Restructuring of Logistics Processes: Case Study of Order Picking at Terminal C2 of Grupo Luís Simões

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ABSTRACT

Order picking is a labour-intensive operation and so it represents significant costs, with any underperformance leading to high operational cost for the whole supply chain. Hence, the objective of the present work is to assess and restructure the storage assignment in the picking area and the order picking process (namely the routing method) in order to enhance the order picking process of Luis Simões’s Carregado 2 Logistic Operations Centre (C2). After a literature review on the optimization of low level, manual-pick order-picking, a simulation model was developed to assess the performance of the order picking in C2, taking in account multiple scenarios varying in storage assignment policy and routing method. Fulfilling its objectives, this dissertation allowed for important conclusions to be drawn for C2 and also for picking optimization in general.

Keywords: Storage Assignment, Routing Methods, Discrete Events Simulation, Order Picking, Warehousing, Logistics

1. INTRODUCTION

Our everyday activities are supported by logistics, responsible for the movement of materials. With this level of omnipresence logistics cost are obviously significant, with Rushton, Croucher & Baker (2006) indicating that the logistics represented between 10 and 15 per cent of the gross domestic product of most major economies. Accumulating significant cost with utmost usefulness, logistics has the awkward combination of being both essential and expensive. Warehousing is an integral part of every logistics system that plays a vital role in providing a desired level of customer service at the lowest possible total cost. Whilst warehouses are critical, they are also substantial from a cost standpoint. And, as more companies look to cut costs and improve productivity, picking has come under increased scrutiny. Order picking is the most labour-intensive operation in warehouses with manual systems, and a very capital-intensive operation in warehouses with automated systems, with any underperformance in leading to unsatisfactory service and high operational cost for the whole supply chain. Studies estimate the picking costs to be above 50% of the total warehouse operating expense (see van den Berg & Zijm, 1999; Ruben & Jacobs, 1999; Broulias et al., 2005; Eisenstein, 2008; De Koster et al, 2007; Rushton et al., 2006). Therefore, in the present paradigm of companies actively competing and seeking cost reductions, warehousing professionals consider order picking as the highest priority area for productivity improvements (Goetschalckx & Ashayeri, 1989; De Koster et al., 2007).
Henceforth, the all-embracing objective of the present work is to assess and restructure the storage assignment in the picking area and the order picking process (namely the routing method) in order to enhance the order picking performance of Carregado 2 Logistic Operations Centre (C2), a warehouse operated by the Luís Simões Group (LS). To accomplish this objective a methodology was developed to assess the performance of the order picking in C2, taking in account various scenarios, respectively before and after the implementation of various storage assignment policies and routing methods. To this end a simulation model, based mainly on discrete-event simulation (DES), was created, using picking time as measure of performance. By analysing the results, the current paradigm of the order picking was evaluated, as were possible modifications in storage assignment policies and routing methods.

The remainder of the paper is organized as follows. Section 2 is a brief literature review focusing on order picking systems optimization. On section 3 the topic is the Carregado 2 Logistic Operations Centre, the case study. Based on the previous, a simulation model was developed (section 4) and applied to the case study (section 5), with the obtained results discussed. Finally, the final conclusions of this work are offered on section 6, as well as indications to future works related with the topic.

2. LITERATURE REVIEW ON ORDER PICKING SYSTEMS OPTIMIZATION

The most common objective of order-picking systems is to maximise the service level while respecting resource constraints. The uttermost important relation between the order picking and service level is that the faster the picking occurs the better (De Koster et al., 2007). Travel represents 50% of order-picker’s time in a typical picker-to-parts warehouse (Tompkins et al., 2003). It is, therefore, the first and most promising candidate for enhancement.

Following De Koster et al., (2007), to optimize travel time (or travel distance) in low level, manual-pick order-picking processes one can focus on ideal (internal) layout design, storage assignment methods, routing methods, order accumulation, order batching and zoning (Figure 1).

![Figure 1 – Optimization of low level, manual-pick order-picking processes.](image)

The optimization of these six policies has the advantage to stay within the tactical and operational levels, which is critical for a built warehouse where strategic decisions are already taken and are difficult and expensive to change.

Please note that since these six optimization objectives are strongly interdependent, and including all decisions in one model is complex, researchers, consequently, restrict their studies to one or few decision areas at a time (De Koster et al., 2007).

The internal layout design concerns the determination of the number of blocks, and the number, length and width of aisles in each block of a picking area. The objective is to find the best warehouse layout with respect to a certain objective function, taking in consideration a set of constraints and requirements. Again, the most common objective function is the travel distance.

In regards to zoning, the order picking area can be divided into zones, each with an assigned order picker that picks the part of the order that is in his assigned zone. Possible advantages of zoning include the fact that each picker is confined to a smaller area, reducing traffic congestion and allowing the familiarisation with the item locations within the zone. The central disadvantage of zoning is that orders are split, requiring consolidation before shipment to the customer (De Koster et al., 2007).

Order batching is the method of grouping a set of orders into a number of sub-sets, each of which can then be retrieved by a single picking tour. According to Choe and Sharp (1991), there are basically two criteria for batching: the proximity of pick locations and time windows.
When batching and/or zoning is applied, usually some additional effort is needed to congregate the items per customer order. These processes are frequently called accumulation/sorting (A/S) (De Koster et al., 2007). The performance of an A/S system depends not only on the equipment capacity (i.e. sorter capacity and conveyor speed) but also on operating policies like shipping lane assignment.

2.1. Routing Methods

The objective of routing policies is to sequence the items on the pick list so that a good route through the warehouse is ensured. So, by definition, the problem of routing order pickers in a warehouse classifies as a Steiner Travelling Salesman Problem (De Koster et al., 2007). The difficulty with the (Steiner) Travelling Salesman Problem is that it is in general not solvable in polynomial time (De Koster et al., 2007). However, there is literature on the subject, under specific circumstances.

In practice, the problematic of routing order pickers in a warehouse is mostly resolved using heuristics. This is caused by some disadvantages of optimal routing in practice (De Koster et al., 2007). Hall (1993), Petersen (1997) and Roodbergen (2001) distinguish several heuristic methods for routing order pickers in single-block warehouses, with examples of a number of routing methods for a single-block warehouse is presented in Table 1.

Table 1 – Routing Methods for a single-block warehouse.

<table>
<thead>
<tr>
<th>S-shape (or traversal) heuristic</th>
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<tbody>
<tr>
<td><strong>Description</strong></td>
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<tr>
<td><strong>Advantages</strong></td>
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<tr>
<td><strong>Drawbacks</strong></td>
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<table>
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<tr>
<th>Return method</th>
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<tr>
<td><strong>Description</strong></td>
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<tr>
<td><strong>Advantages</strong></td>
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<td><strong>Drawbacks</strong></td>
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<th>Midpoint method</th>
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<tbody>
<tr>
<td><strong>Description</strong></td>
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<tr>
<td><strong>Advantages</strong></td>
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<tr>
<td><strong>Drawbacks</strong></td>
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<tr>
<th>Largest gap method</th>
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<tr>
<td><strong>Description</strong></td>
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<tr>
<td><strong>Advantages</strong></td>
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<td><strong>Drawbacks</strong></td>
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<table>
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<tr>
<th>Combined (or composite) heuristic</th>
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<tbody>
<tr>
<td><strong>Description</strong></td>
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<tr>
<td><strong>Advantages</strong></td>
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<td><strong>Drawbacks</strong></td>
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Petersen (1997) carried out a number of numerical experiments to compare six routing methods: the S-shape, return, largest gap, mid-point, composite and optimal in a situation with random storage. He concludes that a best heuristic solution is on average 5% over the optimal solution.

2.2. STORAGE ASSIGNMENT

Products need to be distributed into storage locations before they can be picked to complete customer orders. To assign products to storage locations a set of rules designated storage assignment method can be applied (De Koster et al., 2007). Table 2 summarizes the storage assignment policies, along with their main advantages and drawbacks. The information in this table was summarized by the author from the work of De Koster et al., (2007).

Table 2 – Storage assignment policies.

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random storage</td>
<td>Assigned location is selected randomly from all eligible empty locations with equal probability.</td>
<td>High space utilisation (or low space requirement)</td>
</tr>
<tr>
<td>Closest open location storage</td>
<td>The first empty location that is encountered is used to store the products.</td>
<td>Similar performance to the random storage policy (if products are moved by full pallets only)</td>
</tr>
<tr>
<td>Dedicated storage</td>
<td>Each location is dedicated to a product.</td>
<td>Order pickers become familiar with product locations.</td>
</tr>
<tr>
<td>Full turnover storage</td>
<td>Locations are assigned to products according to their turnover. Products with the highest sales rates are located at the easiest accessible locations.</td>
<td>Decreased travel distance (outperforms class-based storage).</td>
</tr>
<tr>
<td>Class based storage</td>
<td>Products are grouped into classes in such a way that the fastest moving class contains only about 15% of the products stored but contributes to about 85% of the turnover. Each class is then assigned to a dedicated area of the warehouse. Storage within an area is random.</td>
<td>Fast-moving products can be stored close to the depot and simultaneously the flexibility and low storage space requirements of random storage are applicable. Easier to implement than the volume-based method; it does not require a complete list of the items ranked by volume and it requires less time to administer than the other dedicated methods do.</td>
</tr>
<tr>
<td>Drawbacks</td>
<td>Each change in demand rates and product assortment requires a new ordering of products. Requires a more “information intensive” approach than random storage.</td>
<td>Full-turnover storage outperforms class-based storage in regards to the travel distance. Class-based storage requires more rack space than randomised storage.</td>
</tr>
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</table>

Various possibilities exist for positioning the A-, B- and C-areas in class based low-level picker-to-part systems. The optimum storage strategy depends on the routing policies (and on warehouse size and number of SKUs per pick route). In the warehousing literature, there is no set rule to define class partition (number of classes, percentage of items per class, and percentage of the total pick volume per class) for low-level picker-to-part systems, though many studies on the subject exist (De Koster et al., 2007).
3. **The Case Study: Carregado 2 Logistic Operations Centre**

The Carregado 2 logistics operation centre (C2) project was the response to the necessity of LS, as a market leader, to search for solutions that increase the competitive edge and further differentiate the company from other competitors. The initial goal for this project was to implement a multi-client and multi-product warehouse in which the operations where the human resources don’t add value would be automated. It was also needed to maintain the flexibility of a conventional warehouse and integrate the automatic operations with the remaining manual operations (Fernandes, 2010). In Carregado 2 it is possible to identify six separated processes: reception, dispatch, automatic handling, co-packing, picking, reverse logistics process. Besides this six processes there is also a support process, the inventory.

The picking is a very important process in C2. Being an important service to the LS clients, the C2 was specifically designed to support picking. The outcome was a picking area that consists in corridors in the ground floor, below the storage shelves, and is served by the CPAs that operate between the corridors.

The picking event (Figure 2) is triggered by the influx of orders containing pallets with mixed products. This pallets need to be produced by a picker. Once the picking pallets are produced they are stored in the warehouse, in a buffer zone. Their dispatch is then processed normally, as if they were any other storage pallets.

![Figure 2 - Flowchart of the picking event.](image-url)
4. METHODOLOGY: DISCRETE EVENT MODELLING

As discussed in the literature review, simulation is an extensively used technique for warehouse performance evaluation in the academic world as well as in practice. So it was an easy to opt, in the context of this academic work with a real life case study, for a simulation. This simulation model was primary based on Discrete Event Simulation (DES) since process-centric modelling is used widely in the logistics (AnyLogic, 2014).

4.1. MODEL DESCRIPTION

The network based discrete event model that the author developed for this work is conceptually represented in Figure 3.

A source object introduces orders, controlled by an arrival schedule mimicking the real arrivals. Next pickers are selected and allocated to an order and the simulation of their movement begins with a delay object (acceleration). Continuing, a decision object ponders the occurrence of an incident and the corresponding downtime. Succeeding a movement object moves the picker to is picking position, movement that is controlled by the defined network associated to the model that represents the warehouse. After moving, a delay object accounts for the deceleration of the picker. The existence of separate delays representing acceleration and deceleration permits that the pickers are defined in the network with the cruising speed of their forklifts. Following deceleration, the actual picking takes place and if the order list continues the model becomes iterative, continuing to the acceleration object. If every product of the order list is picked a decision object evaluates which produced pallets entrance station is closer, taking into account the last picking location. After movement to the appropriate pallet entrance, the picker is released and the order exists the model via a sink object.

As for the scope of this model it was decided, with consultation from LS, that the model would simulate a full week of orders (week 45, 2014) from one client, which occupies a third of the warehouse (aisle...
21 to 30, from 30 aisles) and it is served by up to eleven pickers. Warehouse schematics were drawn by the author to serve as network, the backbone of the model space-awareness. When programming the model (to achieve the concept represented in Figure 3), the author chose a structure with two main blocks: order entry and exit and picking. Order entry and exit simulates the arrival of orders and their allocation to a picker as well as the liberation of the picker and exit of the order after fulfilment. As for the picking block, it consists of eleven blocks one for each of the pickers that can be allocated to this client. By the author’s observation in loco, it was decided that of those pickers two would be faster than average (represented in green) and one would be slower (represented in orange). The use of three classes is common and while in some cases more requirements. For the same reasoning of the full turnover policy, the class with the highest turnover products (A area) is

The scenarios in this work include three storage assignment policies: current, turnover, and ABC1. As the name indicates, the current policy (scenario A) mimics the actual positions of each product in week 45, 2014. The position of this policy respect a class-based storage policy already implemented by LS in C2. Supported by literature, the author proposes a turnover (scenario B) and ABC1 (scenario C) storage assignments. Scenario B is the full turnover policy, a policy where products are distributed over the storage according to their turnover. The products with the highest turnover are closer to the produced pallets entrance stations and slow moving products are at the back of the warehouse. In this work the author used simply the actual turnover (or pick volume) as measure, obtained from the orders supplied by LS and presented in Appendix VI. By corresponding the turnovers with the positions distance vector the storage assignment was obtained. This full turnover policy, by definition, outperforms class-based storage but requires a new ordering of products every time the demand rates change. Scenario C is a class-based storage policy. It consists of three classes (A, B and C) each with a dedicated area of the warehouse. The use of three classes is common and while in some cases more classes can provide additional gains it has the drawback of increasing the space requirements. For the same reasoning of the full turnover policy, the class with the highest turnover products (A area) is

4.2. VERIFICATION AND VALIDATION OF THE MODEL

If a model is to be accepted and used in general, verification and validation is an essential phase of the development process. Referring back to Reis (2010) for definitions: “Verification refers to the steps, processes or techniques the modeller deploys to ensure the model behaves every initial specification and assumption. Validation refers to the steps, processes or techniques the modeller (and any other interested party) deploys to ensure the model adequately represents and reproduces the behaviours of the real world phenomenon.”

In this dissertation, the process of verification of the model embraced several steps and tests that were performed repeatedly throughout the development of the model. Besides verification, the model was subject to validation. The validation technique adopted in this dissertation was based in the work of Reis (2010). Other steps of validation included interviews with the real world picking personal of LS and comparison of outcomes of the model with real world results.

5. CASE STUDY APPLICATION

In this chapter the different scenarios chosen by the author for simulation will be presented, as well as results and conclusions. There are two dimensions for these scenarios: storage assignment policy and routing method.

The scenarios in this work include three storage assignment policies: current, turnover, and ABC1. As the name indicates, the current policy (scenario A) mimics the actual positions of each product in week 45, 2014. The position of this policy respect a class-based storage policy already implemented by LS in C2. Supported by literature, the author proposes a turnover (scenario B) and ABC1 (scenario C) storage assignments. Scenario B is the full turnover policy, a policy where products are distributed over the storage according to their turnover. The products with the highest turnover are closer to the produced pallets entrance stations and slow moving products are at the back of the warehouse. In this work the author used simply the actual turnover (or pick volume) as measure, obtained from the orders supplied by LS and presented in Appendix VI. By corresponding the turnovers with the positions distance vector the storage assignment was obtained. This full turnover policy, by definition, outperforms class-based storage but requires a new ordering of products every time the demand rates change. Scenario C is a class-based storage policy. It consists of three classes (A, B and C) each with a dedicated area of the warehouse. The use of three classes is common and while in some cases more classes can provide additional gains it has the drawback of increasing the space requirements. For the same reasoning of the full turnover policy, the class with the highest turnover products (A area) is
closer to the produced pallets entrance stations and slow moving products (class C) are at the back of the warehouse. Since there is no firm rule to define a class partition, the author selected an 80/19/1 turnover split to this scenario. This split was achieved by analysis of the cumulative turnover curve, whilst minding the frequently applied Pareto principle (or the 80-20 rule). Within each class the product distribution was random, using for that purpose Visual Basic (VBA) programming. Please note that by assuming that automated supply of the picking positions working flawless, scenarios B and C only assigned one position to every product, which not always happen in scenario A.

As for as routing methods go, the scenarios in this work include five: return (scenario 1), random (scenario 2), “LSPickers” (scenario 3), s-shape (scenario 4), and midpoint (scenario 5).

In regards to the literature routings, return and s-shape were selected for their simplicity while midpoint was selected because, while more intricate to implement, it performs better than the s-shape method when the number of picks per aisle is small (Hall, 1993). Random routing, where the routing is completely random, was selected to serve as a comparison point. “LSPickers” was a routing created by the author to somehow simulate the comportment of the real life pickers in C2.

These five routing methods are combined with every storage assignment policy. For comparison, a routing method identified as “original” (scenario 0) is also applied in the current storage assignment. This routing is the actual travels made by the pickers, obtained from the order list provided by LS.

These scenarios were input in the model using a bi-dimensional array, consisting of order lists and the positions within each list. To create inputs for the model the author used VBA programing within Excel, using as basis the order list provided by LS.

Let’s now address the results of the experiment runs. Every scenario was run 250 times and the picking times of all simulations were statistically treated to withdraw meaningful results. The descriptive statics obtained made it clear that the model results were consistent.

One important aspect to take in consideration about the value of the results is that the picking times resulting from the model represent a picking operation completely unhindered and where the pickers operate always with no drops in productivity. Please note that while this not always corresponds to reality, this high productivity of the picking model does not disrupt the author conclusions as every scenario runs in the same optimum picking ambience.

The results are presented in a box-and-whisker diagram (Figure 4). This diagram includes minimum, first quartile, third quartile and maximum values for each scenario, all in hours for simpler reading and understanding.

Figure 4 – Box-and-whisker diagram (in hours) of the picking time under the different scenarios.

By observing Figure 4, it is clear that scenario A (current SAP), is seriously underperforming and that scenarios B (turnover) and C (ABC1) present a similar and worthy performance. Furthermore routing 1, 4 and 5 (return, s-shape and midpoint) present the best results.

In absolute terms, scenario B4 (combining s-shape routing and turnover SAP) represents the fastest picking times, with a worrying performance gap to the current situation represented by A0. Scenarios B1, B5 and C4 follow close.
6. CONCLUSIONS

The objective of this work was completely fulfilled, with the discovery and validation of alternatives in the picking process and storage assignment capable of largely enhancing its performance. The main conclusions to be drawn from this dissertation, grounded on the attained results, are that in relation with the storage assignment methods:

- The turnover SAP presents the best results, as expected by definition;
- The ABC1 SAP presents results closer to the turnover SAP in every routing while being easier to implement and requiring less time to administer;
- The proximity of turnover and ABC1 performance renders the turnover SAP, with its added complications, less attractive;
- As for the current SAP, it is grossly outperformed by the other two in every routing method, although there are extenuatory circumstances that could help explain the lack of performance like the product demand taken into consideration corresponding to 90 days and the fact that scenarios B and C only assigned one position to every product which not always happens in scenario A;

As for the routing methods:

- Three groups of routing methods exist;
- One, consisting of random and LSPickers, is by far the worst performing, thus assuring that a random behaviour is categorically hurtful to the productivity;
- A second group, comprising only the original routing, serves as proof that the on-the-fly routing decisions of the pickers equal a substantial loss of time over a week;
- The third and final group consists of the best performing methods, return, s-shape and midpoint, all widely studied and applied. These three methods are the better performing methods, particularly s-shape and midpoint;
- Under better performing turnover and ABC1 SAPs the performance gap between the random routings and the literature routings decreases.

As a result:

- It is clear that scenario A (current SAP), is seriously underperforming and that scenarios B (turnover) and C (ABC1) present a comparable and admirable performance. Additionally routing 1, 4 and 5 (return, s-shape and midpoint respectively) present the best results;
- In absolute terms, scenario B4 (combining s-shape routing and turnover SAP) represents the quickest picking time, with a significant performance gap to the current situation represented by A0. Scenarios B1, B5 and C4 follow with similar performance.

With the literature review, analysis of the case study and conclusions provided by the model and its results, this work can sum its main contributions, specifically for C2 and also for picking optimization in general.

For C2, the author suggests that a class-based storage policy equal or similar too ABC1 is applied and that s-shape routing is enforced (scenario C4). This suggestion is backed by the top tier performance of this scenario, the previously mentioned advantages of class-based storage over a full-turnover policy and by the fact that s-shape routing is already implemented in the WMS. These alterations, combined with perfect picking supply, would amount to serious performance improvements of more than 30%.

In general, the author would like to point out that inadequate routing only enhances the SAP shortcomings and, in what the author thinks is the single most important conclusion of this dissertation, that a culture of method should always prevail over cunning actions, as the perceived short-term gains that pickers seek with their in-the-moment decisions do not compensate the losses in productivity caused by the deviation from proven methods over a longer period of time.

Finally the author would like to address potential future research. While satisfying its objectives, the research developed identified other possible avenues for optimization.

Within the established methodology there is still room for further optimization, for example by testing other class-based storage scenarios. There are various literature works regarding the positioning of classes, with several listed in De Koster et al., (2007) (the author suggest especially the works of Petersen et al. (2004) and Le-Duc and De Koster (2005)). As for routing, assessing the optimal routing solution could further add value, as well as assessing any other routing method not addressed by this work.

Additional methodology sophistication can be achieved by complicating the model to include for example the simulation of the automatic handling operations responsible for the supply of the picking area. In this methodology, it is taken as a certain that the automatic handling will never bottleneck the
process, keeping always the picking zone supplied. A simulation of the automatic handling movements would relieve the picking model of this simplification and also allow a possible parallel optimization of the automatic handling, with benefits for all C2 processes.

7. References


