An explanation of some rack layout concepts for warehouses

White paper - February 2011

Kees Jan Roodbergen
University of Groningen
The Netherlands

The layout of the racks in a warehouse has a major impact on the efficiency of the operations. Some recent results on this topic are presented in this paper. By applying the concepts as presented here, it will often be possible to obtain a substantial reduction in order throughput time and simultaneously a reduction of costs. Results have been confirmed by case studies as well as scientific research.

Introduction

We focus on methods to find appropriate layouts for storage areas. This concerns the determination of the number of blocks, and the number, length and width of the aisles and cross aisles in the area. One layout concept that is regularly seen, is a one-block "square-in-time" layout. Square-in-time basically means that it takes the same time to walk from the front to the back of the area as it takes to walk from the left to the right of the area. It can easily be proven mathematically that this layout is optimal if there is only one stop per route (that is, if we are moving full pallets only). However, it is possible to do better nevertheless, as will be shown in the section "Layout for unit load areas". But first we will look into layout issues for order picking areas.

Order picking area layout

Regardless of whether it concerns small parts order picking or case picking environments, a common characteristic is that the order picker travels through the area while making several stops to retrieve products from the racks. It is especially important that several (3 or more) stops are made per route for the theories in this section to apply. If only one or two stops are made, then the concepts as presented in the next section "Layout for unit load areas" must be used.

Figure 1 shows various aspects of the layout of an order picking area. The layout structure is composed of several *pick aisles* that have racks on both sides in which to store products. Order pickers can change from one pick aisle to another pick aisle at one of the *cross aisles*, which are positioned perpendicular to the pick aisles. Typically, there are at least two cross aisles, one at the front and one at the back of the warehouse.

Layouts with just two cross aisles are very common, but actually are rarely the best choice with regards to operational efficiency. More cross aisles in between the front and back cross aisles should be added to increase the number of opportunities to change aisles. The main advantage of having extra cross aisles in a warehouse is the increased number

of routing options, which most often results in lower travel distances. However, it must be noted that the size of the warehouse will inevitably increase if more cross aisles are added, because the total storage area must be kept constant to meet predefined requirements. This in itself may already be considered a disadvantage, but it also tends to have an upward effect on route length.

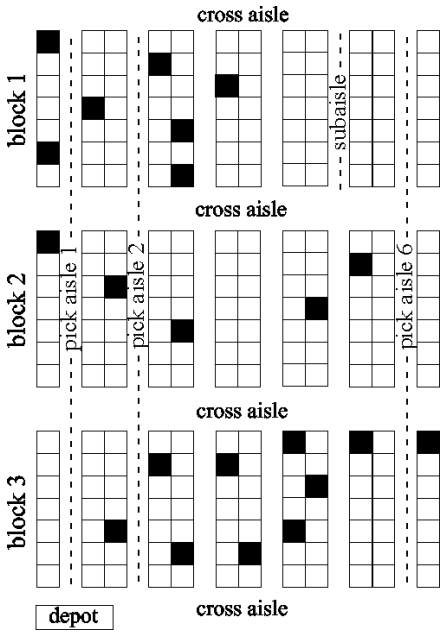

Figure 1
An order picking area with multiple blocks.

From the article of Roodbergen and Vis (2008) it is, however, clear that the balance between these two forces is such that the addition of a few extra cross aisles will decrease travel times significantly in almost all cases. It was also shown in the article that the more picks must be retrieved per route, the fewer cross aisles should be used. The paper itself is quite mathematical, but user-friendly software is available for free at http://www.roodbergen.com/whsim/ that can give insights in the benefits of additional cross aisles.

Layout for unit load areas

Unit loads, such as pallets, are simply picked up at one location and dropped off at another location. Routing is therefore extremely straightforward. These seemingly simple operational characteristics have for decades caused warehouse managers and academic researchers to think that layout was a fairly straightforward issue as well. As already mentioned in the introduction, for full pallet load handling it is easy to prove that a single-block square-in-time layout is best. This proof, however, rests on two implicit assumptions (Meller and Gue, 2009):

1. Picking aisles must be straight and parallel.
2. Cross aisles must be straight and they must meet picking aisles at right angles.

There is no good reason to adhere to these assumptions. Moreover, significant efficiency improvements can be obtained by radically changing the design. Consider for example the layout as presented in Figure 2.

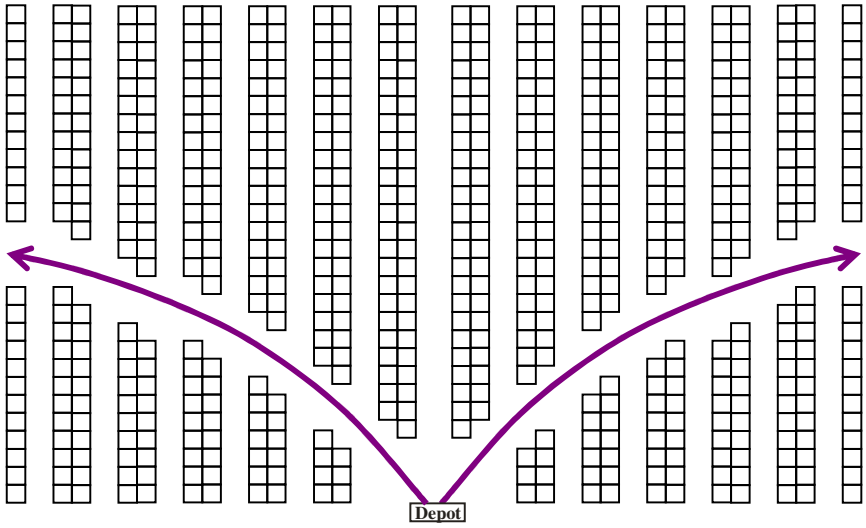

Figure 2: Flying-V layout

The flying-V layout has a curved cross aisle instead of a cross aisle that is perpendicular to the aisles. This enables travel from the starting point (depot) to the storage locations that can be 10% shorter than in the standard layout. One disadvantage is that vehicles must make rather sharp turns when entering the lower part of the pick aisle from the cross aisle. To solve this problem, and simultaneously reduce travel distances even more, Meller and Gue introduced the Fishbone layout as presented in Figure 3.

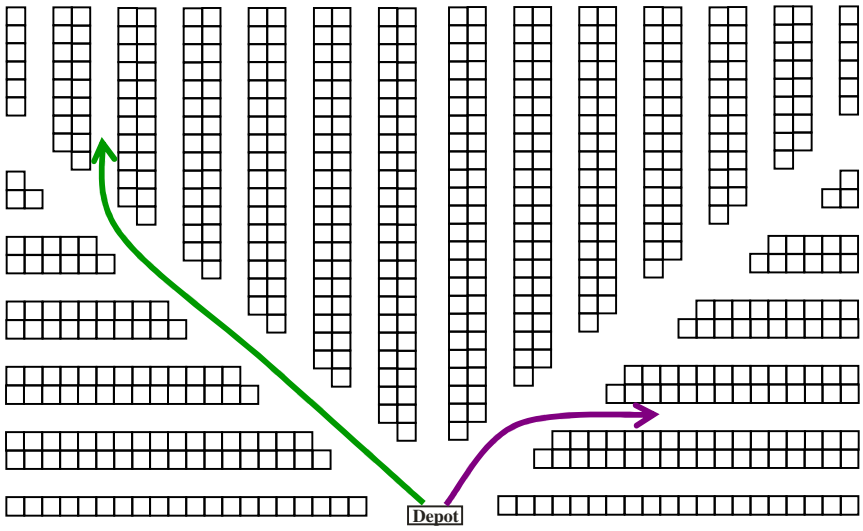

Figure 3: Fishbone layout

Using the fishbone layout it is possible to reach any of the storage locations by almost straight travel from the depot. This strongly decreases the required travel distances. It must be noted that the fishbone and flying-V layouts appear to be most effective for unit load operations, so when the number of stops per route is just one or two. More information on this concept can be found at http://www.kevingue.com For order picking operations with several stops, the reader is referred to the previous section "Order picking area layout".

Limitations

The research cited in this article is based on the assumption of random storage. That is, storage locations are assigned to products randomly. If storage locations are assigned to products based on, for example, an ABC analysis, it can be expected that the gains of the presented layouts are to a certain extent smaller. Preliminary results suggest that for the order picking area layout it is often still beneficial to have more than 2 cross aisles, though fewer will be needed than for random storage situations.

Conclusion

The common one-block square-in-time layout is rarely the best choice in random storage warehouses. For order picking operations, it is almost always beneficial to add one or more extra cross aisles, as depicted in Figure 1. For full pallet load handling, the concept of the Fishbone layout as shown in Figure 3 may result in notable savings in travel distances.

More information:

- Roodbergen, K.J., Sharp, G.P., and Vis, I.F.A. (2008), Designing the layout structure of manual order-picking areas in warehouses. *IIE Transactions* 40, 1032-1045.
- Gue, K.R., and Meller, R.D. (2009), Aisle configurations for unit-load warehouses, *IIE Transactions* 41, 171-182.

Internet resources:

- http://www.roodbergen.com
- http://www.kevingue.com