Optimization of Orders' Processing at Worten's Distribution Center

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Abstract

The emergence of online commerce has changed consumer expectations regarding product availability and presentation, driving the evolution from typically linear to networked supply chains, integrating multiple trade and communication channels (omnichannel) and making operations more responsive to customer needs. At Worten's largest logistics center, the Azambuja warehouse, thousands of products – that vary greatly in size, handling specifications and storage typology – are received, stored and prepared. The combination of large orders (for stores) and small orders (for customers of the online channel) in the same space gives rise to challenges in order to improve these processes. The picking operation for orders attracts most of the resources in its process, making it prone to improvements. Assigning products to storage locations is a strategic decision that conditions the efficiency of picking and, at Worten, this decision is not supported by the most effective and scientifically proven methods. This work aims to analyse the implications of the problem verified in Worten's case study, review similar cases present in scientific literature and, based on these learnings, propose and develop a methodology capable of leading the work to the objectives proposed together with the company.

Keywords: Retail Logistics, Warehouse Design, Storage Location Assignment, Storage Policies, Order Picking.

1. Introduction

Assuming the role of biggest consumer electronics retailer in Portugal, Worten concentrates all its logistics operations in a warehouse located in the outskirts of Lisbon – in Azambuja.

This 50.000 square meters space integrates cross-docking and warehousing operations, working with over 60.000 products, and fulfilling both B2B (retail stores) and B2C (individual customers) orders from multiple channels.

The challenge arises to coordinate omni-channel orders' processing within a lead time that meets customers' expectations. Thus, the pressure is put on the operations that have the most impact in the order cycle, such as assignment of products to storage locations and subsequential order Picking policies and routing.

2. Case Study

2.1. Problem Definition

The storage, handling and preparation of orders, which used to be done in separate channels, are now done in the same space - in the case of Worten, these operations take place in the Azambuja warehouse. Order preparation is a crucial process in all warehouses and its efficiency depends on decisions made for processes that precede it, such as storage policies, the configuration of corridors with racks (layout decision), as well as decisions regarding the Picking methods used and the allocation of resources for the operation.

Currently, 80% of the time invested in Picking operations is confined to small domestic products' storage area – internally referred to as storage zone 708 or WH708. This zone consists of a sequence of 15 corridors with racks on both sides which are crossed by 2 equidistant transversal corridors. Therefore, Worten's Flow Engineering department has concluded that optimizing the order preparation process in storage zone 708 will lead to the greatest benefit – comparing this storage zone to the others – contributing to the overall reduction of the order cycle time in the warehouse.

The assignment of storage locations to items arriving at the warehouse does not take into account popularity (number of times a SKU is ordered), availability (i.e. frequency and quantity delivered by suppliers) or affinity between items (frequency with which different items are ordered together). This leads to an order in the Picking process setting up items that are often not available in active locations or are in locations far away from each other, which makes the routing of operators inefficient – this negative effect is amplified by the fact that there are many Picking circuits every day.

The decisions regarding the layout of the warehouse also create restrictions for the optimization of Put-Away and Picking processes, in the sense that, at this moment, the layout of the aisles (of racks) configures a defined circulation direction for each aisle, and the directions of the aisles along the 708 storage zone follow an S-shaped configuration – which conditions the routing of Picking circuits. Another restriction that conditions the routing of these circuits is a circulation rule, in the warehouse, which defines that only reach trucks (used in replenishment) can cross the transversal corridors - as they are slower than the other vehicles and the replenishment operation has priority over the other operations developed there – all other vehicles can only pass briefly through the transversal corridors when they intend to bypass a corridor.

2.2. Warehouse Operation Flows

Inside Worten's warehouse, operation flows for each product are defined by labels – assigned to products as they arrive in the warehouse.

These labels follow a colour system that indicates the destination of the articles, that is, the flow that the articles will follow in the warehouse. The colours of the labels indicate the following:

- *Yellow Label*: indicates that the goods will be prepared for shipment the same day, in a cross-docking process, to the stores. This flow is called PBL (or "production to store").
- *Pink Label*: indicates that the merchandise is of the long-tail type, that is, they are specialized articles or with a value that leads Worten to choose not to have inventory of them. Typically, the lead time for orders of these items is longer than that of other items. These items may be destined for the PBL flow – being sent to a store in order to create stock – or for the Online flow – being sent to a store for collection by a customer (click-and-collect) or sent directly to the customer's home.
- *White Label*: indicates that the goods are destined only to create stock in the warehouse, that is, they will be stored (Put-Away) – this process belongs to the PBS flow and to the PBLS sub-flow (internal nomenclature that does not refer to an acronym, is a sub-flow that links the stock to production, or PBL) – so that later they can be collected for order preparation, through the PBS or Online flow. The handling of goods with this label has a lower priority when compared to the priority of the other labels. A depiction of these warehouse flows is shown on *Figure 1*.

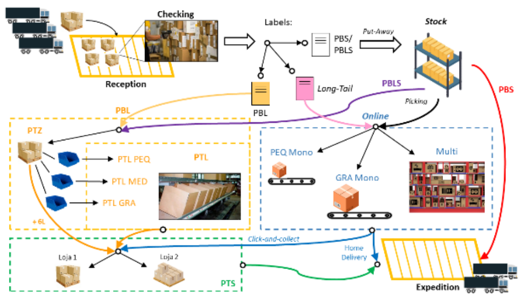

Figure 1 – Warehouse Flows.

Looking from the perspective of items stored in storage zone 708, they may only be picked to integrate in one of two flows: either the product is picked to follow the PBL flow – in which case it will be carried from the storage location to a zone called PTZ – or it is picked to follow the PBS flow – being carried from its storage location to another zone called PTS.

In PTZ, products arrive in bulk and are broken down into smaller units, following their way to the next zone, which is called PTL (as in “Put-To-Light”). In this next zone, products are sorted into boxes – being that each box represents a single order – and, once a box has all the products for its order, it follows on to the final preparation zone: PTS (Put-To-Store). In the PTS zone, boxes (i.e. orders) are sorted according to their destination, in order to build full pallets that will later be delivered at stores (for stock or customer collection) or at the courier post (in case they are destined to individual customers’ addresses).

3. Literature Review

3.1. Planning Warehouse Operations

In addition to decisions taken at the strategic level – such as warehouse design decisions, which will define and limit the operations that will take place there, as well as the type of products that will be stored and handled – it is necessary to choose and implement methods and/or policies - at the tactical level – that will serve as the basis for the operations to be performed in the warehouse.

A major challenge for warehouses today is to reduce the order cycle time – an aspect that has been gaining importance in omni-channel operations. The expectation of short delivery times by customers creates pressure to reduce the time from the moment the order is placed, picked (Picking), consolidated, packed and shipped (Hübner et al., 2016). To overcome this challenge, operations in omni-channel warehouses - such as Worten's warehouse - set up more cross-docking flows, cutting out storage (Put-Away) and Picking processes and taking the items from their reception directly to order preparation and shipping. Even so, the replenishment of physical stores and online order fulfilling is often done using items that are in stock, therefore it is necessary to coordinate their Put-Away and Picking operations. This is where the importance of tactical decisions that will allow these operations to be carried out efficiently comes into play.

Davarzani and Norrman (2015) highlight the following tactical decisions crucial to the operation of a warehouse: where to store SKUs; how much space is needed for each item; what storage policy should be followed; how items should be classified; and how to plan the sequence of operations. These decisions must consider the Picking activities because everything that is done in the storage phase (Put-Away) directly influences the efficiency of these activities.

3.2. Product Classification and Allocation

After receiving a product in a warehouse (or logistics center), the warehouse management system (WMS) will have to assign a typology to this product, in order to decide the destination of the product and to allow the subsequent operations (namely the storage operation) – this task can be carried out by a person or the WMS.

According to Brynzér and Johansson (1996), products typically have several characteristics that can be used to classify them and assign a storage location, such as frequency (of arrival and/or dispatch), volume (or dimension in a given axys), weight, serial number (or relative number, in case it is a constituent part of a device), supplier, among other characteristics.

In 1999, Liu noted that the reduction of costs, space used and distances covered should be taken into account in the operation of any warehouse considered efficient. Therefore, the objective of finding solutions to the problem of assigning locations to the stock is to reduce space requirements, as well as minimize the total distance travelled within the warehouse – these are the main operating costs of a warehouse. It should be noted that for many products, these objectives may conflict. Different policies for assigning storage locations can reduce different operating costs in the warehouse.

In order to support the decision regarding the assignment of storage locations to items in a warehouse, the scientific literature suggests adapting the storage location assignment problem (or SLAP) using policies that fit the SKU profiles (dimensional characteristics and handling requirements) to be stored in each area/department and the technology available there.

Typically, optimization problems - such as SLAP - produce the best results, but taking into account their limitations, other methods of location assignment have emerged to meet the specific needs of storage operations that do not fit those studied by SLAP.

Quoting Hsieh and Tsai (2006), one of the criteria/methods used to assign storage locations to product classes that is able to capture popularity – refers to the frequency with which a product is stored or ordered for order preparation – and space requirements of a product, is the COI (or "Cube-Per-Order Index"). Muppani and Adil (2008) define COI as the ratio of the storage space occupied by a product (usually its volume) to its popularity. This storage policy – created by Heskett in 1963 and later developed by Kallina and Lynn (1976) – dictates that products should be ordered in ascending order of their COI and, in the same order, placed in storage locations as close to the loading and unloading docks as possible.

The principle of the COI rule for assigning storage locations is based on reducing the distances travelled in a storage area where Put-Away and Picking movements are made. In a context where there is great variability in the volume of SKUs, the implementation of the COI method results in shorter travel distances than those verified by the implementation of the traditional ABC method – this is due to the fact that among SKUs with the same popularity, but with different space requirements, it is possible to place more items with smaller dimensions near the loading/unloading docks. Thus, most movements will be made in the areas closest to the places where the Put-Away and Picking operations begin and end.

3.3. Order Picking

Picking in warehouse is referred by Hall (1993) and Caron et al. (2000) as the process of collecting products stored in various locations for the preparation of a customer's order – a strategy called individual order picking or pick to order – or for the preparation of a set of orders at once – this case branches into some different strategies. Coyle et al. (1996) claim that the Picking process is an important link in the supply chains and that it constitutes about 65% of a warehouse's total operating costs.

Koster et al. (2007) state that, traditionally, the design of a Picking system intends to determine the general configuration of the warehouse that ensures minimum values for the distances covered and, consequently, processing times. The authors add that there is a crucial relationship between order picking and the level of service of a warehouse, because the faster the products of an order are collected, the sooner they will be available for shipment to the customer.

Petersen and Aase (2004) infer that the three process level decisions - considered most recurrently in the existing literature - refer to: how to store products (storage strategies/policies), how to collect products (Picking strategies and methods) and how to make Picking routes for the operators in the warehouse.

4. Methodology

A methodological proposal is presented in this chapter for the development of an operational planning tool that will support the decision of assigning storage locations to the items arriving at Worten's warehouse.

4.1. Storage Allocation Methods (Slotting)

Some examples of slotting algorithms can be found in the scientific literature: Li et al. (2015) propose a genetic algorithm based on the affinity between items that minimizes the distances travelled when you want to pick items on demand and for items that tend to be ordered together; Jahani (2016) designs an algorithm that optimizes the allocation of items based on their dimensions and cost of handling and replenishment; Petersen et. al (2005) lists some slotting methods that use different measures as factors for deciding the locations of items in a warehouse and conclude that the COI (Cube-Per-Order Index) method – which makes a ratio between the volume of an item and its turnover – comprises the most important measures for the other methods while maintaining a simplicity of implementation that makes it adaptable to the most varied storage operations.

Considering the time available for collaboration with Worten – the six-month internship – and the work associated with conducting the data from the operation (WMS database) to the environment where it was processed (SQL language conjugation with R's development environment), it was necessary to find a balance between the complexity of the slotting algorithm – the amount of data that would serve as input and a multiobjective optimization – and the feasibility of implementing it in Worten's operation.

Therefore, the COI method appears as an alternative to optimization methods, and its implementation is less complex and adaptable to Worten's operation. This method considers the popularity of the products and their dimensions – which enable ensuring that the most popular items are in more accessible locations in terms of distance travelled and ease of collection, thus contributing to reduce the distance travelled within storage zones**.** By adapting the COI – considering the different storage typologies of the items and dimensions of the storage locations in Worten's warehouse – and using information regarding the number of units of each item that tend to configure each order, it becomes possible to calculate (and maximize) the number of orders satisfied by a given active location (storing an item), thus reducing the number of replenishment movements.

4.2. Adaptation of the COI Method

The COI methodology follows the logic depicted in *Figure 2*, allocating the best storage locations (or zones) – according to their accessibility – to the items with the best COI – best being the lowest calculated COI.

In this work, COI calculation follows an adaptation to the original formula, depicted in *Equation 1*.

$$\mathbf{COI} = \frac{[\#\ \text{Orders fulfilled per location}]^{-1}}{\text{Popularity}} \qquad (1)$$

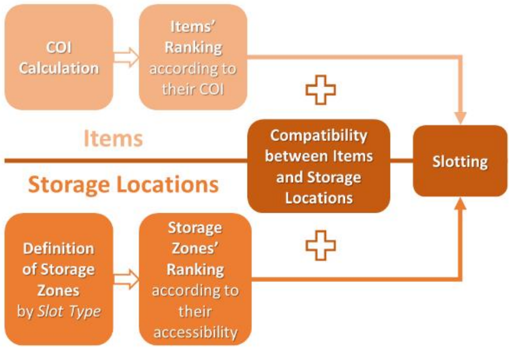

Figure 2 – COI Methodology

The change in this new COI formula is in the numerator, where – in the original formula – the dimensions of the item were, now a new factor is used: the number of orders fulfilled per (average) location that stores the item. This factor is calculated from data that Worten has for each item and storage location – as depicted in *Figure 3*.

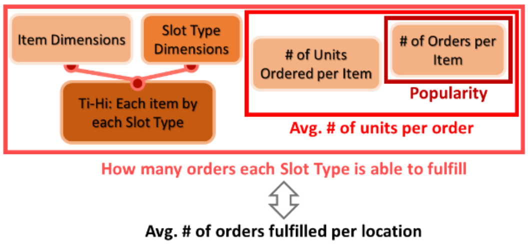

Figure 3 –Calculation of New COI Factor.

As to storage locations, zones are to be created following the COI method (see *Figure 2*). WH708 (in Worten's warehouse) has aisles that traverse the whole warehouse with storage racks on both sides. These aisles – from EV (far left) to SD (far right) – are crossed by two equidistant cross-aisles, leaving each storage aisle segmented in three parts – a North (N) segment, a Center (C) segment and a South (S) segment. Each of these segments becomes a particular storage zone, being that in each of these zones only one slot type exists and the accessibility is considered uniform in each storage zone (and different from one zone to another). The resultant layout is depicted in *Figure 4*. The colour of each storage zone represents the slot type of that zone, being: red (Low Pallet slot), green (Medium Pallet slot), purple (High Pallet slot), yellow (High Shelf slot) and blue (Large Honeycomb-like slot).

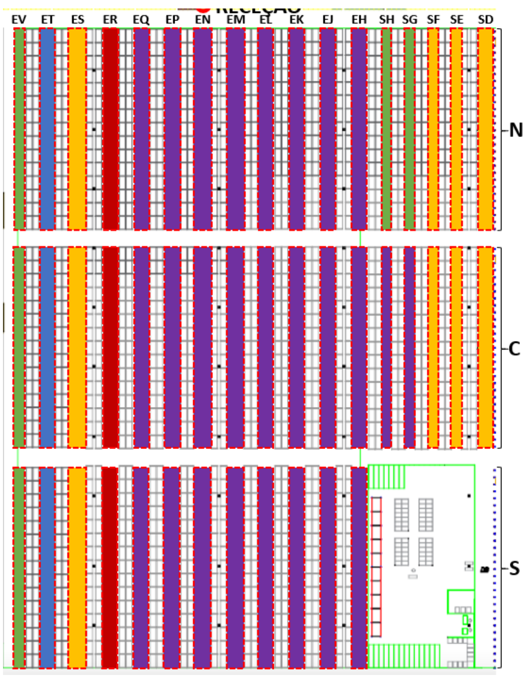

Figure 4 – Storage Zones in WH708.

The accessibility of each storage zone is measured by bringing together the distances from each zone to each of the input and output (I/O) points – being that input refers to the reception zone and output refers to both the PTS and PTZ zones – as well as the relative weight of the Put-Away and Picking movements made from or to each of these I/O points. As an example, in the year of 2019, the relative weight of Put-Away movements (from the reception zone) was 9.04% while Picking took the remaining 90.96% of total movements in the warehouse, 1.84% of which were destined to the PTS zone, while the remaining 98.16% were destined to the PTZ zone.
The compatibility between items and storage locations (or zones) is assessed by looking at the dimensions of each item and slot type of each zone. If at least one unit of the item fits into the slot type of the zone, then those two are considered compatible.
The allocation of items to storage zones (i.e. slotting) will be done automatically by an algorithm that will be encased in the tool developed for Worten.

4.3. Development of Worten's Slotting Tool

In order to deliver a fully functional slotting tool that uses Worten's data (collected in real-time by the warehouse management system, i.e. WMS) to feed a slotting algorithm, from which results are extracted and then displayed in Power BI dashboards that will be used to assign tasks to operators – who will move items to their assigned locations –, a data mining methodology based in CRISP-DM (or Cross Industry Standard Process for Data Mining) was employed – see *Figure 5*.

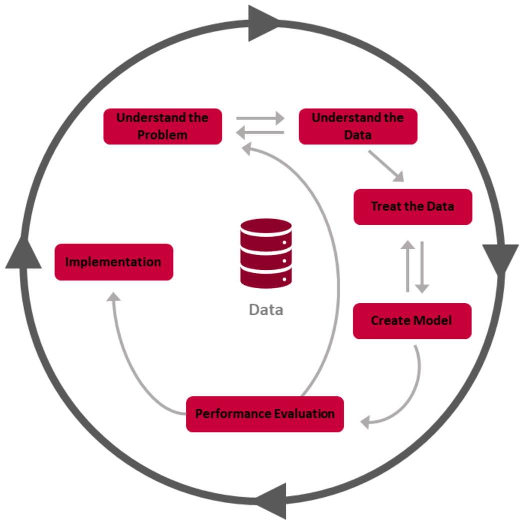

Figure 5 – Methodology used to deploy Worten's storage allocation solution.

Following the definition of the problem and close cooperation with both management and operational employees on Worten's side, there is a consensual understanding of the problem at hand – the first phase of the methodology depicted in *Figure 5*.
In the next phase, there needs to be an understanding of the data structures and flows in Worten's systems, in order to enable collection of all relevant data that may serve the purpose of solving the verified problem.
Worten's WMS saves data collected from the warehousing and order fulfilment operations in tables which are stored in SQL (Oracle) databases. The overall structure and content of these tables is depicted in *Figure 6*.
Having understood the data available, the next phase consists of treating this data in order to turn information in bulk into meaningful data that can be used to calculate factors which may serve as input for a storage allocation model.

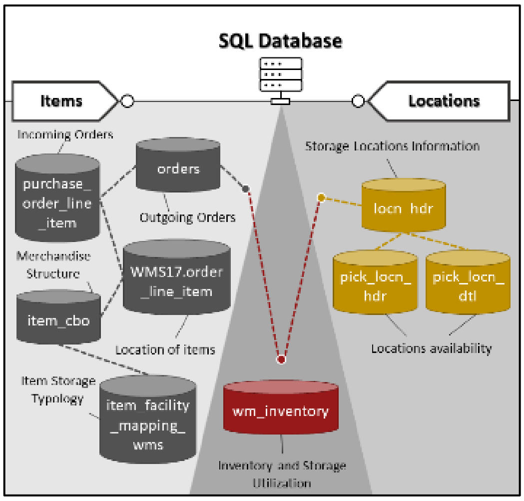

Figure 6 – Worten's SQL Database Structure.

The treatment of the data is done through means of a script – in R programming language – which integrates SQL queries to extract the data (in bulk).

Following the development of the whole data flow – from Worten's WMS to the treatment in R's script and subsequent exportation to Excel worksheets – a slotting algorithm is created in order to match items to storage locations. This algorithm is built in GAMS IDE (or Integrated Development Environment) and ensures the items with the lowest value of COI are assigned to the storage zones with most accessibility (less weighted distances to I/O points) – according to the COI method, which minimizes distances travelled in Put-Away and Picking processes.

Evaluation of this whole model's performance is made by comparing the results of the slotting tool (To-Be scenario) against the actual situation (As-Is scenario). The As-Is scenario has items stored in their actual locations (the locations they are assigned to at the time of writing this paper), while the To-Be scenario has items stored in the locations suggested by the slotting algorithm. Both of these scenarios are evaluated through means of a simulation made in AnyLogic (a Java-based simulation software). This simulation consists of a deterministic analytical model, where orders for items are perfectly determined (in terms of the quantities of items ordered and the time they arrive at the warehouse) and the only distances travelled are confined between storage zones and the I/O points.

5. Results Analysis

5.1. Data Processing

Specifications on the data collected (referring to the year of 2019) and treated are provided in *Table 1*.

The analysed storage areas are 46 (6 of which are blocked and unavailable for allocation), which represent more than 19,000 storage locations that were active in the period under analysis. Regarding these storage locations, there are five different types of locations or slot types, which due to their size characteristics or other restrictions will have limitations on the SKUs they can store.

Table 1 – Data collected from Worten's operation.

ITEMS	Nr. of items	13.000+
	Categories	102
	Classes	24
	Subclasses	32
	Incoming Orders	189.774
	Outgoing Orders	1.434.456
LOCATIONS	Nr. of Storage Zones	40
	Nr. of Picking Locations	19.388
	Nr. of Distinct Slot Types	5

The five types of existing locations (or slot types) - which are: High Pallet, Medium Pallet, Low Pallet, Large Shelf and Large Honeycomb - vary in terms of dimensions, both in area and height available for storage of items. The area of the High Pallet, Medium Pallet and Low Pallet locations allows the storage of articles on Euro pallets (120 by 80 centimeters) - allowing the storage of articles as they arrive at the warehouse, sometimes without the need to break the pallet, thus saving time in intermediate operations that do not add value. The Large Shelf and Large Honeycomb type locations only have the capacity to store products in smaller typologies (storage by the unit or in boxes with multiple SKU units).

Furthermore, storage zones destined to the PBL flow (smaller items) have more storage locations with low volume capacity – such as the Large Honeycomb and Low Pallet type – , while the zones that store PBS flow items (larger items) have more storage locations with higher volume capacity – such as the High Pallet type.

Having delimited the different storage zones with varying slot types (see *Figure 4*), it is intended to determine the accessibility of each zone. Having into account the circulation directions in each aisle, as well as the location of the input/output points and relative weights of movements done from and to these points, the slotting algorithm will dynamically calculate the weighted distances from each storage zone to the I/O points – this will be our accessibility measure.

5.2. Adapted COI Index Calculation

After calculating the COI value (adapted) for the items that belong to WH708 *Racks*, three classes were created in order to analyse the most relevant factors that influence this index and to validate this COI method adaptation. Those three classes are: Class 1 (items with COI ≤ 1); Class 2 (items with COI higher than 1 and COI ≤ 10); and Class 3 (items with COI > 10). Note that, adding to these three classes is another class with items for whose COI is equal to 999999 – which means that there is no history of outgoing orders for these items, therefore they are allocated to reserve storage locations.

From the 13.000+ items considered, the distribution in the classes mentioned before is as following: 6792 items configure Class 1; Class 2 has 1580 items; Class 3 has 1017 items; and 3833 items have a COI of 999999 and therefore are allocated to reserve locations.

To analyse the characteristics of items in each class, average values for volume, number of outgoing orders and number of orders fulfilled per location were calculated – these are the main factors that influence the adapted COI calculation. These average values can be seen in *Table 2*.

Table 2 – Average COI factors by COI Class.

Class	Volume (cm^3)	Outgoing Orders	Orders Fulfilled per Loc.
1	3.800	423	340
2	17.186	34	103
3	47.042	7	16

The values in *Table 2* indicate that items from Class 1 have, in average, less volume, more outgoing orders and orders fulfilled per location that Class 2 and Class 3. The same can be said about Class 2 in comparison to Class 3.

Taking another look at Figure 8, it is possible to understand that Class 1 is the most representative, containing around 51% of all items that belong to WH708 Racks – meaning that roughly 51% of the items to be stored have a COI index of less than 1. Thus, it is relevant to develop a detailed analysis on this class alone. *Table 3* shows the distribution of items belonging to Class 1, regarding their COI index.

Table 3 – Distribution of items into divisions of Class 1, according to their COI index.

Division	COI Interval	% of Class 1
1	[0; 0.059022668]	51.18%
2	]0.059022668; 0.118022668]	13.13%
3	]0.118022668; 0.177022668]	8.19%
4	]0.177022668; 0.236022668]	5.23%
5	]0.236022668; 0.295022668]	4.03%
6	]0.295022668; 0.413022668]	5.58%
7	]0.413022668; 0.590022668]	5.57%
8	]0.590022668; 1]	7.08%

In *Table 3*, one can see that more than 51% of the items that compose Class 1 have a COI between 0 and 0.059022668 (Division 1), while only 7.08% of the items in this class have a COI higher than 0.590022668 – which corresponds to roughly 40% of Class 1's COI interval (i.e. COI from 0 to 1).

Aiming at studying the same factors present in *Table 2* – but this time for the 8 divisions of Class 1 – a statistical analysis comprising the distribution of items in each division regarding their levels for each factor (volume, number of outgoing orders and number of orders fulfilled per location) is developed.

By comparing the COI classes (in terms of distribution of the articles according to the factors described), it is possible to verify that the adapted COI method rewards articles with low volume, high popularity (i.e. many outgoing orders) – similarly to the original COI method – and additionally gives weight to the quantity of orders satisfied per location, thus rewarding items whose dimensions are small and whose sales trends – in terms of the average number of units configuring each order and number of orders of the item – allow minimizing the replenishment movements. Faced with this comparative analysis, it is also possible to verify that the popularity factor (outgoing orders) has greater weight than the other factors – thus considering the reduction of distances covered in Put-Away and Picking movements without, at the same time, bleaching the distances covered in replenishment movements. In conclusion, there are strong indications that adapting the COI method – as an item classification criterion – is a robust and relevant method for Worten's operation, enabling the classification of the wide range of products marketed by this company.

5.3. Slotting Algorithm and Simulation Model

After running the slotting model, a table containing the matching between items and storage zones is obtained. To make these results easier to read and to communicate to the teams that will move the items, another R script is made – which will automatically read the table with results and make those results (along with statistics report) available in a Power BI dashboard. The resulting dashboard is depicted in *Figure 7*.

In the centre of *Figure 7*, a table shows, in each row (from the leftmost column proceeding to the right): the identification of the SKU, the type of flow in which this SKU is inserted (that can be PBL, PBS or SM, if the items is a slow mover), the storage zone where the SKU is currently stored (As-Is location) and the storage zone allocated to the SKU by the slotting tool (To-Be location). The pie chart on the left of the table shows the distribution of SKUs (that will be subject to slotting) per type of flow, while the pie chart on the right corner of *Figure 7* shows the distribution of Put-Away movements according to the type of flow of the SKU that is being moved. Below this last pie chart is another chart which refers to the distribution of Picking movements according to the type of flow of the SKU moved.

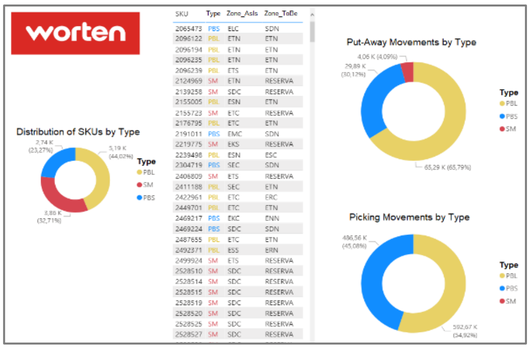

Figure 7 – Dashboard with Slotting Results Report (Power BI).

Moving on to the evaluation of the slotting model's performance, two simulation models were developed in AnyLogic: one for the As-Is scenario (containing current storage location assignments) and another one for the To-Be scenario (containing the item-to-location assignments suggested by the slotting model). Due to the extensive data that needs to be loaded into the simulation model (for both scenarios), the problem was divided in three parts, each referring to a different time period of the year of 2019. Some statistics about the simulation model (including time periods, orders fulfilled and simulation times of each part of the problem) can be seen in *Table 5*.

Table 5 – Statistics of the simulation model.

	Periods	Orders Fulfilled	Simulation Time (s)
Part 1	01/01/2019 ~ 30/04/2019	560366	12840
Part 2	01/05/2019 ~ 31/08/2019	531927	15357
Part 3	01/09/2019 ~ 31/12/2019	1145606	23390
Total	Year of 2019	2237899	51586

By then comparing the results of both simulation models – presented in *Table 6* –, it is possible to prove that the slotting model based on an adapted COI method produces improvements to the slotting method currently used by Worten – providing savings around 27% in terms of distances travelled in Put-Away and Picking movements around the warehouse.

Table 6 – Results Comparison: As-Is vs To-Be.

Results	As-Is	To-Be	Change
Total Distance (km)	650734.30	472904.99	-27.3%
Total Cost (€)	429,714.0 €	312,288.0 €	-117,426.0 €

These savings – which correspond to around 110000€, calculated by comparing the travelled distances in both scenarios (As-Is and To-Be) and assuming an average travelling speed of 2.52 m/s (combination of the different mobility devices used in the warehouse) – are equivalent to approximately 7 FTEs (Full-Time Employees) per year.

6. Conclusions

The current structure of the tables in Worten's database does not include data that relates the search for a given item to that of another item – the concept of affinity between items –, so changes in this structure and in the scope of the data collected from the operation may lead to new interpretations of the data and reveal new possibilities for improvements in storage processes.

The inclusion of variables/factors related to product affinity in the adapted COI method should lead - in conjunction with Cluster Picking circuits – to more significant improvements in the order preparation process, so this is an aspect that should be studied in the context of the continuous improvement of processes in Worten's warehouse.

By aggregating orders in such a way that more Batch Picking circuits can be created, it will be possible to verify the benefits associated with the synergy between the slotting method developed here and this Picking policy, leading to conclusions regarding the impact this decision may have on the warehouse's service level and operational costs. The service level should reduce – since there will be fewer Picking circuits due to the aggregation of orders that should delay their preparation – but this negative effect can be compensated by a reduction in operating costs – fewer Picking circuits (compared to Cluster Picking circuits) that should configure more items imply fewer trips within the warehouse.

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