Decision method for optimal selection of warehouse material handling strategies by production companies

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Abstract: Adequate establishment and operation of warehouse logistics determines the companies’ competitiveness significantly because it effects greatly the quality and the selling price of the goods that the production companies produce. In order to implement and manage an adequate warehouse system, adequate warehouse position, stock management model, warehouse technology, motivated work force committed to process improvement and material handling strategy are necessary. In practical life, companies have paid small attention to select the warehouse strategy properly. Although it has a major influence on the production in the case of material warehouse and on smooth customer service in the case of finished goods warehouse because this can happen with a huge loss in material handling. Due to the dynamically changing production structure, frequent reorganization of warehouse activities is needed, on what the majority of the companies react basically with no reactions. This work presents a simulation test system frames for eligible warehouse material handling strategy selection and also the decision method for selection.

1. Introduction
Due to the extending customer orientation and the fourth industrial revolution promptness, flexibility and increased self-tailoring have initiated a launch in product diversity. This process gives intense challenges for production and supply chain management operating in mass production [1]. Increase in number of product variety required by customers, decrease of product lifecycles, seasonally changing customer requirements have lead to an increase in material stock level and/or to an increasing uncertainty in production planning. The costumers would like to receive the ordered products as soon as possible. For that reason decrease in production lead time means serious market advantage for the companies [2]. Production lead time can be interpreted as a sum of the following components:

- lead time of material purchasing,
- lead time of material stock-in into the warehouse,
- lead time of material stock-out of the warehouse, commissioning of materials and delivery to the technological containers,
- lead time of the technological operations of products and lead time of storage between two operations,
- lead time of packaging, composing unit loads and shipment to the customers.

Decrease of production lead time come to material storage-in, -out and relocation is important by the materials with increased product spectrum, means short life cycle and small amount of order. This can
be ensured by adequate selection of material handling strategies and optimized conducting of material handling tasks [2, 7-8]. Presently applied storage-in, storage-out and relocation strategies and their optimal selection concept will be presented in the thesis.

2. Presently applied warehouse storage material handling strategies
This part contains a certain overview in professional literature and material handling strategies presently applied in practice and the possible relations can be defined between them (Figure 1).

![Types of stock-in strategies](image)

- Random stock-in: materials to be stocked-in are placed to the free store places on a random way [3].
- Stock-in to the closest free store place: Placement of materials happens to the closest free store place [3].
- Stock-in with fix places: Materials to be stocked in are placed to a fixed store places according to product types. In case of constantly changing environment, this model can be applied only with heavy losses [4].
- Stock-in based on classes: Based on a chosen aspect, the stored materials are entitled to groups, ABC categories and the possible store zones are determined for them according to their groups. Forming of groups can happen based on: popularity, turn-over, volume, Pick Density, Cube per Order Index [5].
- Optimal stock-in: The goal of optimal stock-in is to have a mixture of stock-in strategies. It means a costumized application of different stock-in strategies within certain zones of the warehouse. This allows to stock-in the surplus arose within a day.
Introduction of stock-out strategies:
- FIFO (First In First Out): The firstly stocked-in product will be stocked-out firstly according to product type.
- LIFO (Last In First Out): The latest stocked-in product will be firstly stocked out according to product type.
- FEFO (First Expired First Out): Product with the shortest expiry will be stocked-out firstly according to product type.
- LOFO (Low First Out): the product purchased on the lowest price will be stocked-out firstly according to product type.
- HIFO (High First Out): the product purchased on the highest price will be stocked-out firstly according to product type.
- Optimal stock-out: The goal of the optimal stock-out is to have a mixture of stock-out strategies. It means a costumized application of different stock-out strategies within certain zones of the warehouse. This allows to stock-out the surplus arose within a day.

Introduction of relocation stock strategies:
- Without relocation: materials are not moved from one place to another place while they are in the warehouse waiting.
- With relocation: In a dynamic stock environment, it is possible to move materials among warehouse places while they are in the warehouse waiting. The goal of the relocation is to have the materials closer to the storage-out point, which results to a decrease in the distance of material moving routes. (ensures opportunity to take away material moving tasks from the peak times) [6-7]. Relocation can be applied in case of all stock-in strategies except by the stock-in with fix places. The advantage; simple systematization on fixed shelf system would be eliminated with relocation in case of the stock-in with fix places strategy.

The thesis examines the cases, where the material handling within the warehouse happens in a form of whole unit loads (there is no commissioning).

3. Selection concept of optimal warehouse material handling strategy
For a production company, the planning of mid-term and long-term strategy with an eye to the future is a crucial process besides the daily operational management. The base for determining strategy is an environment with such conditions, that is able to provide comparable proposals, referred to same basis and dimensions, depending on the changing parameters. These data are used for the return, time planning of possible investments determined by mid-term and lon-term strategy. In a production company, row material management, stock strangulation are essential parts of strategy forming, for founding which is needed the selection concept for optimal material handling strategy introduced in this chapter. Selection of optimal warehouse material handling strategy version is planned to achieve by using a simulation model, which „simulates” the opration of material flow-system according to the different strategy versions by using up data of specific time-period in the past, than it selects the version with the best objective function value based on the logistics indicator values gained per strategy versions. The process steps are shown in figure 2. The introduced conception outlines the frames of a research work topic.

Selection concept of adequate material handling strategy consists of the following steps:
1.) Recording the examination data: Hereinafter, data basis and their content needed for the examination is introduced.
   - Store system data base:
     - storing system size data (overall dimension, size of storing boxes, size of delivering corridors, etc.),
     - occupied store places, empty store places,
     - type of materials on store places,
distance between warehouse store places and out- and in-stock points.

- Material handling system data base:
  - number of material handling machines,
  - position of material handling machines at the start of simulation,
  - fuel level of material handling machines at the start of simulation,
  - acceleration, working speed of material handling machines,
  - fuel usage, filling of material handling machines,
  - maintenance of material handling machines,
  - delivering capacity of material handling equipment,
  - time for picking up and handing down materials in case of material handling machines,
  - material handling routes,
  - delimation of applied roads of material handling equipment.

- Product data base:
  - store position of starting stock per product types,
  - placing possibilities of product types,
  - assembly matrix of parts,
  - overall dimension, filling amount of a unit load per product types,

- Data base for material handling tasks:
  - formation time and execution time-frame of stock-in tasks per product types,
  - formation time and execution time-frame of stock-out tasks per product types,

- Data base for evaluation:
  - weigh of objective function components,
  - specific cost functions based on data gained from the past.

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**Figure 2.** Selection concept of optimal material handling

2.) **Start up of simulation program:** After the record of data of sheets, the simulation program is started, which ensures the possibility to evaluate all together 60 kind of warehouse material handling strategy versions (5 stock-in, 2 relocation stock and 6 stock-out strategy, that means 60 versions in total) based on given data gained from the past and also to select the best version. Basic requirements towards the simulation program based on the data gained from the past are automatic creation of examined system, run of all material handling strategy versions and also selection of adequate version.

3.) **Automatic creation of examination model:** Based on the examination data, the examined logistics system will be established automatically (material handling system, store system, start-up stocks).

4.) **Initiating of variable values:** In the simulation examination model, initialization of two basic variables are done, namely the v, which contains the examined material handling strategy versions and
the Opt, which contains the optimal version identifier. Certainly, there are other technical kind of variables applied in programming, that are needed to be initialized, but now they are out of consideration.

5) Determining of logistics indicators in case of v-th version:
- Warehouse material handling cost [EURO]: The warehouse material handling cost is defined as a product (multiplication) of specific cost function determined by the data gained from the past time-period and all the material handling rout distance determined by the simulation program. The specific cost function will be defined by linear regression calculation by applying the least-square method. Dependent variables of the function are daily-executed route distance in average and its standard deviation. The dependent variable values are defined also by the simulation program (essentially, the specific cost is gained from substitution of dependent variable values into the specific cost function).
- Total stock-out delay time [sec]: Total deviation from stock-out deadlines within the examined time-period.
- Stock-in performance [ER/Hour]: Maximum amount of stocked in products by hours within the examined time-period in the past.
- Stock-out performance [ER/Hour]: Maximum amount of stocked out products by hours within the examined time-period in the past.
- Subjective factor: total impression on the material handling strategy version (e.g. low chances for mistakes, stable, easy to apply, etc.). The value of the factor needs to be determined between 1 and 10 (10 is the best value).

6.) Data record of determined logistics factors: The logistics factor values defined according to each material handling strategy version will be recorded in a predefined data sheet. Based on these data, the normalization of objective function components (Step 9.) and also the establishment of objective function can happen at a later point of time.

7.) Examination whether each of the possible version has been examined?: In case, it happened, than selection process of the optimal version takes place. In case, it did not happen, the next version will be chosen for examination.

8.) Incrementation of identifier for material handling strategy version.

9.) Normalization of objective function components: definition of objective function value of v-th strategy version of z, that happens based on the logistics indicator values determined by the simulation model. In order to ensure that indicators with different dimensions could be applied as objective function components, they need to be normalized. After normalization, all the values will range between 1-10 in our case. Besides that we will aim to select a material handling strategy version, where the goal is to minimize. Steps for normalization:
- Normalization of objective function components to be minimized (warehouse material handling cost, total stock-out delay time):
  - determination of mean value of logistics features to be minimized,
  - splitting parts between the minimum value and the mean value, and also between the maximum value and the mean value for 5-5 intervals,
  - scoring the values of examined versions by help of gained scale (1-10 scores).
  - the smaller the examined component value is, the better the objective function value is.
- Normalization of objective function components to be maximized (in- and out-stock performance, subjective factor):
  - consideration of mean value of logistics features to be maximized,
  - splitting parts between the minimum value and the mean value, and also between the maximum value and the mean value for 5-5 intervals,
  - scoring the values of examined versions by help of gained scale (1-10 scores),
  - for the aim of standard handling, execution of objective functions’ transformation to be maximized
- egységes kezelhetőség érdekében a maximalizálandó célfüggvények transzformációját el kell végezni (subtract from 11, the objective function to be maximized will be formed to a component),
- after the transformatiation it can be achieved that the goal will become to reach the smallest value possible also by the objective function components to be maximized.

10.) Record of normalized data: The normalized versions of logistics indicator values determined by different material handling strategy versions will be recorded in a predefined data sheet.

11.) Determining the identifier of optimal version: The only parameter of the objective function determined in the (1) relation is the identifier of the material handling strategy version. Actually, the objective function selects the best version \( \text{Opt} \) based on the weighted sums of normalized objective function components determined in accordance to the material handling strategy versions, and defines its objective function value \( C \).

\[
C = \min \left\{ \sum_{i=1}^{5} w_i \cdot Y_{i\nu} \right\}, \quad 0 \leq w_i \leq 1 \quad \text{and} \quad \sum_{i=1}^{5} w_i = 1, \tag{1}
\]

where:
- \( C \): objective function value belonging to optimal material handling strategy version,
- \( \nu \): identifier of examined material handling strategy version,
- \( l \): identifier of objective function component,
- \( W_l \): weight of objective \( l \) function component,
- \( Y_{l\nu} \): value of objective \( l \) function component value of version \( \nu \).

4. Summary

Selection and operation of adequate row material warehouse material handling strategy have a major influence on the companies’ competitiveness by executing internal warehouse material handling tasks more effectively and increasing efficiency in production service. The currently applied in-, out- and relocation stocking material handling strategies are reviewed in this work. In professional literature, sophisticated examination system cannot be found based on which adequate material handling strategies could be chosen. Due to the dynamically changing customers’ needs, review of warehouse material handling strategies applied in the present is needed in order to increase effectiveness. In the publication, an examination system conception for selecting the adequate material handling strategies is introduced. This will be worked out in details in our future research work.

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