Simulative analysis of the performance in the handling of goods for a small sized highbay warehouse by storage strategies

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1 Introduction

In the industrial production huge warehouses, mostly as a highbay warehouse, are used for the coordination of procurement processes, production processes and distribution processes within an enterprise and also between enterprises along the logistic process chain, see Figure 1 and [1], [2], [4], [5], [6], [7], [8] as well as [9].

Figure 1: View of a highbay warehouse – Klug GmbH integrated systems

Beside this time bridging structure an inventory management becomes more and more important which realises an efficient order related picking, see [2], [3], [5], [6], [7] and [8]. Particularly, with an extremely fully occupied automatic warehouse the performance necessary for the handling of goods is not reached for picking in the warehouse. Often people try to improve the achievement of warehouses by costly storage technical and materials handling technical measures, see [1], [2], [4] and [5].

An important performance criterion is the maximization of the handling of goods in the warehouse, i.e. the warehouse should be able to transfer to stock or to remove from stock as many as possible storage unities within a given time span (e.g., an hour), see [1], [2], [4], [5] and [8].

2 Storage

With automatic warehouses the product is stored in free-mounted racks. Figure 2 shows a model of a rack of the length L, height H and depth T (see. [1], [2], [5], [6], [7] and [8]) and a rack feeder (RF). The RF is used to access the stored product.

With a RF it is accessed the stored product – the product is normally stacked on palettes. A RF is an automated conveyor which simultaneous goes within a lane in a warehouse, heads for a certain rack shelf by the height H about a lifting device and a goes into a rack shelf by the depth T in order to pick or lay a bin about a load suspension device (LSD).

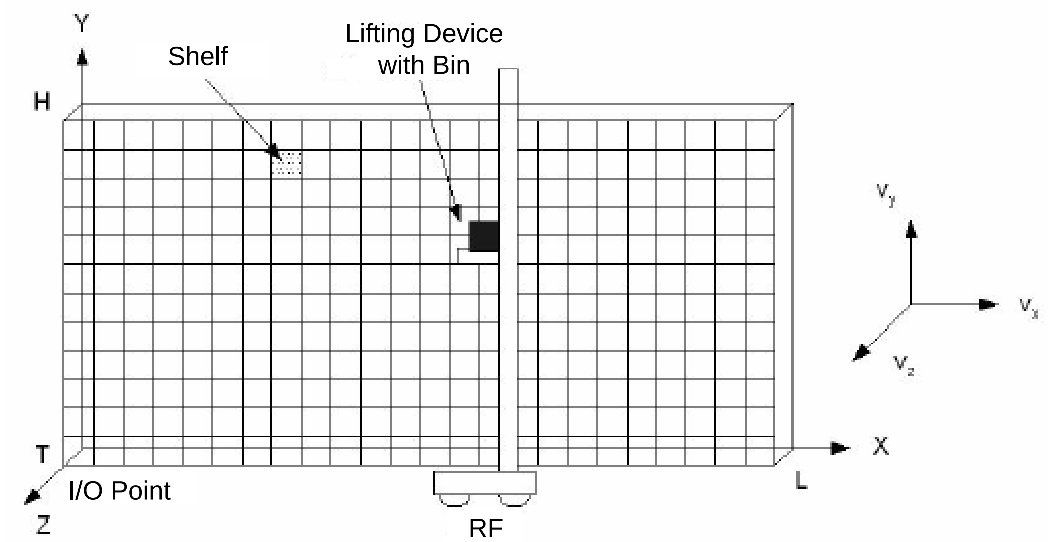

Figure 2: Model of a rack with rack feeder (RF) and entry (I) / exit (O) point (I/O point); speed (v)

A rack feeder, see [1], [2], [4] and [8], can be used with single cycle or double cycle. With a single cycle the rack feeder in the entry (I) / exit (O) point (I/O point) of the rack waits for a transport order. In the case of a transfer to stock a bin is laid in the nearest free rack shelf. Afterwards the rack feeder returns to the transfer point. In the case of remove from stock the needed rack shelf is headed and the bin is provided in the transfer point. With a double cycle, however, the rack feeder after an occurred storage (transfer to stock) can head immediately for another rack shelf from which an retrieval (remove from stock) should be effected. In every warehouse accidental storages and retrievals appear. So in every simulation experiment the number of storages and retrievals are generated by chance with a normal distribution.

3 Key Figures

The Operation of rack feeder has an effect on storage and retrieval times. These times are determined by the trajectory for the carriage and for the lift, because the number of goods, which are transferred to stock or removed from stock, are to be held steady during the analysis period. Such a trajectory is called working cycle, and the required time is called cycle time. The trajectory of the rack feeder consists of these phases: accelerating, driving at steady speed, braking, positioning at the destination. In the destination a load suspension device cycle is carried out to take up or to deliver a bin. Such a cycle consists of extending telescopic fork or table, lifting lift truck, retracting telescopic fork and lowering lift truck – with belt conveyor there is no lifting and lowering.

Working cycles have variable driving times. The real speed is shown in Figure 3, see also [1], [2], [5] and [7]. In most publications, times for accelerating, braking and positioning are not regarded. Instead, the well known Tschebyscheff metric is applied on the constant speed in x and y direction.

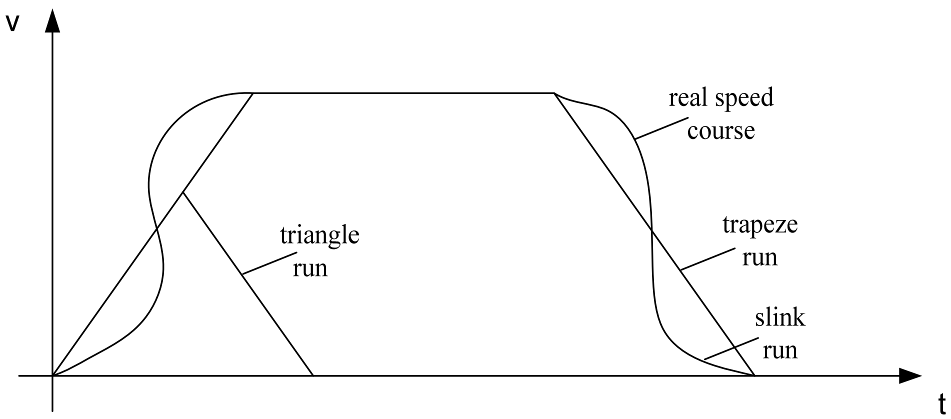

Figure 3: real and simplified speed course (v)

Beside these variable driving times a load suspension device cycle has constant times for positioning, for controlling that the right shelf was reached and for switching as well as control operations are used. These times depend on specific technical data of a rack feeder. Altogether this time is called “dead time“.

In [1] and [7] for each single time a formula is deduced in detail. The simulation system calculates the single times by these formulas and their sum is the (total) cycle time. For the test problem, which is described below, cycle times were measured and compared to the calculated ones. In each case the difference between these times was less than one second. Therefore, the simulation of storages and retrievals of goods in a warehouse by a rack feeder corresponds with reality.

4 Storage strategies

In today's industrial warehouse processes the following storage strategies are applied, see [1], [2], [5], [6] and [7].

1. Accidental (storage): By an accidental storage any free shelf is selected for the bin to be stored. Only restrictions about the size of a shelf and the allowed weight are considered.
2. (Storage after) Zones: The shelves in the warehouse are divided into zones. Each good is stored in exactly one zone. Therefore each product has a so called zone flag. For storing a product with zone flag F a free shelf near to the I/O point with zone flag F is chosen.
3. (Strategy of the) Fastest neighbour: With double cycles a storage shelf A to a retrieval shelf B is selected so that A can be reached from B as fast as possible. With singe cycles the shelf for storage is chosen that can be reached from the storage track as fast as possible.
4. Channel (optimized storage): In a multiple-depth warehouse the bins are stored in a channel from two consecutive shelves. A free channel is searched so that
    - as many as possible bins of the load suspension device fit – different bin types are often excluded for channels – and
    - the beginning of the allocation of a channel is avoided.
5. Combination of different storage strategies: A strategy is the combination of the strategies zones and fastest neighbour. In the case of single cycles the strategy after zones is used. With double cycles the strategy of the fastest neighbour is applied. In addition various combinations of the strategies zones and channel – with various channels – are regarded.

5 Testproblem

The problem is a modification of small sized highbay warehouse at Leopold Fiebig GmbH in Karlsruhe, Germany. It consists of one aisle and two racks. Each rack has 10 fields in x direction (compare with Figure 2) and 32 fields in y direction. In z direction there are two shelves one behind the other. Each shelf can carry a bin. If both shelves are used and only the bin in the second shelf is taken, a stock transfer is necessary. Altogether the warehouse has 1280 shelves. A rack is 4.5 m long, 8.5 m high and 1.30 m deep. The fields are started by a rack feeder which owns a load suspension device with two shelves. By a lifting bar construction of the rack feeder high speeds in x and y direction are realized. Loading aids are stored twofold-depth or fourfold-depth.

6 Results

In industrial warehouses the storage and retrieval orders have a different importance which is described by an ABC indicator. For the simulations we chose as a ABC indicator with the storage and retrieval orders 80% of A bin, 15% of B bin and 5% of C bin. With the single cycles or with the single und double cycles 15 is the number of the storages and retrievals per simulation experiment and 5 is the standard deviation. With pure double cycles the standard deviation is put on 0 to receive the same number of storage and retrieval orders for every simulation experiment. The highbay warehouse in the test problem has three channels. Therefore there are three combinations of the strategy zones and optimized channel, namely “combination of zone and channel 1”, “combination of zone and channel 2” as well as “combination of zone and channel 3”.

In the case of single cycles Figure 4 shows the mean cycle times for the different storage strategies. These cycle times increase with the warehouse fill degree. The increase is about 5 to 10% if the warehouse fill degree rises from 50% to 99%. The strategy “channel” is mostly influenced from the warehouse fill degree. With a warehouse fill degree of 50% and 80% the strategy “zone” delivers the maximum mean cycle times. With a warehouse fill degree of 99% the strategy “channel” has the worst value. The strategy “combination of zone and channel 3“ always delivers the minimum mean cycle times. The percental deviation of the best strategy to the worst strategy amounts with a warehouse fill degree of 50% to 7.96%, with a warehouse fill degree of 80% to 6.96 %, and with a warehouse fill degree of 99% to 5.08%. So the increase in output by the application of the best storage strategy with rising warehouse fill degree becomes smaller.

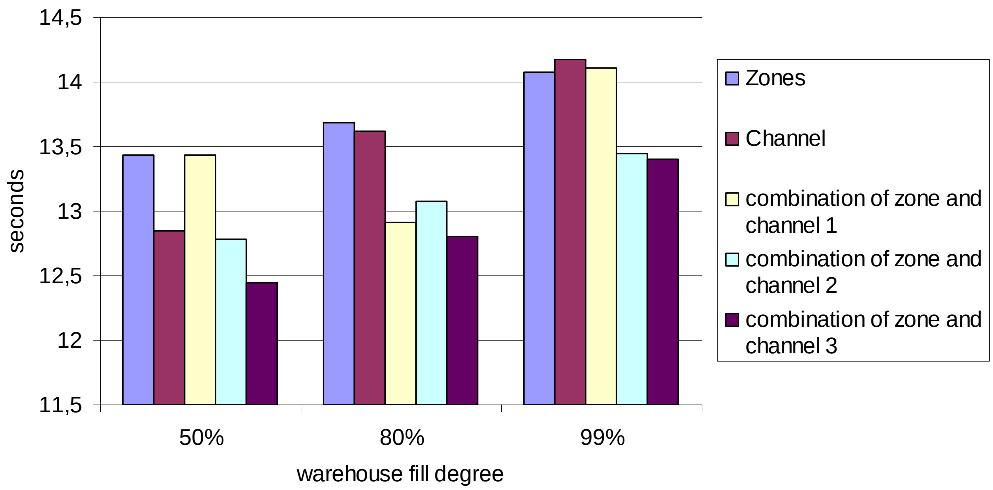

Figure 4: Mean cycle times with single cycles

The use of the strategy “combination of zone and channel 3“ causes the least stock transfers, see Figure 5. The decrease of the number of stock transfers arises by accidental determination of the number of bins for retrievals – in this case the number of bins for retrievals decreases. The probability of stock transfers is between 44% and 52%. The smallest values are reached for every warehouse filling degree by the strategy “combination of zone and channel 3“.

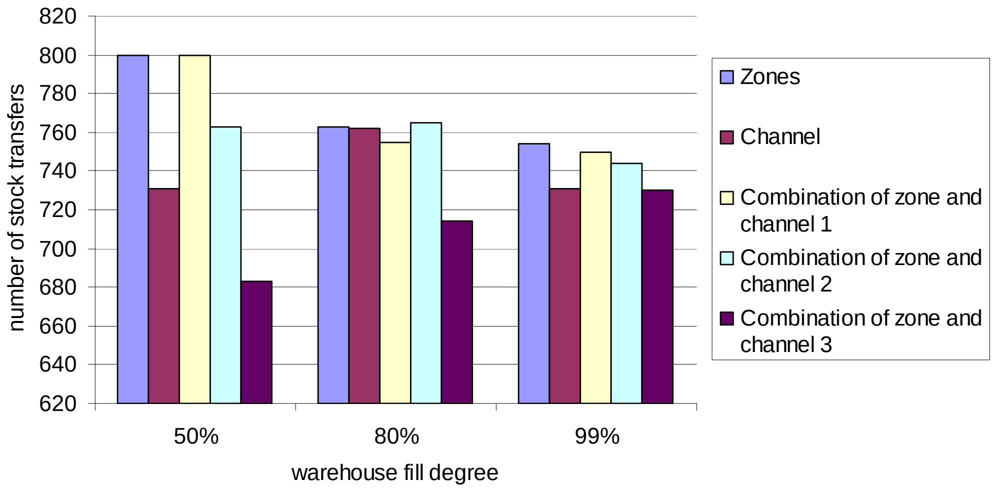

Figure 5: Number of stock transfers with single cycles

For single cycles and double cycles arise the same results structurally like with the single cycles, they are shown in Figure 6. The percental deviation shows that the relative difference decreases between the best strategy and the worst strategy with rising warehouse filling degree by which also the improvement in performance decreases by the use of the most favorable strategy. Also in this case rise the mean cycle times with the warehouse filling degree.

Figure 6 shows the stock transfers to the single warehouse filling degrees for every storage strategy. The strategy “combination of zone and channel 3“ has the smallest number of stock transfers at the warehouse filling degrees of 50% and 80%. With a warehouse filling degree of 99% strategy “channel” causes the smallest values.

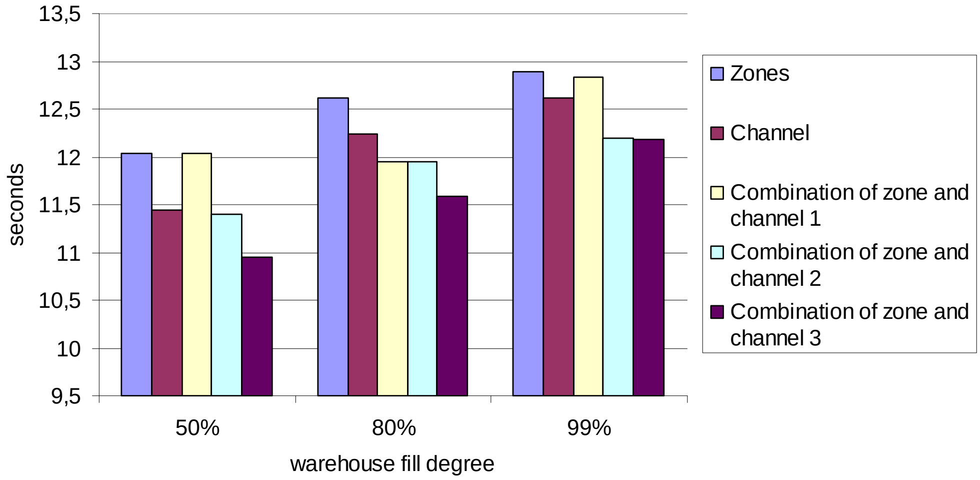

Figure 6: Mean cycle times with single and double cycles

Comparing Figure 6 and Figure 7 shows that the strategy with the highest mean cycle times not always has most stock transfers and vice versa. Also the strategies with the smallest mean cycle times not always have the least stock transfers. Therefore the number of stock transfers to a strategy permits no statement about the quality of this strategy.

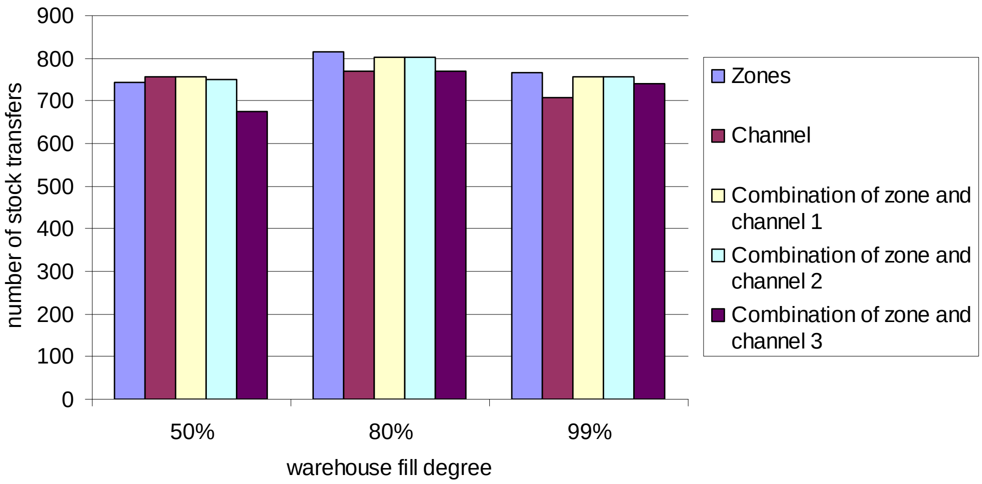

Figure 7: Number of stock transfers with single and double cycles

The results for double cycles are essentially the same like with single cycle and double cycle. They are shown in Figure 8 and Figure 9. Also here the strategies of type “combination of zone and channel“ react most clearly to the increase of the warehouse filling degree. A comparison of these deviations with the deviations from both previous simulation runs shows that with double cycle the relative profit is the largest by the most favorable storage strategy. Indeed, the improvement in performance also here decreases with the warehouse filling degree.

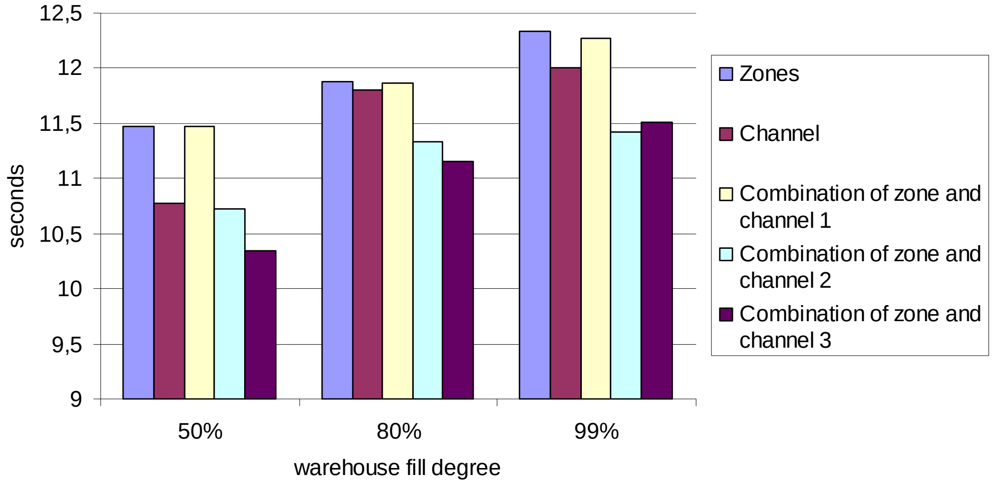

Figure 8: Mean cycle times with double cycles

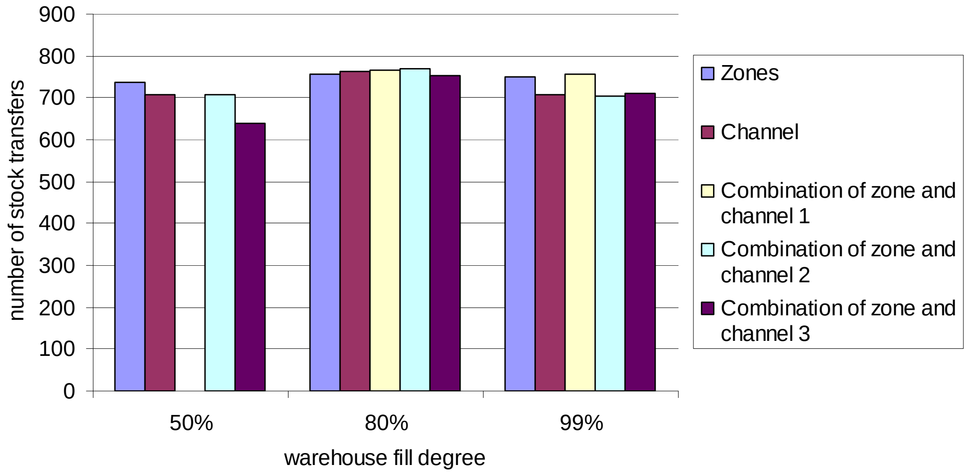

Figure 9: Number of stock transfers with double cycles

There is no storage strategy which generates always mostly or least number of stock transfers. With a warehouse filling degree of 50% there is a correlation between the number of stock transfers and the mean cycle time. Such a correlation does not exist with other warehouse filling degrees. Hence, it cannot be inferred from the number of stock transfers from the mean cycle time and vice versa.

There are no quantitative results published about the improvement in performance of multiple-depth warehouses by storage strategies. Nevertheless, investigations about storage strategies for multiple-depth warehouses were published. Seemüller regards in [7] the strategies “chaotic storage”, which fites with the strategy accidental (storage), “storage close to retrieval”, which is comparable to the strategy of the fastest neighbour, and multiple storage in which several bins are stored side by side. So, the most effective strategy in this investigation is not investigated by Seemüller.

The probability of stock transfers is analyzed in [6]. The authors (of [6]) describe the run of the probabilities of stock transfers in a twice-depth warehouse as a function of the warehouse filling degree by a curve. For a warehouse filling degree of 50% the probability of stock transfers is 32%, for a filling degree of 80% the probability for stock transfers result in with 45% and at a filling degree of 100% the probability lies with 50%. The probabilities for stock transfers in this investigation are higher. With a warehouse filling degree of 50% the probability for stock transfers is already 44%. Furthermore, probabilities for stock transfers of more than 50% appear. The number of stock transfers is determined by the retrievals. The retrievals depend on the orders. Hence, a stochastic process is given. This is not considered in the static curve in [6]. By allowing the beginning of the allocation of a channel even if this can be avoided, the probability for stock transfers should become smaller. This will be analyzed in further investigations at the IPF.

7 Summary

All together a combination of the strategies zones and channel causes the best results.

The up to now published results are often not quantitative. On the other hand the simulation introduced here delivers quantitative results for concrete enterprises. This investigation proves partly clearly higher performance in the handling of goods and probabilities of stock transfers.

Subsequently the results should be concretized and be generalized by the consideration of other camp types. At this problem the IPF will research further in the future.

8 Literature

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