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RANKING OF SERVING POLICIES WITH SIMULATIONS OF INDIRECT ACCESS WAREHOUSE

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Abstract: *The efficiency of warehouse processes is influenced by the design, layout and operation of the warehouse. We have developed a simulation process to valuate how the initial arrangement of products affects logistics activities in an inhomogeneous storage environment with no direct access. Continuing our research, we compared the operational logics commonly used in warehouses with indirect storage access through that simulation. The results were classified using a complex evaluation method, and then the ranking of the service logics was established. We believe that our research results can be useful for all those who want to achieve a more efficient use of warehouse space while respecting service time limits.*

Keywords: *warehouse service policies, indirect access storage system, simulation, drive-in rack handling*

1. INTRODUCTION

In recent years, risks in supply chains have brought to the fore again the importance of warehousing, the efficiency of warehouse service and, more generally, the importance of increasing the efficiency of inventory management in production-distribution processes.

We believe that storage systems that do not provide direct access can also be operated with high dynamics, since transport distances are also reduced due to a more closed layout, the only question is how material handling can be minimized.

There are two ways to influence the material handling performance, that is, how long it takes to load and unload the given material. The first option is to define the layout of the warehouse, that is, you can specify the layout from which the process should start. Alternatively, we provide recommendations on the placement of incoming materials and from where the picking demand should be served, that is how the material flow process should work.

In this paper we introduce a simulation process for modelling how the warehouse works and compare some material handling policies.

2. HYPOTHESIS

The literature aimed at optimizing warehouse operation primarily concerns warehouse design and order picking route planning [1]. There is little literature on exploiting the potential of indirect access storage [2], [3]. This paper aims to demonstrate what results can be achieved in a direct access drive-in racking system by consistently applying simple logics.

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Seven logics were defined and it was supposed that more complex logics would perform better in simulations than simpler greedy procedures. In the simulation environment set up to investigate this question, the physical environment was described in detail: material handling devices have acceleration, move at different speeds when loaded than when empty, etc. At the same time, we assumed that the material handler has the necessary information and can judge how long it takes to place material in a given location, and see for each material how long it takes to unload it. Using this data, it makes the decision that best fits the operational logic in each situation.

During the simulation, either a decision must be made on the placement of a material or its removal must be carried out. During removal, the material needed must always be chosen that can complete the task as quickly as possible. The decision made during storage is described in seven compared logics:

1. The aim of the first logic is to minimize the time spent during the material placement, so this greedy method is going to have short time local optimum and the materials set around the entrance.
2. The second logic is going make easy the outputting of the given material and opposed to the previous one, it set materials around the exit and put the timesaving into an unknown future.
3. According to the third logic, the aim is not to minimize the input and output procedure, but the whole process. Choice is made by the sum of expected input and output time in aspect of the available places.
4. The fourth logic is modelling a behaviour seen in practice. The placement is chosen from available places, where the given material is appearing most time, where the most of the same material is placed behind it. (When the options are equally good, then the previous logic has to be accomplished.) With this decision other materials could be disturbed at least and on other hand it can help workers to search for materials in incomplete booking system – but it cannot be seen in simulations.
5. The fifth logic maximize the availability of the materials in local aspect. A material counts most available if it has the least output time. The placement is chosen if the materials behind it would win the most with it, or loose the least.
6. The sixth logic continues the previous logic and extend the material availability not just behind the chosen placement, but in whole warehouse, so it tries to put for from every existing material.
7. In the seventh logic the availability is weighted by the commercial speed of material in sixth logic. According to the ABC analysis is the fastest A material on the most prominent place and the slowly rotating C materials a left a bit back on less advancing place.

To evaluate the simulation, we compare the weighted average execution time of the tasks with the following formula:

$$v = \frac{\sqrt{\frac{\sum_{i=1}^{n}\left(\sum_{j=1}^{m} t_{ij}\right)^{2}}{n}}}{m} \tag{1}$$

where

v – is the value of simulation, the weighted average execution time [seconds],

t_{ij} – is the time required to complete *j* task from *i* task-list [seconds],
n – is the number of task-lists,
m – is the number of tasks in each task-list.

Each simulation executes 100 task-lists starting from an empty warehouse. The task-list only includes tasks that can be performed, i.e. it does not request the release of material that is not in the warehouse and does not specify a loading task if there is no free storage space. Tasks are stochastic, that is, the probability of possible events occurring is predetermined, but chance affects the development of a particular state. The turnover and average stock level of materials are aligned with those of the sampled original warehouse.

3. RESULTS

Because the initial layout has a significant impact on the outcome of each logic, it's a good idea to start with an empty warehouse and see how each logic performs. To make the conclusion statistically sound, thirty simulations were made with all seven logics and the results were recorded for each task to show how the simulation result changed over time (i.e. the number of tasks). The average and twice the deviation of the simulation's results are shown in the figure below (Fig. 1).

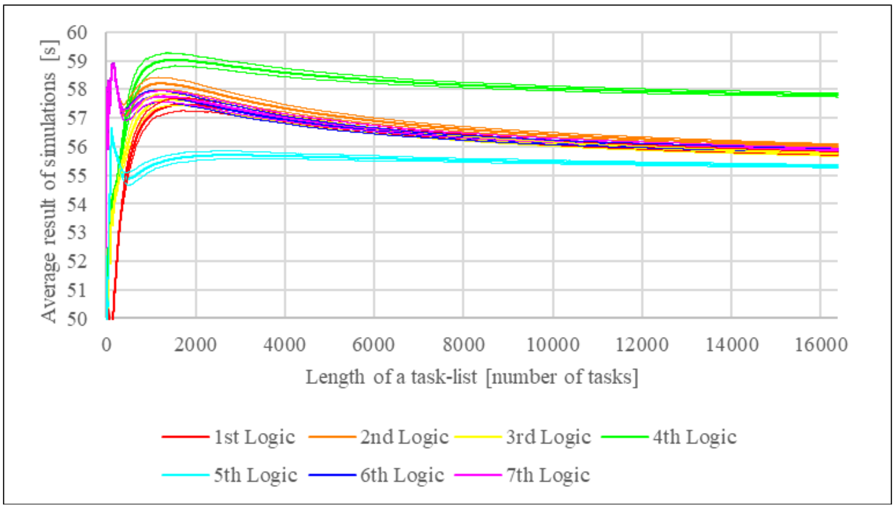

Figure 1. The seven logics' average result and twice increased-decreased deviation value of simulation depending of task lists' length (Source: self-edited)

In terms of the length of the task-lists, the first part always takes place with the filling of the warehouse, followed by an increase in storage times, which is explained by the fact that picking also appears among the tasks, during which it may happen that the required material is not directly accessible and making it available costs a significant time investment. During continuous operation, the layout pattern resulting from logic is formed, along with which the order of logics is created, and henceforth the initial higher values and the established operation result in a hyperbolic graph. Apart from the initial phase, the simulation results show a clear separation between fourth and fifth logic. The high value of the fourth logic corresponds to what we have experienced before, but the outstanding performance of the fifth logic exceeds the idea established on the basis of the experience of the installed warehouse simulations. Its separation from other logics is sharp, but since it does not produce high values even in the initial phase, the decrease in its hyperbola is also smaller compared to other logics.

During the initial stage, the standard deviation of the results is low. The exception is the fourth logic, which initially starts with a high and increasing standard deviation, then this standard deviation decreases as the warehouse becomes saturated. This was an expected event, since as the warehouse becomes full, the materials shown in it should approach the average stock level, but initially there is more freedom to choose materials. (The initial phase is presented in Fig. 2 without deviation.)

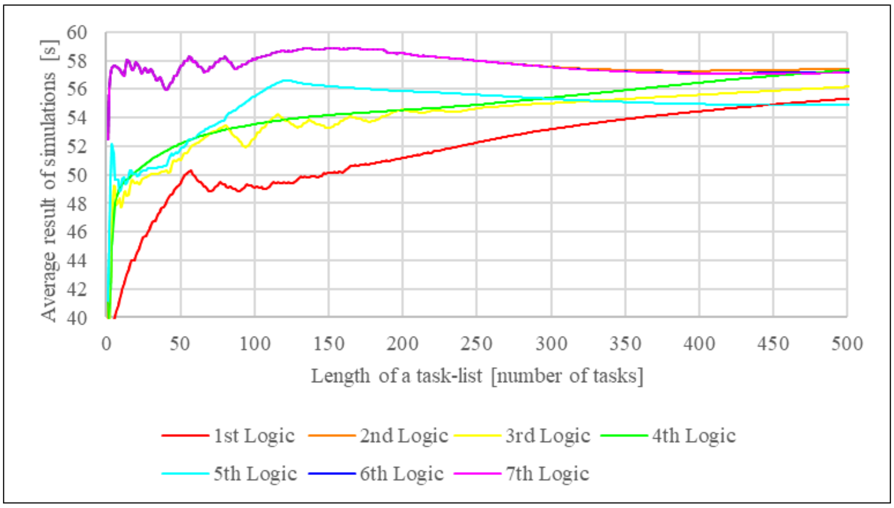

Figure 2. The first phase of simulated process: warehouse-fulfilment (Source: self-edited)

It is interesting to note that the second, the sixth and seventh logic move together so much that the seventh logic practically hides the other two on the graph, only after fulfilment do the differences become visible. Another interesting fact is that, the highest value taken up during the simulation by the fifth logic is reached already in a warehouse that is one-third full. At the end of the initial stage, the rank of logics is not clear yet.

During continuous loading and unloading, the set of installation (where the materials are stored) is established according to logics' behaviour. The length of this process varies by logic. The second, sixth and seventh logics are moving together and reach the highest values simultaneously around 1000 tasks in length. After that the third and the fourth logics comes to their top values in this phase around 1400 task lengths, and then the first logic reaches its own with 1800 task length. The fifty logic arrives lastly to its top in this phase and begins its descent. The second phase is presented in Fig. 3.

In the arrangement phase, the fourth and the fifth logics are clearly separated from the others, and their differences to others are clearly existing during the whole simulation. The second logic's place in the rank list is also made clear, but its distinction is much smaller than in the case of the two logics mentioned earlier.

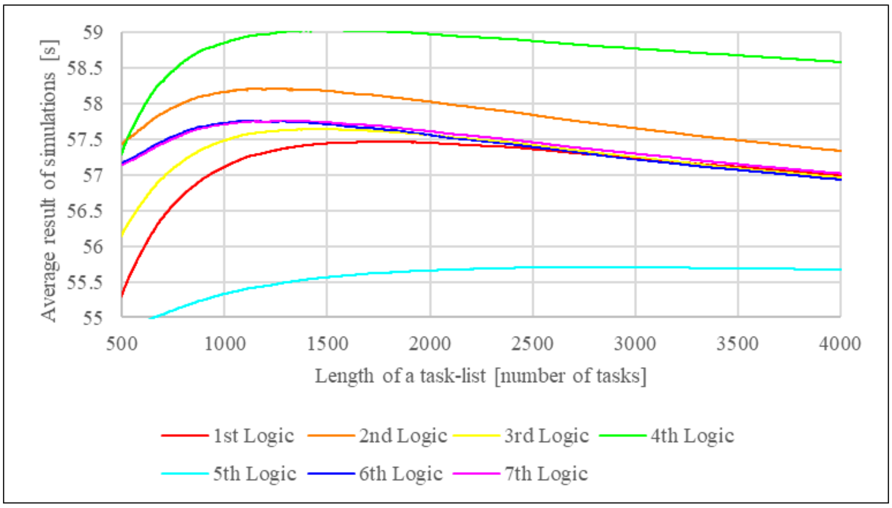

Figure 3. The second phase of simulated process: arrangement (Source: self-edited)

The rank of the logics is changed a bit in the third phase, the first, the third, the sixth and the seventh logics are close to each other in results as it can be seen on Fig. 4. The curves are hyperbolic and decreasing even less and less, the simulations' result is going to be constant. After 11,000 task-list length the rank is established. The best of the logics is the fifth, the worst is the fourth, followed by the second logic, as it has been seen in the previous phase too. At the end of all simulations rank of the rest logics is the following: the best of them is the third logic, then come the first logic, sixth logic and seventh logic.

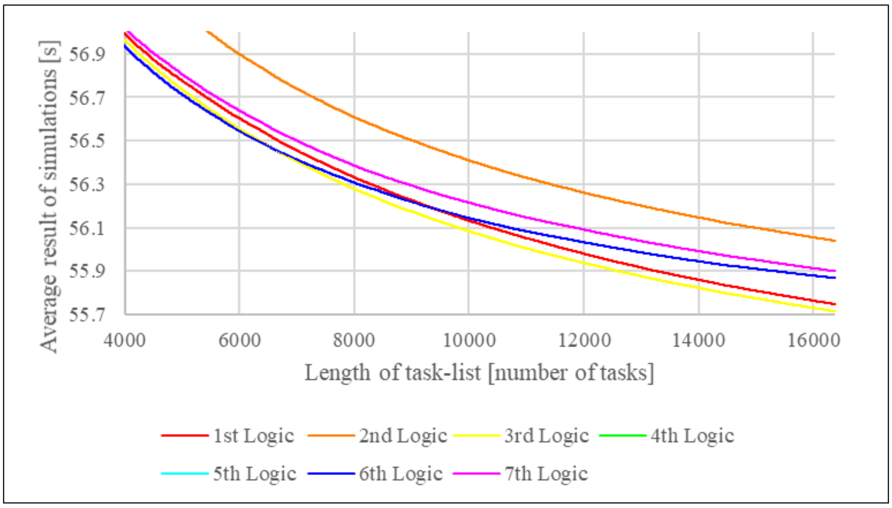

Figure 4. The third phase of simulated process: rank establishment (Source: self-edited)

We compared every logic with each other by Wilcoxon's paired rank tests on 5% significance level. According to those calculations the results are equal between sixth and seventh logics about 900 and 1,400 tasks length. The third and sixth logics are equal from

1,850 to 2,400 and from 5,250 to 7,500. From 2,550 to 3,200 the first and the sixth logics are equal as well as between 8,350 and 10,250. The first logic is also equal to the third logic between 2,800 and 3,800, but the third logic is not equal to sixth between the common section of first logic. The common sections after the first phase are demonstrated in the Fig. 5.

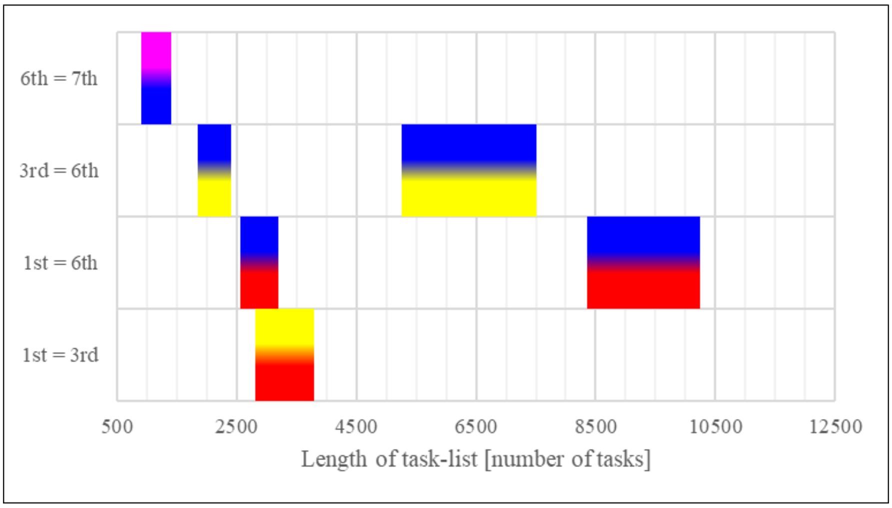

Figure 5. The equalities of logics' result depending on length of task-list (Source: self-edited)

4. CONCLUSION AND PROPOSAL

In this paper seven easy-to-calculate, simple logics were presented and examined. They were tested with simulation of an indirect access warehouse. Some of them were nearly equal effective, one was excellent to others and some were less useful in the simulation. The least effective logic was the most used by manual managed warehouses. The greedy algorithms were the fastest to runs in simulations and their results were also quite good. The best solution was the local optimum searching logic.

The logics have to be used consequently and long-term application is necessary for the logics to prevail. The logics were really simple and there were only small differences in results, only 2-3%. The rank was set up and we made a Wilcoxon paired rank test to show out how near they are to each other.

Interesting research area is to define more complex material management logics and to know what could be achieved if the future is better known, not just one task is what we see for, but for a full shift in work or a whole working day. Another interesting question is how sensible are the logics for the layout design of the warehouse.

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