input measures, measuring changes of the influencing factors of the stocking strategy will be done.

(1) Logistic costs: It is important that all costs are monitored which are affected by or influence the stocking strategy. These costs are actual and variable inventory costs, which are determined through the inventory levels as well as process costs. These costs are divided up into actual and variable transport- and handling costs.

Adequate performance measures need to be integrated in the SSPMS.

Having planned optimal disposition parameters in terms of warehouse replenishment policies and therefore the corresponding optimal inventory levels in each warehouse with methods described in e.g. (Axsäter, 2006, Simchi-Levi et al., 2005, Klosterhalfen, 2010), the SSPMS should be able to compare the actual inventory levels with the planned inventory levels. Respective measures of inventory levels or costs need to be integrated in the SSPMS.

Furthermore, the SSPMS needs to integrate indicators, which imply best practice allocation strategies. These indicators should control whether the current allocation strategy corresponds with best practice strategies proposed in e.g. (Magee et al, 1985, Boone 2001, Botter et al. 2000). A typical ABC-Analysis could be conducted to develop a differentiated allocation strategy for certain article classes to reduce the
overall logistic costs (Magee et al, 1985). By integrating such indicators (indicators of suboptimal allocation of articles), the SSPMS will be enabled to advert to misallocations of certain articles.

Additionally, the delivery service of suppliers is important to measure, as bad delivery service of suppliers in quality, amount or time results in higher safety stock levels. In this context a measure of the procurement lead time is necessary to explain high safety stocks.

The forecast accuracy influences inventory levels and should be as high as possible. Applicable measures are needed.

The volatility of demand has a particular impact on the stocking strategy. A former high-demand article for which a decentralized stocking was prioritized due to lower transport costs might have developed within time to a low-demand article which should be stocked centralized to reduce the overall inventory in the system by risk pooling (Boone, 2001). So the SSPMS needs to be able to monitor the change in the volatility of demand for each article.

If an article is not available on the procurement market, companies build up higher inventories to protect against possible stock outs. Measuring the availability of articles on procurement market would help to decide whether articles should be placed decentrally or centrally to reduce inventory.
The article-warehouse allocation is influenced by the volatility of prices on the procurement market, as articles having a high volatility in price should rather be stored centrally to reduce inventory and avoid windfall losses. A corresponding indicator within the SSPMS is required.

(2) Logistic performance: This dimension focuses the customer’s view. In the long run, a distribution system needs to be able to fulfill customers’ needs to avoid loss of sales. Hence, the SSPMS needs to have indicators measuring the actual distribution delivery service to the customer as the output of the followed stocking strategy. A bad distribution delivery service due to long transport distances might force to allocate articles in a warehouse closer to the customer.

Target delivery service impacts lead times to customers and is influenced by competitors’ delivery service as well as the delivery service expected by customers. Appropriate indicators should measure these strategic influencing factors.

The determination of the stocking strategy, which is connected to the determination of the target delivery service, is influenced by the type of customers. By the importance of a customer differentiated delivery services are able to optimize the stocking strategy (Chopra et al, 2007). Over the course of time, a former small customer could become a key account and should get offered an adequate delivery service. Shifts of the importance of customers might occur, so that the SSPMS needs
to fulfill the requirement to monitor the importance of customers.

Some of the influencing factors have the nature of describing the framework of the distribution system of interest. To give the user of the SSPMS a fast overview of the characteristics of the distribution system of interest, structural indicators need to be integrated and assigned to an additional group “structural indicators of distribution network”. They should inform about the structure of suppliers, structure of distribution warehouses, structure of customers, structure of orders as well as structure of articles.

4. REQUIREMENTS TO A PMS FOR A CHANGEABLE STOCKING STRATEGY

In the following table 1 the in section 2 described PMS will be evaluated in respect to the developed and listed requirements to a PMS for a changeable stocking strategy.
### TABLE 1  Evaluation of existing PMS

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x considered
As it can be seen in table 1, while most of the existing PMS consider resulting logistic performance as well as resulting logistic costs in certain ways, they all lack certain requirements for a SSPMS. Since none of the described logistical PMS was specially built for the purpose of evaluating the current stocking strategy (article-warehouse allocation and inventory levels), none of them include indicators deduced from the relevant influencing factors.

In conclusion, neither the in table 1 exemplified nor any other PMS described in literature (to the best of author’s knowledge) fulfill all the listed requirements for a PMS for changeable stocking strategy. None of these systems were specifically built to evaluate the current stocking strategy in respect to logistic costs and logistic performance. None of them incorporate all major influencing factors on the stocking strategy and deduce corresponding indicators.

Therefore, a PMS needs to be developed, fulfilling all of the listed requirements.

5. SYSTEM OF OBJECTIVES FOR A PMS FOR A CHANGEABLE STOCKING STRATEGY

In this chapter a system of objectives for a SSPMS will be illustrated (fig. 2) designed to identify need for planning action to adjust the current stocking strategy in respect to logistic performance and logistic costs matching all acquired requirements of section 3. It is the first step towards a SSPMS specially constructed to evaluate the current stocking strategy.
Figure 2 System of objectives of SSPMS
In the following the construction of the system of objectives will be described on an aggregate level, as the deduced objectives should be clear.

The structure of the system of objectives for a changeable stocking strategy is mainly influenced by VDI 4400 (Verein Deutscher Ingenieure, 2000), which is a widely recognized PMS measuring the performance of distribution systems. That is why the main differences of the developed system of objectives for a changeable stocking strategy to VDI 4400 are highlighted in figure 2.

The overall objective is to reach an optimal stocking strategy, which is equivalent to the objective of reaching a high logistic efficiency (ratio of logistic performance and logistic costs (Verein Deutscher Ingenieure, 2000)) through the tasks of the article warehouse allocation as well as the determination of corresponding inventory levels. There is currently no PMS which is especially constructed to reach this goal, so that the existing logistical PMS (such as VDI 4400) needs to be advanced by incorporating the requirements of chapter 4, in order to achieve changeability in the stocking strategy.

As described in section 3, changes in the influencing factors result in changes in the dimensions logistic costs and logistic performance. Apart from these dimensions, there is a third branch within the system of objectives which encompasses all objectives of measuring structural changes to the distribution system. By doing so, the
system of objectives corresponds with all requirements to a SSPMS worked out in section 3.

Having constructed a system of objectives, concrete indicators can be deduced “top down” from the objectives. By doing this the indicators will be automatically assigned to the corresponding objectives.

The proposed system of objectives for a SSPMS should be understood as a general guideline helping companies to construct their own individual PMS with individual calculation rules. Already existing indicators within the companies should be taken into consideration in order to reduce the development time to construct and implement such a PMS.

6. BUILDING A SSPMS BY ASSIGNING INDICATORS TO THE PRESENTED SYSTEM OF OBJECTIVES

To give companies an example how to assign indicators to the system of objectives to create a SSPMS leading to changeability in stocking strategy planning, this section provides example indicators for each of the 26 numbered objectives of figure 2. The assignment will be done tabulated in table 2:
These are just examples of some possible indicators. They can and should be supplemented by further indicators which need to be assigned to the 26 objectives to provide the ability to monitor all the stocking strategy influencing factors in a holistic way. By assigning adequate indicators to the 26 different objectives in the system of objectives for a SSPMS a PMS will be constructed which will be able to discover the need for stocking strategy planning action in such a fast way that changeability can be reached.

<table>
<thead>
<tr>
<th>Objective #</th>
<th>Example Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lead Time to Customers</td>
</tr>
<tr>
<td>2</td>
<td>Target Lead Time to Customers</td>
</tr>
<tr>
<td>3</td>
<td>Competitor’s Average Lead Time to Customers</td>
</tr>
<tr>
<td>4</td>
<td>Expected Lead Time by Customers</td>
</tr>
<tr>
<td>5</td>
<td>Sales per Customer</td>
</tr>
<tr>
<td>6</td>
<td>Annual Inventory Cost</td>
</tr>
<tr>
<td>7</td>
<td>Actual Inventory Level per Article</td>
</tr>
<tr>
<td>8</td>
<td>Number of Warehouses the Article is stored in</td>
</tr>
<tr>
<td>9</td>
<td>Change in % of Inventory Carrying Cost (e.g. monthly update)</td>
</tr>
<tr>
<td>10</td>
<td>Change in % of Order Setup Cost (e.g. monthly update)</td>
</tr>
<tr>
<td>11</td>
<td>Change in Sales of Demand per Item (e.g. weekly update)</td>
</tr>
<tr>
<td>12</td>
<td>Forecast Error (e.g. mean squared error)</td>
</tr>
<tr>
<td>13</td>
<td>% of Orders delivered in Time per Supplier</td>
</tr>
<tr>
<td>14</td>
<td>Number of Suppliers on Market per Article</td>
</tr>
<tr>
<td>15</td>
<td>Standard Deviation of Procurement Prices (e.g. last 6 months)</td>
</tr>
<tr>
<td>16</td>
<td>Target Inventory Level per Article</td>
</tr>
<tr>
<td>17</td>
<td>Target Allocation Strategy per Article (e.g. Article should be stored in</td>
</tr>
<tr>
<td>18</td>
<td>Annual Transport Costs</td>
</tr>
<tr>
<td>19</td>
<td>Change in % of Variable Transport Costs (e.g. monthly update)</td>
</tr>
<tr>
<td>20</td>
<td>Annual Handling Costs</td>
</tr>
<tr>
<td>21</td>
<td>Change in % in Variable Handling Costs (e.g. monthly update)</td>
</tr>
<tr>
<td>22</td>
<td>Average Inbound Distance Supplier-Warehouse (e.g. monthly update)</td>
</tr>
<tr>
<td>23</td>
<td>Average Size of Orders (in e.g. tonnes)</td>
</tr>
<tr>
<td>24</td>
<td>Share of high Value Articles</td>
</tr>
<tr>
<td>25</td>
<td>Average Outbound Distance Warehouse-Customer (e.g. monthly update)</td>
</tr>
<tr>
<td>26</td>
<td>Number of Warehouses in the Distribution Network</td>
</tr>
</tbody>
</table>
7. CONCLUSION

Discovering the need for action planning, the proposed SSPMS forms the foundation to enable supply chain decision makers to react soon to changing market conditions by adapting the stocking strategy of articles within the distribution system to reach changeability and high logistic efficiency.

Taking the system of objectives for and the developed requirements to a SSPMS as a basis, commercial enterprises are encouraged to derive their individual PMS adapted to their specific requirements and sectors. Example indicators have been supplied and assigned to the developed system of objectives to give the reader an idea how to create his or her own SSPMS by using this article as a manual.

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