FINDING A GENERIC ALGORITHM FOR INTEGRATING VALUE-BASED OBJECTIVES AND LOGISTICS GOALS – OPERATIONALISATION OF ORDER PRIORITISING IN PRODUCTION CONTROL BASED ON CUSTOMER VALUE MANAGEMENT

Michael Hülsmann[1], Christoph Illigen[2], Katja Windt[3], Oliver Jeken[4]
[1]m.huelsmann@jacobs-university.de, [2]c.illigen@jacobs-university.de,
[3]k.windt@jacobs-university.de, [4]o.jeken@jacobs-university.de
Jacobs University Bremen

Acknowledgement
This research was supported by the German Research Foundation (DFG) as part of the Collaborative Research Centre 637 "Autonomous Cooperating Logistic Processes – A Paradigm Shift and its Limitations".

INTRODUCTION

One megatrend in logistics in recent years is a shift from traditional cost-oriented goals to a value-based management (Bowersox et al. 2000), which focuses on maximizing shareholder value instead of just minimizing the costs (Müller-Stewens & Lechner 2005, Straube et al. 2005). From a logistics perspective, this means giving more attention to the target punctuality and not only focusing on capacity utilization. However, there is still a missing link between logistics and the value-based management (Straube et al. 2005) hampering an integration of both perspectives. Thus, a successful and simultaneous integration of the postulates of both perspectives – those of logistics and those of value-based management – into the operations management seems to be difficult.

One way to connect logistics to the concept of value-based management is to integrate the customer value management (CVM) into logistics. This concept explicitly focuses on customers contributing the most to a company in terms of monetary value (Stirling 2000). This in turn contributes to the value-based management, since a concentration on more valuable customers increases shareholder value. By that integration, logistics goals (e.g. short throughput times or high machinery utilization (Nyhuis & Wiendahl 2008)) can be linked with those of the CVM (i.e. maximizing lifetime profit from a customer or increasing information exchange frequency with customers (Pease 2001)). Hülsmann et al. (2010) conceptualised the implementation of CVM into the logistics planning and control for which both goals settings (logistics and customer value) are considered concurrently. Thus, the goal settings can therewith be optimised simultaneously enabling companies to increase their shareholder value. However, this research is still on a conceptual level.

Therefore, the **central objective** of this paper is to develop an algorithm based on the approach of Hülsmann et al. (2010) to enable logistics companies to integrate the value-based management into real world logistics scenarios: **(1)** Sets of requirements for a formulation of the algorithm will be developed in order to have a profound basis for its development, which includes also a description of the conceptual approach of Hülsmann et al. (2010). **(2)** The algorithm itself – including functions and routines – will be formulated for generating a generic description of the processing steps for implementing in a dedicated programming environment. This also comprises a critical reflection on contributions and limitations regarding the applicability, the feasibility and the benefits of the algorithm in order to outline its implications for theory and practice.

INTEGRATING CUSTOMER VALUE MANAGEMENT INTO THE LOGISTICS GOAL SETTING

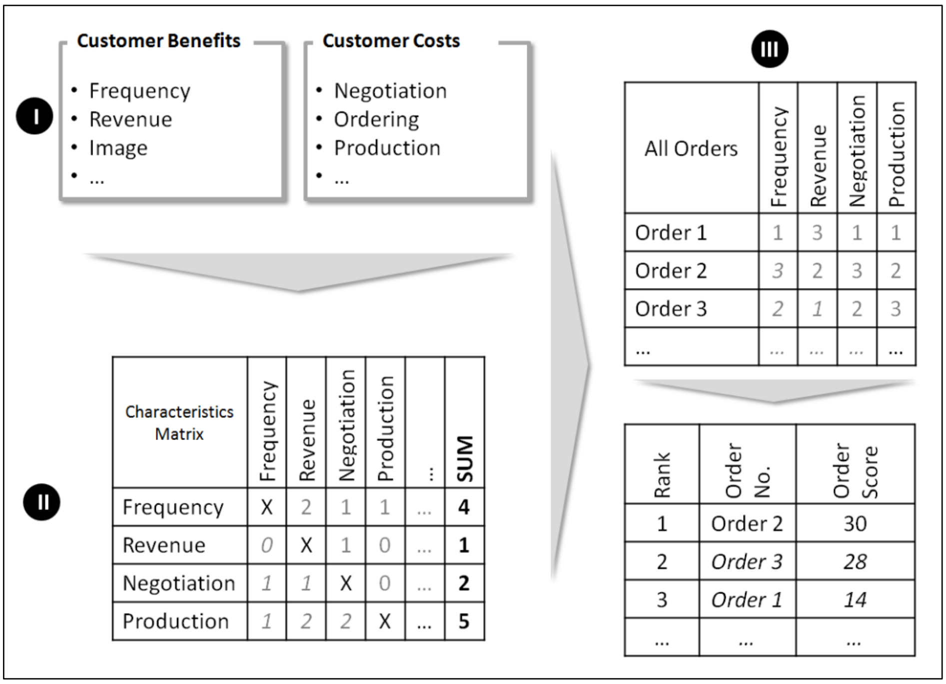
The conceptual approach of Hülsmann et al. (2010) for integrating logistics objectives (according to Nyhuis and Wiendahl (2008) e.g., high machinery utilization or high due date reliability) with those of the CVM (maximizing lifetime profit from the whole customer base (e.g., Pease (2001), Verhoef (2007), Gupta and Zeithaml (2006)) comprises two central concepts: The Autonomous Production Construction Cycle (APCC) and the CVM.

The **APCC** implements the idea of autonomous control to logistics manufacturing systems (Windt & Jeken 2009). The resulting autonomous logistics processes enable logistics objects (i.e. parts, containers) "*to process information, to render and to execute decisions on their own*" (Windt et al. 2008). Hence, the APCC is one potential approach to cope with new requirements to logistics (Scholz-Reiter et al. 2004) caused by nowadays logistics system's inherent complexity significantly influencing its performance (Bozarth et al. 2009), since the concept of autonomous control enables these systems to better handle these new requirements (Hülsmann & Grapp 2005). Accordingly, logistics objects in a job shop manufacturing system are able to route themselves through the production process without being steered by a central controlling entity. In the APCC a part decides autonomously about its next production step and thereby bases its decision on information about available product variants and customer orders. Each product is manufactured incrementally corresponding to an existent customer order pool, whereas each item receives regularly updated information based on a situational product variant – customer order combination. This loose allocation of items to customer orders provides additional flexibility for the system and can therewith contribute to a better logistics target achievement (Windt & Jeken 2009). Moreover, this approach allows for an integration of logistics objectives with e.g. those of the CVM, which can easily be integrated in the decision process of the logistics objects via e.g. rules in the corresponding logistics objects.

The **CVM** is an approach to analyse and increase customer value. The central idea is to achieve maximum lifetime profit from the whole customer base (Stirling 2000). It strives for these goals by increasing profits generated through customers and minimizing costs at the same time (Müller-Stewens & Lechner 2005). Thereby, the main goals of CVM according to Pease (2001) can be realized: (1.) the right customers (i.e. the most valuable) can be identified, (2.) the right relationship (no complaining or discussing customers) can be established, and (3.) the right retention towards customers (focusing on most important customers) can be kept (Pease 2001). There are two ways to increase customer value: First, increasing customer benefits like revenue per customer or frequency of customer orders. Second, decreasing customer costs such as negotiation or production costs (Müller-Stewens & Lechner 2005). By focusing on these elements the total value of a customer for a company can be increased. Thus, the CVM offers an appropriate way to investigate and improve the financial impact of a customer. By integrating these goals into the logistics objects as described above it is possible to link the CVM to the APCC. Consequently, logistics can be linked to a value-based management via the CVM. Exemplarily, a semi-finished part on the shop floor level would decide to allocate itself to a respective customer order where the customer order is ranked high, but eventually not the most urgent one.

As a combination of the proposed concepts APCC and CVM offers an opportunity to link logistics to a value-based management and therewith a value-orientation in logistics, this paper proceeds with the conceptual approach of Hülsmann et al. (2010). They elaborated an appropriate conceptual model for logistics combining both perspectives exhibiting two steps: First, establishing a ranking of customer orders. Second, release these ranked orders into the APCC. To create the ranking, they proposed the following three steps:

1. Identification of the constitutive characteristics of customer benefits and customer costs by conducting e.g. literature analysis or surveys,
2. formulating weightings in relation to the importance of every characteristic based on a pair-wise comparison, and
3. deducing a prioritization according to the overall score of each customer order by summing up the value of the weightings for each order (Hülsmann et al. 2010).



Characteristics Matrix	Frequency	Revenue	Negotiation	Production	…	**SUM**
Frequency	X	2	1	1	…	**4**
Revenue	*0*	X	1	0	…	**1**
Negotiation	*1*	*1*	X	0	…	**2**
Production	*1*	*2*	*2*	X	…	**5**

All Orders	Frequency	Revenue	Negotiation	Production
Order 1	1	3	1	1
Order 2	*3*	2	3	2
Order 3	*2*	*1*	2	3
…	…	…	…	…

Rank	Order No.	Order Score
1	Order 2	30
2	*Order 3*	*28*
3	*Order 1*	*14*
…	…	…

Figure 1: Pair-wise Comparison for building an Order Prioritization according to Hülsmann et al. (2010)

After having a ranking of customer orders, each order is released to the APCC and a backward scheduling is performed in order to determine the release date for the customer order. Thereby, the most important orders are released first according to their overall score leading to a better system performance from a value-based perspective (i.e. more valuable orders are treated prioritized). Additionally, if new orders are available for the APCC the ranking is updated and potentially more important orders than those already in the system are executed first and the whole system adjusts autonomously to the new order situation (e.g., if there is a part currently becoming a backlight without a fog lamp and a new and more important order exhibiting a fog lamp as the final product is released than the part would switch automatically to the new order and follow the required treatment steps for the new final product, if technically possible). Thereby, the integration of logistics and a value-based perspective takes place. However, since this approach is still on a conceptual level, the next step this paper takes on is to develop an algorithmic description of the whole procedure as a pre-condition for a later empirical validation (e.g., through simulation). Thus, the next section introduces a pseudo-code formulation of the APCC and the CVM including a description of both concepts. Further consequences are e.g. to redefine due date reliability or better to already consider important customers in prioritized due dates.

A PSEUDO-CODE BASED ALGORITHM TO IMPLEMENT THE CONCEPTUAL APPROACH FOR INTEGRATING FINANCIAL AND LOGISTICS GOALS

To illustrate how the integration of the APCC and the CVM is performed, this section is divided in three major parts: First, the product variant corridor as the underlying concept of the APCC is introduced in depth in order to fully understand the idea of the APCC. Then, the design logic for the APCC is introduced as pseudo code followed by the design logic for the CVM method. Thus, a concrete manual for an implementation is given.

The APCC concept is based on the idea of a **product variant corridor** that comprises all updated decision alternatives of a part, i.e. the combination of still possible product variants and currently unsatisfied customer orders. We define a part as a combination of different product features. Each of the features can have different feature specifications that define the final product variant. In order to obtain the product features the part has to run through different production process steps. At the start of the manufacturing process the part has no product variant specific features. During its production process the part gradually evolves towards a specific product variant by selecting the currently preferable alternative among the available different operations. What a preferable decision alternative is depends on the current demand situation represented by the orders in the order pool. Among other information such as due date the order contains the detailed specification of the requested product. In order to determine the elements of the product variant corridor for a part the subset {O*} of all {O} orders has to be identified. This subset {O*} of the set of all unsatisfied orders {O} fulfils the condition that all feature specifications of the part do either match the specification of the part or are zero, i.e. not specified yet. Due to the fact that the parts eventually progress to a specific product variant the subset {O*} decreases over the course of time. Only if additional customer orders enter the customer order pool the subset {O*} increases again. Figure 2 illustrates exemplary the development of the subset {O*} during the production process.

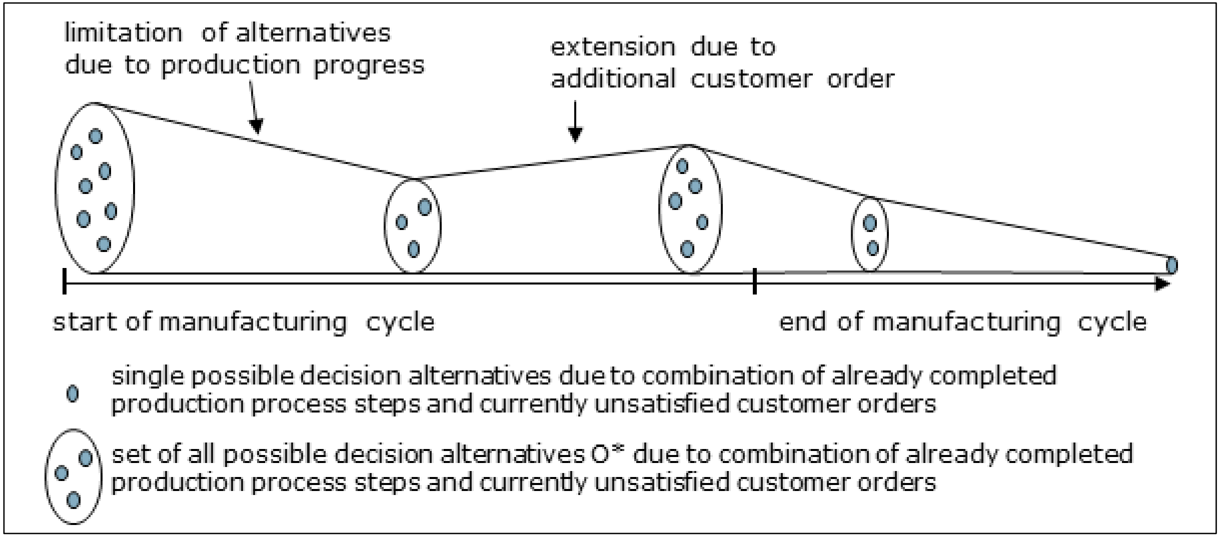


Figure 2: Product Variant Corridor (Windt, Jeken, 2009)

In order to determine which of the decision alternatives within the subset O* to choose the alternatives have to be evaluated according to suitable criteria. Simulation studies show that autonomous control methods perform quite good compared to classical scheduling heuristics depending on the dynamic and complexity of the production conditions (Scholz-Reiter et al. 2010). The so called *Queue Length Estimator* method for example allows parts after each production step choose the machine with the lowest workload to perform the next operation step. This method delivers shorter throughput times than classical scheduling heuristics for dynamic and complex production environments.

Apart from the routing related decision rules different dispatching rules can be applied at each individual work station. A huge variety of different dispatching rules has been researched over the past decades, of which some are capable to produce optimal schedules in specific production environments or are at least competitive heuristics (Pinedo 2008). A very well known rule is the *Earliest Due Date* rule, which sorts the parts at a machine in descending order of the due dates. This rule obviously aims at minimizing the lateness i.e. it increases the logistics target due date reliability. As the APCC allows for a loose and situational allocation of parts to customer orders the parts do not need to get sorted in the work station buffers, but they choose the order they aim for according to its due date. After these logistics related criteria have been applied to evaluate the available decision options it can be the case that more than one customer order fulfils them. Then it is necessary to refine the subset of feasible options by the application of further criteria, these can be other logistics related criteria depending on the overall company target system. The CVM approach offers a way to select the most beneficial customer orders for the company.

The pseudo code below shows first the generic **decision logic for the APCC**. Based on an initial set of orders (line 1), the algorithm reads the feature list for all parts (line 2-4). It compares the current production state of the actual part *i* with the current orders in the order pool {O} (line 5-7) and puts them in the candidate list {O*} (line 8), if it can fulfil orders of the order pool. The candidate list {O*} represents the product variant corridor of the specific part at that very moment. In order to choose one of the candidates this list is then sorted according to the applied logistics criteria x (line 9). After that the first entry of the candidate list is copied to the options list (line 10). If there are more than only one option i.e. there are candidates with the same logistics target achievement, all the orders that fulfil the criteria x are put in the options list $\{O^{*x}\}$ (line 11-15). If the options list contains more than one element (line 16), the one with the highest order score based on the CVM approach gets selected and fulfils the order (line 17). That is where the CVM is integrated into the APCC: If more than one part can fulfil a particular order at one point in time, the order comprising the highest customer value is served first. The order scores of all orders thereby get computed for each new order that enters the order pool {O}. Thus, new orders are considered as soon as they enter the system. The algorithm to determine the order score for each individual order is shown in Figure 4. If the very unlikely case of identical order scores occurs based on the CVM (line 18) the order with the earliest release date i.e. the one which is the longest in the production system is picked.

```
1: initial situation: setup order ranking {O}
2: for (i=1; i≤#parts; i++)
3:    for (n=1; n≤#features part$_i$; n++)
4:          get feature_list[n]
5:    for (j=1; j≤#orders; j++)
6:          for (k=1; k≤#orders; j++)
7:                if ($f_{i,n}$=$f_{i,k}$)
8:                      put in candidate_list                    % {O*}
9:    sort candidate_list (ascending to x)
10:   put candidate_list[1] in options_list
11:   for (l=1; l≤#elements candidate_list; l++)
12:         if (candidates_list[l]=candidates_list[l-1]
13:               put candidates_list[l] in options_list
14:         else
15:               break                                          % {O*$^x$}
16:   if (#elements options_list>1)
17:         select max order score of options_list
18:               if #elements max order score of options_list>1
19:                     select longest in system
```

Figure 3: Pseudo Code for Autonomous Production Construction Cycle Decision Logic

The **design logic for the CVM** to determine the CVM scores of the orders follows the approach described in section 2. First all customer benefits and customer costs (cb/cc) are updated if any changes occurred (line 1). If there are more than one cb/cc criteria (line 2), a pairwise comparison is conducted in order to weight the different criteria (line 3-16). Each cb/cc criteria is compared with all others in a matrix. The diagonal of the matrix contains no weighting (line 6). If the criterion i is more important than the criterion j the weighting is set to 2 (line 9). If the criteria are of the identical importance the weighting is set to 1 (line 11). If the criterion i is less important than the criterion j the weighting is set to 0 (line 13). In order to compute the weighting factor for each cb/cc criteria the single values are summed up (line 14-16).

In order to normalize the CVB order scores the algorithm searches for the maximum value of all weighting factors (line 17-21) and divides every order score by the maximum value (line 22-23). To compute the final CVM order score for each order the algorithm multiplies the normalized weighting factor with the row sum of the order score (line 24-26) and puts the final value in the customer value list (line 27). Finally the customer value list gets sorted (line28) and is then released to the APCC for further production.

```
1: update cb/cc list (if applicable)
2: if (count (cb/cc) > 1
```

```
   for (i=1; i≤#cb/cc;i++)
      for (j=1; j≤#cb/cc;j++)
         if (i=j)
            cell_value[i,j]='x'
         else
            if ($cb/cc_i$>$cb/cc_j$)
               cell_value[i,j]=2
            else if ($cb/cc_i$=$cb/cc_j$)
               cell_value[i,j]=1
            else
               cell_value[i,j]=0
   for (i=1; i≤#cb/cc;i++)
      for (j=2; j≤#cb/cc;j++)
         $weight_{i,j-1}$ += $weight_{i,j}$
for (k=1; k≤#cb/cc; k++)
   Max=O
   for (l=1; l≤#cb/cc; l++)
      if ($O_{l,k}$>Max)
         Max=$O_{l,k}$
   for (m=1; m≤#O; m++)
      y=$O_{m,k}$/Max
for (n=1; n≤#0; n++)
   for (o=1; 0≤#cb/cc; o++)
      $O_{sum,n}$+=$row\_sum_o$*y
      put $O_{sum,n}$ to CV_List
sort CV_list (descending)
```

Figure 4: Pseudo Code for Customer Value Management-Ranking

CONTRIBUTIONS AND LIMITATIONS OF THE INTRODUCED ALGORITHM

The following table gives a brief overview about some selected contributions and limitations of the introduced algorithm from the last section:

Selected Contributions	Selected Limitations
+ The algorithm offers a detailed manual for an integrated application of the APCC and the CVM to a simulation.	- Finding a good initial situation (i.e. number if parts & orders in the system) for starting a simulation is difficult and not verified.
+ It is generic and applicable to different production logistics scenarios.	- The algorithm does not consider sequence constraints between single treatment steps.
+ It is flexible regarding logistics goals and costumer benefits/customer costs.	- It assumes a fix number of treatment steps for every part.

Table 1: Contributions and limitations of the introduced algorithm

The algorithm introduced before offers some new potential for logistics scenarios by integrating the APCC and the CVM and thereby integrating logistics as well as value-based goals. Thus, logistics target achievement can be ensured and overall logistics system's performance can be improved by focusing also on financial aspects. To begin with, the algorithm provides a **detailed manual** for a practical implementation, since all implementation steps are given as pseudo code allowing a programmer to realise it as real programming code. Thus the algorithm can be transferred to e.g., a computational simulation for further analysis and investigations. Therewith, verification tools like logical tests for simulations can be applied to intensively test and verify the algorithm. Additionally, the algorithm is **generic** and therewith applicable to various logistics scenarios. This is achieved through omitting scenario-specific characteristics like machinery capabilities or capacities and concentrating on parts and orders. Hence, the approach can be tested in plenty environments and thereby be compared under changing circumstances regarding its performance. This enhances the validity of the algorithm and might reveal some further potential for improvements. Finally, the algorithm is **flexible** regarding logistics goals and considered customer benefits as well as customer costs. The reason is that first the logistics goals can be exchanged in a way that a system initially focusing on e.g., high due date reliability can switch to minimum processing time as a goal. Second, the list of the examined customer benefits and customer costs can be expanded or reduced during production due to changing characteristics of orders. It might turn out that some formerly considered benefits or costs are irrelevant they and can be excluded in the next ranking, as every time the ranking is rebuilt it is updated for all orders according to the current benefits and costs. In conclusion, this flexible adaptability to new requirements allows the algorithm to react appropriately to changes in the objectives of a system.

Beside the described contributions the algorithm also exhibits some limitations. First, finding a good **initial situation** for a simulation of the algorithm might be difficult, since there is no experience at the moment about good initial conditions for a particular environment. Furthermore, a good initial setup of one specific scenario could be suboptimal for the next scenario, since various parameters might change between them (e.g., number of orders and parts). Thus, before starting a simulation a good way to find out appropriate starting parameters for the algorithm has to be identified via e.g., intensive parameter testing. Moreover, the algorithm **neglects sequence constraints** between single treatment steps, as this is omitted in the pseudo code. This limits the method for a practical application, as these constraints (e.g., cleaning a part before painting) usually exist in real scenarios. Accordingly, by that the algorithm is unrealistic to a certain extend and this could be improved by simply adding this feature in a next release. Finally, the algorithm **assumes a fix number of treatment steps** for every part, since this is fixed in the code. This might also be unrealistic, since parts in reality could feature a different number of treatment steps (e.g., a reflector containing a regular light and a fog lamp has more treatments steps to go through than a reflector without a fog lamp). This could also be added as a feature of the algorithm in the future to make it more realistic.

Further contributions and limitations might be revealed during implementation: For example, potential bottle necks in a job shop scenario could be identified throughout applying this method. On the contrary, since the method applies the concept of autonomous control, it might encounter the threat that it runs into local optima like autonomously controlled systems might do (Hülsmann et al. 2010).

CONCLUSIONS

This paper **intends to develop an algorithm** based on the approach of Hülsmann et al. (2010) in order to enable logistics companies to integrate the value-based management to real world logistics scenarios. The **main contribution** towards the described concept is that it offers a clear and in-depth description of how to integrate the APCC and the CVM, which is a precondition for a practical application. Thus, the designed approach of Hülsmann et al. (2010) can be tested under realistic circumstances: Logisticians can utilise the idea of integrating the APCC and the CVM for a simulation. Thereby, they can answer the question, whether an integration of both goal settings in their particular scenario is beneficial: It is also possible to test various parameterisations of their goals and to examine the effect of changes in weightings and goals settings. However, the concept has **remaining limitations**, which has to be considered. The algorithm excludes some facts from reality like sequence constraints or a changing number of treatment steps for parts during production. Additionally, the behaviour of the algorithm regarding parameterization and changing scenarios is unknown. Hence, a testing in different setups and under various conditions might help to estimate the overall quality of the algorithm.

Therefore, **further research** should focus on the revealed limitations and add the feature of varying treatment steps per part as well as the fact of sequence constraints to the algorithm. A simulation of a particular logistics scenario should also be performed in order to further examine the method in a realistic scenario. Finally, a procedure to automatically identify and weight qualitative variables of customer benefits and customer costs might further increase the quality of the algorithm.

Following **practical implications** of the developed algorithm can be named: Through the loose allocation of parts to orders and the possibility to change assignments during production the whole system becomes much more flexible. This allows reacting faster to changes and thus the logistics system's and processes' robustness is likely to be increased. If too many reallocations can also have a negative impact on the overall performance is still an open question, which needs further research attention. Additionally, through the realisation of the concept of autonomous cooperation to logistics scenarios by applying the given algorithm logisticians are enabled to cope with highly dynamic and complex systems in situations where common heuristics come close to their limits.

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