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FAILURE AND RESTART OF AN AISLE: SOLUTIONS FOR A HIDDEN PROBLEM WITH SIGNIFICANT EFFECT IN HIGH BAY RACKING SYSTEMS FOR WAREHOUSING

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ABSTRACT

Fulfilling essential functions in transport and distribution logistics, industrial warehouses are usually equipped with automatic high bay racking systems, the aisles and especially the automated storage/retrieval systems of which happen to fail temporarily in the course of operation.

The common operating strategy "uniform aisles distribution" prepares warehouse control systems for such cases of failure: the operation of the total system is usually kept up with reservations during the down-time of a single aisle. But when the necessary restoration has been carried out and the control system restarts the aisle – the efficiency of the total storage system doesn't recover to its original level but temporarily decreases even more.

This paper explains the underlying causes of this problematic effect and points out its possible consequences. Furthermore possible solutions are indicated.

REVIEW OF RELEVANT LITERATURE

Based upon a data pool covering the last 39 years about number, variety and commissioning date of high bay rackings with location in Germany, the specifications of the typical system were generated.

Their first implementation in form of an executable model showed proof of the phenomenon [Gei98] [GS01]. Experiments with up-to-date parameters and a new model in Plant Simulation, a software-tool for discrete, event-oriented simulation, reveal the correlation of down-time, range of storage units and efficiency [Wil10] and allow further examinations. The objective is the development of concepts according to common methods of design and modes of operation (e.g.[GK09]), which minimize or even totally avoid negative impacts – such as already outlined in an exemplary way [Sch10].

DESCRIPTION OF THE PROBLEM

The logical structure of warehouse control systems is designed according to the chosen operating strategies of the logistic system. The following two rules could be regarded as part of the standard set of strategies for most high-bay stores.

The "uniform aisles distribution" means, that the stock of one article is equally distributed over the aisles in order to achieve maximum accessibility and availability [GK09].

The "first-in-first-out" strategy determines the out-storing sequence of units: the storage unit, which has been stored in first, must be stored out first [GK09].

The underlying logic of both operating strategies uniform aisles distribution and first-in-first-out appears to be coherent at first sight – what might be the reason, why these strategies happen to be prescribed for storage dimensioning [GK09]. But there are situations when these two strategies interfere with negative consequences for the warehouse system as it is shown below.

Figure 1: "numbered units of one article distributed over three aisles" (cf. [Wil10]) represents schematically a high-bay store with three aisles. The aisles are numbered with 0, 1 and 2. The stock is not entirely pictured. Only the units of one single article are represented in form of small numbered squares. There are four of them stored in each aisle. The numbers of these twelve units stand for the sequence of their in-storing. The first unit, which was stored in is numbered with "1", the second with "2" and so on. Thus it is possible to understand that all units were stored in according to the strategy of uniform aisles distribution – with the result, that each aisle stores the same amount of four units.

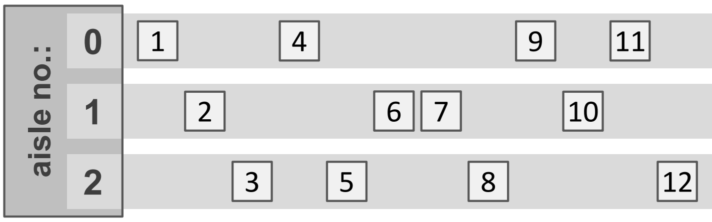

Figure 1: numbered units of one article distributed over three aisles

Assuming that aisle "0" happens to fail in this situation, figure 2: "in- and out-storing of units during downtime of an aisle" (cf. [Wil10]) shows the further development of the stock for the case that the storage devices in use are aisle-fixed. Because of the failure of the one aisle, it is impossible to store any units in or out of it. Nevertheless the operation of the warehouse system is kept up with the result, that out-storing orders are fulfilled with units from the two operating aisles.
Assuming eight units of the regarded article have to be stored out during the downtime of aisle "0", the numbered units 2, 3, 5, 6, 7, 8, 10 and 12 will be removed from stock. In an equivalent way all in-storing orders only can be carried out with the operating aisles, too. This leads to the result that eight incoming units will be stored in aisle "1" and "2" – pictured with the numbers 13 to 20 in squares with dashed lines.

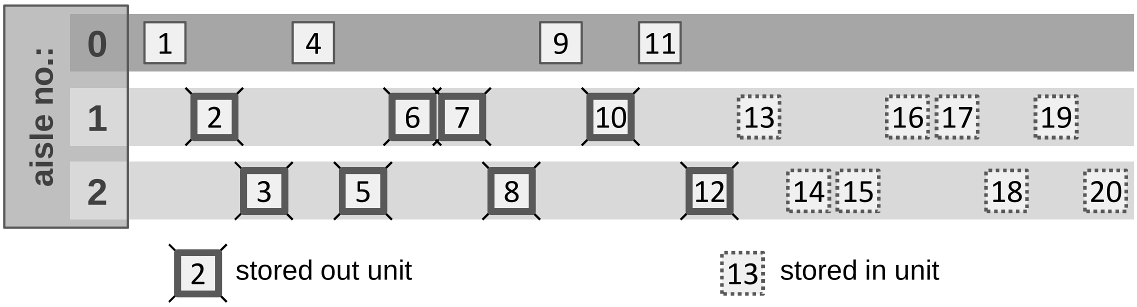

Figure 2: in- and out-storing of units during downtime of an aisle

After eight units are stored out and eight new ones are stored in, the problem which caused the failure of aisle "0" may be resolved. The downtime stops with a restart of the aisle. This situation is pictured in figure 3: "resulting out-storing sequence by failure of an aisle" (cf. [Wil10]).

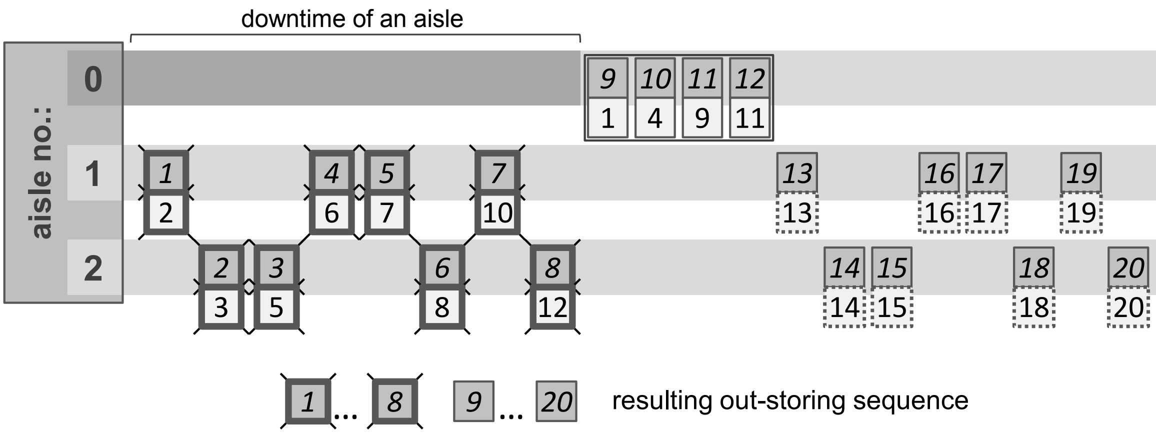

Figure 3: resulting out-storing sequence by failure of an aisle

It shows the same distribution of units as in figure 2 with some additional information: squares filled with dark grey colour are placed at the original positions of unit-symbols. They are numbered from 1 to 20 and show thus the out-storing sequence that would result in this situation, if the principle of first-in-first-out was applied. The numbers 1 to 12 are here given retrospectively to those units which were stored out during the downtime of aisle “0”. The four units of the regarded article with the original numbers 1, 4, 9 and 11 spent the downtime in the failed aisle. They now form the group of the ‘oldest’ units – marked with an additional empty rectangle. According to first-in-first-out the units of this group have to be all stored out consecutively from their store places which are all situated in aisle “0”.

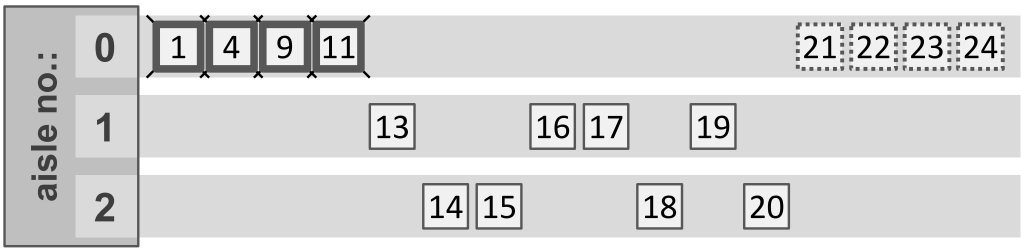

Figure 4: in-storing sequence in consequence of out-storing sequence

Assuming this group of four units are stored out one by one – each followed by one new unit of the regarded article that hast to be stored in the warehouse, the further development of this situation is illustrated in figure 4: “in-storing sequence in consequence of out-storing sequence” (cf. [Wil10]). Each removed unit reduces the stock of the corresponding aisle by one. If the strategy “uniform aisles distribution” is pursued, the reduced stock of one aisle has to be filled up with the next new entries. Figure 4 shows what happens when four new units are stored in after the group of the four ‘oldest’ has left the store: the sequence of storing out units of one aisle leads to a sequence of storing in new units into the very same aisle.

RESEARCH WORK

The considerations above of a limited amount of units of one single article indicate that one possible consequence of the failure of an aisle may result in a form of significantly unbalanced grade of utilisation concerning the automated storage/retrieval systems of the regarded high-bay store.

To develop and enrich the preliminary indications a simulation model was generated on the platform of Plant-Simulation which allowed examining the relevant interference of the two operating strategies in an automatic high-bay store under defined conditions and in dependence on several selected parameters.

The model represents an automatic high-bay store with three aisles. Each aisle consists of two shelf racks with 100 (length) x 20 (height) store places for storage units. All considered shelf racks are single-unit: no storage units are placed behind others – there's direct access to all storage units in the store. The range of articles and the duration of the downtime of one aisle are parameters to be defined before each experiment. The average filling degree is 80%.

The technical data of each storage/retrieval device are composed by its maximum speed and its acceleration in horizontal (index "x") and vertical (index "y") direction ($a_x = a_y = 1{,}0 m/s^2$; $v_x = 5{,}0 m/s$; $v_y = 2{,}5 m/s$), the duration of the handing over of a unit from device to a store place or vice versa ($t_z = 2{,}0s$) and the reaction time of the device control ($t_0 = 0{,}75s$) [GK09].
A part of the in-feed system of each aisle is a buffer place. In- and out-storing orders are continuously generated. Their contents concerning the type of article and the store place are the results of a stochastic algorithm (equally distributed).

The following operating strategies are implemented: free storage order, uniform aisles distribution, first-in-first-out, single- and double-cycle strategy. If there are both an in-storing and an out-storing order in the moment of the arrival of a storage/retrieval device at the single buffer place at the point of input for the corresponding aisle – the storage/retrieval device will carry out a double-cycle. If there's only one type of order at the relevant moment, the storage/retrieval device will carry out a single-cycle.

Further strategies, such as the fast mover concentration, and other conditions like additional buffer places would surely increase the efficiency of the storage system. Changes like these would not support the examination of the relevant effect.

RESULTS/ANALYSIS
Experiments with the described simulation model led to different results, such as the impact of varied downtimes on the maximum efficiency (see Figure 5: variations of downtime (1) (averaged graph) [Wil10]). The diagram shows the results of four different simulation experiments that differ in the duration of the downtime. Each experiment consisted of 30 simulation runs.

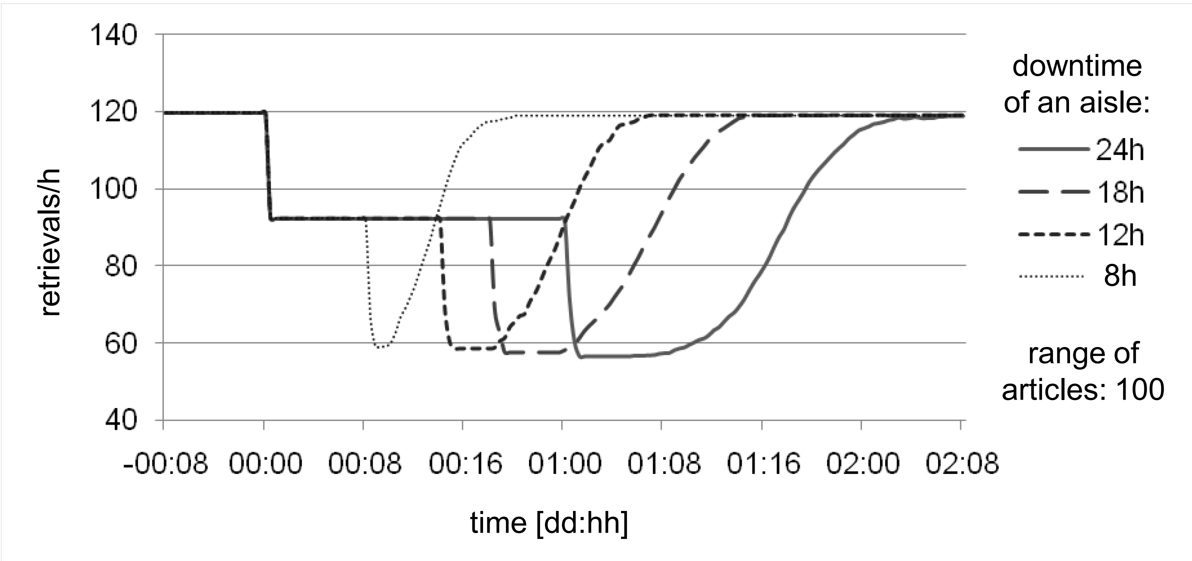

Figure 5: variations of downtime (1) (averaged graph)

Figure 5 clearly shows how the efficiency of the storage system decreases on a level of roundabout 95 retrievals/h when one aisle stops operating at 00:00. With the restart of the failed aisle, efficiency decreases again slightly below 60 retrievals/h. This level represents the maximum throughput that can be carried out by one single storage/retrieval device aisle that had failed before. This device represents a bottleneck of the whole storage system in this situation. The recovery back to the original efficiency level takes a time in dependency of the corresponding downtime.

If the downtime is reduced below 6h the decrease after the restart of the aisle is less and less extensive. The level of maximum throughput that can be carried out by one single aisle is not longer reached – see Figure 6: "variations of downtime (2) (averaged graph)" [Wil10].

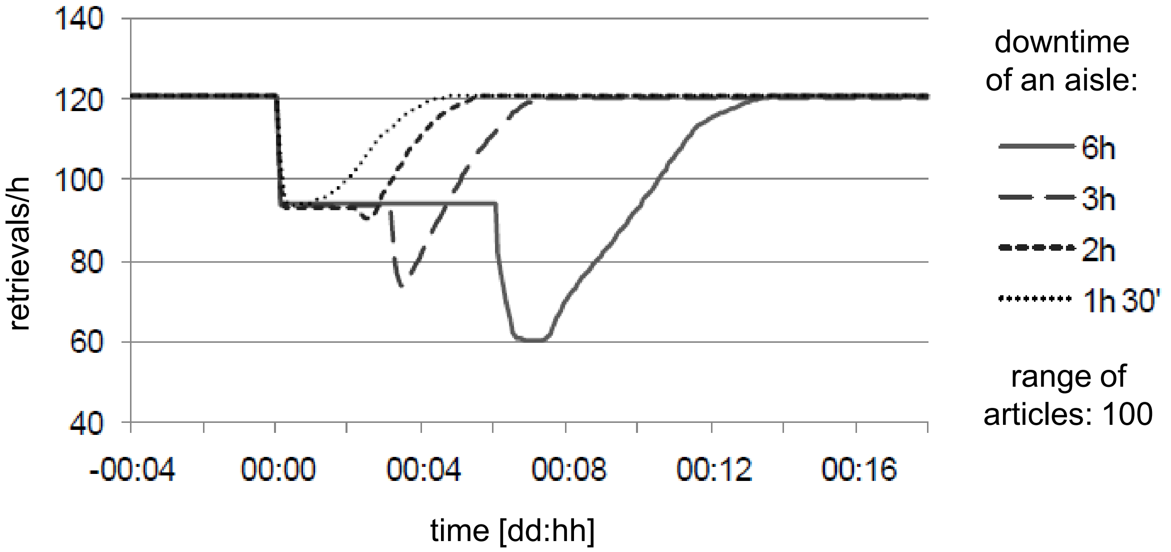

Figure 6: variations of downtime (2) (averaged graph)

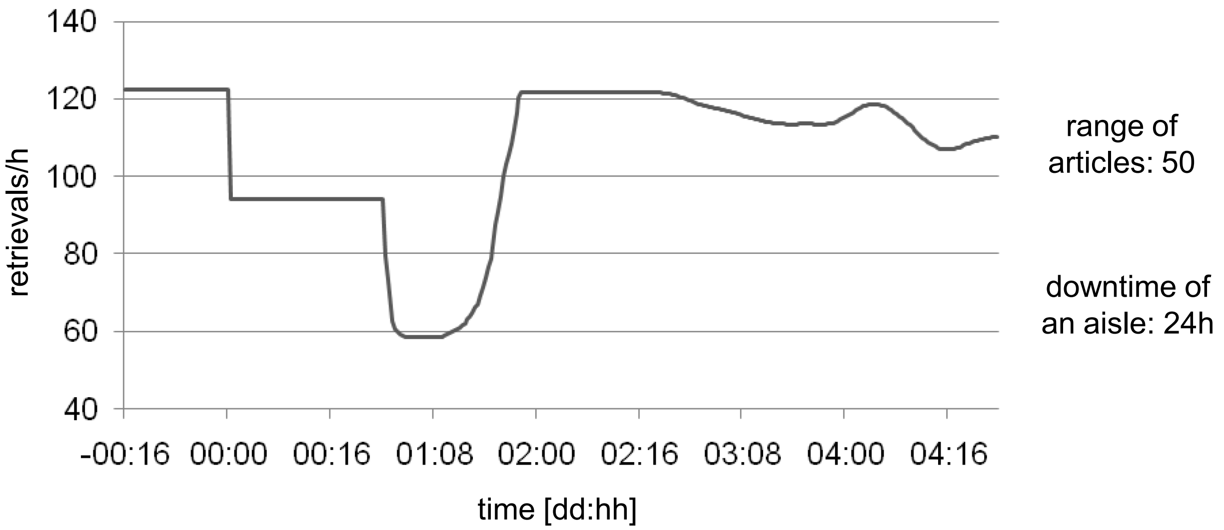

Figure 7: example of later effects (averaged graph)

Figure 7: "example of later effects (averaged graph)" (cf. [Wil10]) shows that those changes in stock distribution which cause the efficiency to decrease after the restart of the aisle may not be undone with the recovery back to the original efficiency level. The diagram of figure 7 shows that it is possible that these circumstances can cause later declines, too.

DISCUSSION

Strategies usually represent means to achieve certain objectives. Questioning the mentioned operating strategies and revealing their corresponding objectives leads to different indications for specific solutions:

The strategy "uniform aisles distribution" can be pursued for two different reasons.
The first reason might be the achievement of maximum accessibility. The term accessibility refers here on one hand to the function of storing out units of one article. In this case accessibility expresses the possibility of removing ordered units of one article from several aisles at the same time, instead of removing them all consecutively from only one aisle. On the other hand accessibility can also refer to the process of how units of one batch are stored in. The necessary time of this process can be reduced by distributing them over several aisles instead of putting them altogether in one single aisle.
These explanations show that the term of maximum accessibility in this context is obviously used as one possibility to increase throughput or efficiency. There are surely other possibilities such as other operating strategies to achieve this objective, too.

The second reason for pursuing the strategy of uniform aisles distribution is expressed by the term of availability. Stored units should be available at any time and under any condition. The failure of an aisle could make it impossible to remove the ordered amount of units of an article from the store if all of these units were stored in right the failed aisle. If all units of an article were distributed over several aisles of the store instead, the failure of one aisle would be of no further consequence as long as the ordered amount of units can be removed from other aisles.
The concept of the interruption reserve [GK09] may appear as a restriction to the idea of maximum availability: the interruption reserve serves as a reserve stock that is preserved for cases of accidentally interrupted supply caused by failure, breakdown or damage. In this context the distribution of more than the defined reserve stock is unnecessary in terms of availability.

The strategy first-in-first-out was originally applied to save those goods with limited durability or expirations dates. It efficiently helps to prevent single units from extensive times of storage. First-In-First-Out was thus implemented more and more for all other kinds of inventory, too [Gra93].
Regarding the inventory risk rate could be taken as an alternative in generating an out-storing sequence. The inventory risk rate takes into account the storekeeping risks, such as shrinkage, ageing, deterioration, obsolescence and loss [GK09]. This rate in connection with the turnover rate of one article should make it possible to define a priority algorithm for out-storing with less of the described negative side effect of first-in-first-out.

CONCLUSIONS

The described phenomenon can be taken as an example for the limitations of the existing concept of availability in technical logistics: the focus on failures without taking into account their further consequences might miss significant effects.
Different strategies in use might interfere with hardly predictable negative consequences within or between other logistic systems, too. The approach of managing the risk of a supply chain in combination with means of simulation should be able to deal also with similar problems in future.

The given explanations should make designers and operators aware of the described problem. Questioning the relevant operating strategies made it possible to indicate possible solutions which should result in the development of efficient modifications for warehouse control systems to avoid the significant declines in efficiency in consequence of failures of single automated storage/retrieval systems. The presented information contributes to the design of efficient warehouses, to the quality of the management of supply risks and to the service level of transport and distribution networks in general.

REFERENCES

[Gei98] Geinitz, Jens: Unerkannte Abhängigkeiten mindern die Leistungsfähigkeit automatisierter Lager. In: Marktbild Lager, Bd.18 (1998), p. 16-18

[Gra93] Grafe, Wolfram; Jünemann: Gestaltung und Betrieb von Lagersystemen mit hohen Umschlagleistungen. In: Jünemann, Reinhardt: Logistik für die Praxis. Dortmund: Praxiswissen (1994)

[GK09] Gudehus, Timm; Kotzab, Herbert: Comprehensive Logistics, Berlin, Heidelberg: Springer (2009)

[GS01] Geinitz, Jens; Scheid, Wolf-Michael: New Demands on automated Logistics Systems to be met by new Strategies. In: Proceedings of the 6th. Pawar, K.S.; Muffatto, M. (eds.): Logistics and the Digital Economy. Proceedings of the 6th International Symposium on Logistics, Salzburg, Austria (8th-10th July, 2001)

[Sch10] Scheid, Wolf-Michael: Havarie bei Anlagen der Intralogistik. In: Jahrbuch Logistik 2010, Bd.24 (2010), p. 30-33

[Wil10] Wildner, Christian: Anlaufstrategien für Hochregallager bei Wiederinbetriebnahme eines ausgefallenen Regalbediengeräts. In: Wissenschaftliche Gesellschaft für Technische Logistik: Tagungsband 6. Fachkolloquium der Wissenschaftlichen Gesellschaft für Technische Logistik (WGTL), Garbsen: PZH Produktionstechnisches Zentrum (2010), p. 163-174