Stacking property based storage location assignment for minimising order picking lead time

Tamás Bódis [1] and János Botzheim [2]

[1]Széchenyi István University, Department of Logistics and Forwarding, Győr, Hungary
[2]Széchenyi István University, Department of Automation, Győr, Hungary

Abstract. There are many studies in the field of labour and capital-intensive order picking operations. Many solutions have been defined for harmonising Storage Location Assignment (SLA) and routing to decrease the picking lead time, however, the product stacking properties are rarely taken into consideration. The aim of this paper is to highlight the effects of the SLA on the order picking lead time, with considering the relevant product stacking aspects. Furthermore, this paper examines the necessity of the unit load reconstruction during order picking. The defined SLA alternatives will be evaluated based on order picking lead time by the previously developed stacking property based order picking routing algorithm. The basis of the evaluation is a test environment which has been developed based on industrial experiences by the authors. The set of the applied order picking lists contains several orders with different characteristics.

1 Introduction

Order picking is the most labour and capital-intensive warehousing operation. The order picking operator visits every picking position of the picking list and collects the ordered items into a pallet to build a unit load (UL). The primary development goal is the routing optimisation, because the travelling time gives approximately 50% of the whole picking time. It is a special case of the Vehicle Routing Problem (VRP) with loading constraints, when one operator has one set of positions, which should be visited and the items should be arranged on a pallet [1] [2] [3].

The main VRP loading constraints have been summarised in the literature: geometric dimensions, fragility, orientation, stacking, and priority [4]. The characteristics of orders should also be considered during picking position sequencing. The same items can behave differently because of the different ordered quantity, for example low amount of an item can be less stable on the pallet. The customers usually define the expected pallet making rules, which may limit the possible picking sequence or cause a non-optimal routing sequence. The proposed research defines these factors as Pallet Loading Features (PLF), which depend on product properties, order picking list characteristics, and order picking system. These aspects result in a complex routing optimisation which can be solved by the already developed stacking property based order picking routing Bacterial Memetic Algorithm. This algorithm has been developed as part of this research by the authors [5].

The Storage Location Assignment (SLA) methods have a huge impact on the routing. These are responsible for defining the order picking positions of the items on the warehouse layout [6]. The warehouse layout defines the dimensions of the picking zones, the storage system, the direction and number of aisles, and the order picking departure and arrival (DA) positions [1]. The main aim of SLA is to support the routing algorithm minimising the order picking lead time and costs on the given layout [6]. Therefore, every aspect should be considered altogether, like product parameters, order characteristics, and the order picking system itself. Many solutions have been defined for harmonising SLA and routing to decrease the picking lead time. However, the stacking property is rarely taken into consideration, or only simple, product parameter based solutions are applied [5].

The picker might should spend time with UL reconstruction during order picking because of the order characteristics. Two ways could be possible, longer distance might result in shorter lead time, because of less pallet loading time. At the same time, reconstruction can result in shorter lead time because of shorter routing distance. This decision should be made list by list, which depends on the SLA, the time requirement of movements, and the order characteristics. The well-designed SLA and routing algorithm should count with the possibility of UL reconstruction for reaching minimal lead time [5].

The aim of this paper is to highlight the effects of the SLA on the order picking lead time, with considering the above highlighted aspect. This paper examines the necessity of the UL reconstruction during order picking. The defined SLA alternatives will be evaluated based on order picking lead time by the previously developed stacking property based order picking routing algorithm. The basis of the evaluation is a test environment which has been developed based on industrial experiences by the authors. The set of applied order picking lists contains several orders with different characteristics.

2 Test environment and alternatives

For evaluating the effects of the layout, the SLA, the stacking property based routing, and the different order characteristics a computer simulation environment has been realised in Plant Simulation discrete-event simulation tool. Figure 1. shows the order picking zone layout of the test environment with the order picking operator. The colleague walks from position to position (rectangles) with the UL via the footpath (grey line). The grey rectangle visualises the DA position [5].

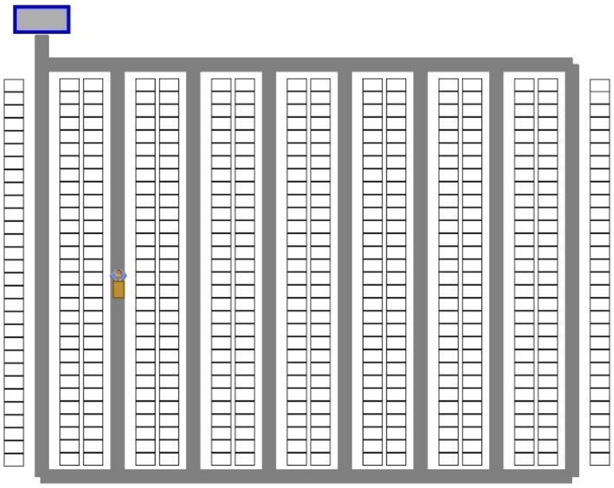

Figure 1. Layout

The layout is scaled, but the distances between the positions can be varied proportionally to evaluate the effects of smaller and bigger picking zones. This paper examines the "small" zone with realistic distances and the four times bigger "big" zone with doubled distances. The DA position can change during warehouse operations in the case of different forwarding areas of orders. This paper examines 3 alternatives, when it is defined on the left, middle, or right part of the manipulation area.

This paper compares a totally randomized SLA (Figure 2.) with a SLA based on PLF (Figure 3.). The PLF based SLA allocates the items to the positions based on those stacking classes. The stacking class zones are sequenced on the layout based on a theoretical picking sequence from left to right. (Figure 4.)

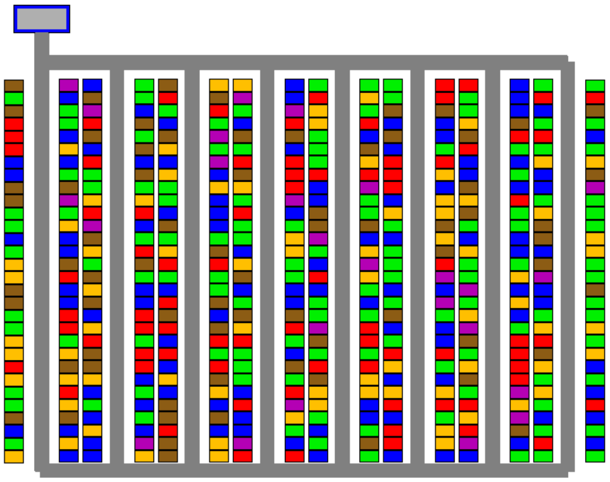

Figure 2. Randomized SLA

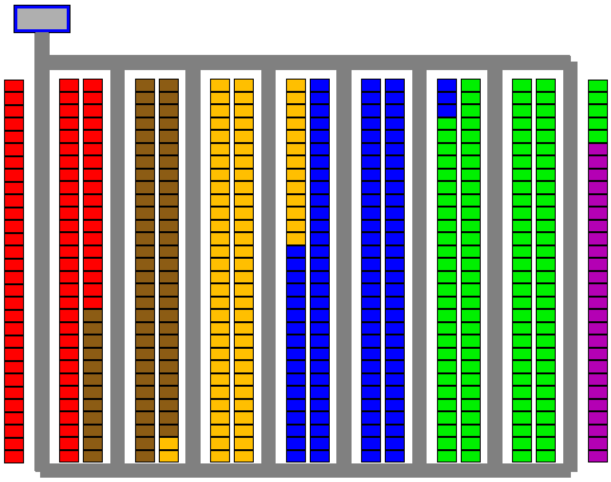

Figure 3. SLA based on PLF

Theoretical stacking sequence	Stacking classes
1	Bag
2	Pail
3	Can
4	Big_Box
5	Small_Box
6	Fragile

Figure 4. Legend and theoretical picking sequence

Each record of the order picking list is classifiable into Pallet Loading Classes (PLC) based on previously developed methodology. It considers the order parameters, for example the low ordered quantity of "Can" has different stacking property. It has own PLC, like "Can_LQ". The stacking possibilities are defined in a simple symmetrical and triangular Pallet Loading Features based Decision Matrix (PLFDM), where "1" means stacking is possible (Table 1.) [7].

Table 1. PLFDM

	Bag	Pail	Can	Big_Box	Can_LQ	Small_Box	Fragile
Bag	1	1	1	1	1	1	1
Pail	0	1	1	1	1	1	1
Can	0	0	1	1	1	1	1
Big_Box	0	0	0	1	1	1	1
Can_LQ	0	0	0	0	1	1	1
Small_Box	0	0	0	0	0	1	1
Fragile	0	0	0	0	0	0	1

The proposed simulation model has already been used for developing routing algorithm for order picking routing problem based on PLF. The aim of the defined Bacterial Memetic Algorithm is to sequence a given order picking list while following the pallet loading rules and to minimise the order picking lead time. The applied algorithm for the proposed evaluations has 2 alternatives. While the "Non-strict" algorithm allows UL reconstruction during order picking, the "Strict" algorithm does not. The lead time is calculated by the sum of travel time, picking time, and reconstruction time [5].

Therefore, the 24 alternatives have been defined for evaluation (Table 2.).

Nine order picking lists have been defined for evaluation with different characteristics. Three order types have been defined, which have 8, 10, and 12 record long alternatives.

- "Simple", which contains items from the middle of the PLC zones.
- "LQ", which contains "Can_LQ" PLC.
- "Border", which contains items from the borderline of the PLC zones and "Can_LQ" PLC.

Table 2. Examined alternatives

Alternative	Algorithm	SLA	DA	Layout
PLF_left_big	Non-strict	PLF	left	big
PLF_left_small	Non-strict	PLF	left	small
PLF_middle_big	Non-strict	PLF	middle	big
PLF_middle_small	Non-strict	PLF	middle	small
PLF_right_big	Non-strict	PLF	right	big
PLF_right_small	Non-strict	PLF	right	small
RND_left_big	Non-strict	RND	left	big
RND_left_small	Non-strict	RND	left	small
RND_middle_big	Non-strict	RND	middle	big
RND_middle_small	Non-strict	RND	middle	small
RND_right_big	Non-strict	RND	right	big
RND_right_small	Non-strict	RND	right	small
Strict_PLF_left_big	Strict	PLF	left	big
Strict_PLF_left_small	Strict	PLF	left	small
Strict_PLF_middle_big	Strict	PLF	middle	big
Strict_PLF_middle_small	Strict	PLF	middle	small
Strict_PLF_right_big	Strict	PLF	right	big
Strict_PLF_right_small	Strict	PLF	right	small
Strict_RND_left_big	Strict	RND	left	big
Strict_RND_left_small	Strict	RND	left	small
Strict_RND_middle_big	Strict	RND	middle	big
Strict_RND_middle_small	Strict	RND	middle	small
Strict_RND_right_big	Strict	RND	right	big
Strict_RND_right_small	Strict	RND	right	small

3 Simulation results

The alternatives have been examined based on every order picking list. The lead times of each order picking list have been summarised for alternatives. While the average lead time of performing the 9 lists is 58:21 (mm:ss) in the case of randomised SLA, it is 48:40 in the case of PLF based SLA, which is 16,61% lower. The results highlighted, that the alternatives with PLF based SLA generally reached lower lead times.

In the case of randomised SLA, the reconstruction is often necessary. The order picking operators should spend on average 44 seconds with reconstruction during performing every list. When PLF based SLA is used, the necessity and the average time (11 sec) of reconstruction is decreased, but it is used in the case of complex lists. The summarised lead time of every list is on average 7% (03:40) lower when reconstruction is allowed.

Table 3., Figure 5., and Figure 6. highlight, that the DA position has impact on the reconstruction and travel time based on the Border_10 list. Furthermore, strict sequence (Figure 7. and Figure 8.) results in higher lead time.

Table 3. Results for Border_10 list

Border_10	Lead time	Picking time	Reconstr. time	Travel time
PLF_right_big	6:25.95	1:40.00	0:45.00	4:00.95
PLF_left_big	6:37.39	1:40.00	1:15.00	3:42.39
Strict_PLF_right_big	6:44.67	1:40.00	0.00	5:04.67
Strict_PLF_left_big	6:57.36	1:40.00	0.00	5:17.36

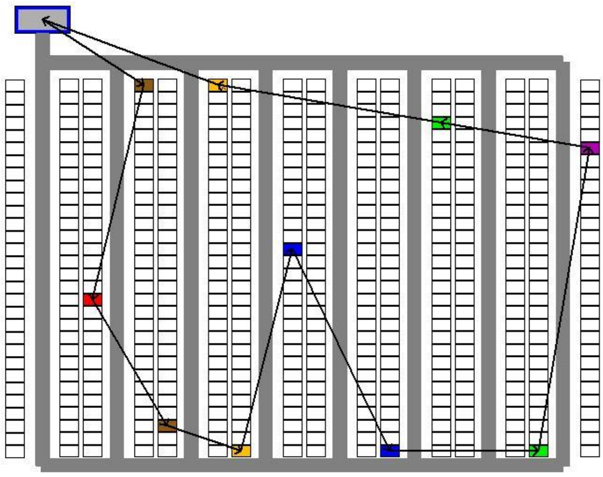

Figure 5. Border_10 – PLF_left_big (The upper Can position is a “Can_LQ” PLC)

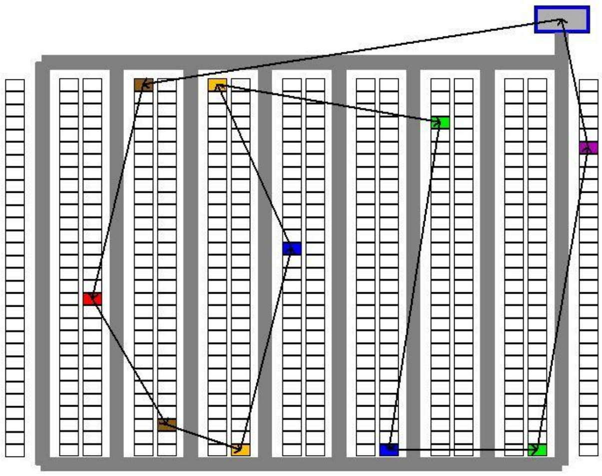

Figure 6. Border_10 – PLF_ right_big

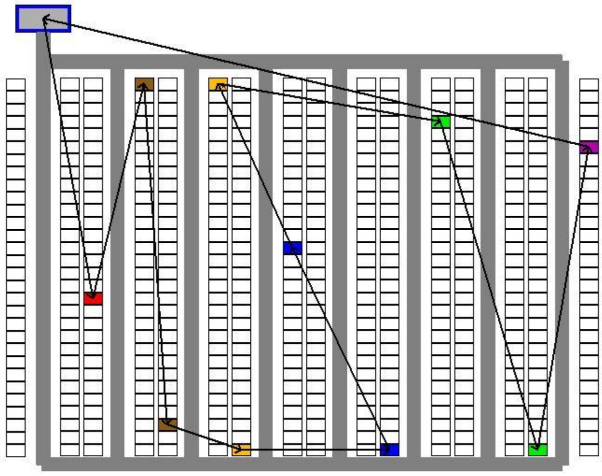

Figure 7. Border_10 – Strict_PLF_left_big

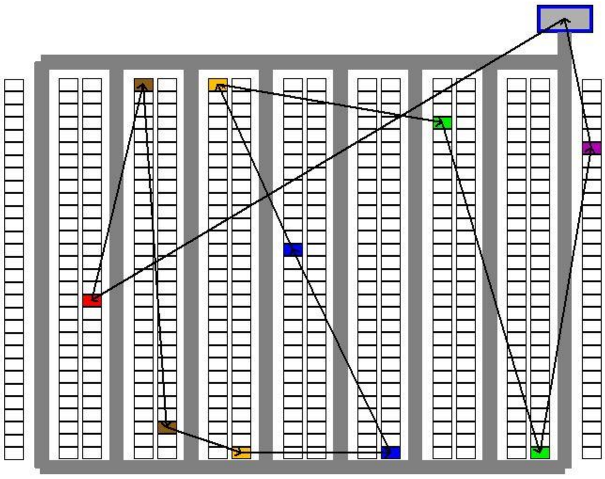

Figure 8. Border_10 – Strict_PLF_ right _big

4 Conclusion

The proposed paper highlighted the importance of PLF based SLA and the following statements:

- When PLF is relevant, then PLF based SLA results in lower lead time.
- Allowing reconstruction is necessary even in the case of PLF based SLA because of the order characteristics.
- The DA position has impact on the travelling and reconstruction time, which also highlight the necessity of reconstruction.

Acknowledgement

The publication is financed based on 1687/2015. (IX. 25.) government decision of Hungary about financing the innovations of Széchenyi István University.

References

[1] R. d. Koster, T. Le-Duc and K. J. Roodbergen, “Design and control of warehouse order picking: A literature review,” *European Journal of Operational Research,* vol. 182, p. 481–501, 2007.

[2] J. Ashayeri and M. Goetschalckx, “Classification and design of order picking,” *Logistics Inf Manage,* vol. 2, no. 2, p. 99–106, 1989.

[3] K. Braekers, K. Ramaekers and I. Van Nieuwenhuyse, “The vehicle routing problem: State of the art classification and review,” *Computers & Industrial Engineering,* no. 99, pp. 300-313, 2016.

[4] H. Pollaris, K. Braekers, A. Caris, G. K. Janssens and S. Limbourg, “Vehicle routing problems with loading constraints: state-of-the-art and future directions,” *OR Spectrum,* vol. 37, no. 2, pp. 297-330, 2014.

[5] T. Bódis and J. Botzheim, “Bacterial Memetic Algorithms For Order Picking Routing Problem With Loading Constraints,” *Expert Systems with Applications - UNDER REVIEW (since 26. 06. 2017.),* 2017.

[6] K. L. Choy, H. Y. Lam, L. Canhong and C. K. H. Lee, “A hybrid decision support system for storage location assignment in the fast fashion industry,” in *Technology Management in the IT-Driven Services (PICMET), 2013 Proceedings of PICMET ’13*, San Jose, California, USA, 2013, p. 468–473..

[7] T. Bódis and J. Botzheim, “Modelling Order Picking Sequencing Variations of Pallet Setup Clusters,” in *Proc. of The International Conference on Logistics and Sustainable Transport 2015*, Celje, Slovenia, 2015.