Testing the performance of warehousing rival policies through discrete event simulation

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Abstract

This research tested the performance of alternative warehouse designs concerning the picking process. Travel Distance and Total Fulfillment Time were the chosen measures. An explanatory case study was built up around a model implemented with SIMUL8. Hypotheses were set by selecting outcomes of the literature survey matching popular empirical findings. 15% reductions were found out for Total Fulfillment Time and Resource Utilisation, which was used as a proxy for operational efficiency. Literal replication of theoretical data patterns was considered as an internal validity sign. Assessing estimated changes benefits ahead of implementation was found out as a relevant contribution to practice.

Keywords: Warehouse discrete-event simulation; Storage policy selection and assessment; Performance evaluation of order picking

Introduction

The sponsor of this project, GrandVision's Logistics, has questioned about ways to improve organization, operation and performance of its main warehouse, with a minimum disturbance, in Portugal. Thus, the main objective of this assignment is to use previous research findings to propose improvements to the current performance of the warehouse of GrandVision, supported on theoretical grounds. Moreover, a convincing what-if tool should back up the change process, in order to mitigate the disruption risk of the commercial operation.

In fact, *"Performance evaluation provides feedback on the quality of a proposed design and/or operational policy, and more importantly, on how to improve it"* (Gu et al., 2010). Therefore, it is essential for every warehouse operation to have its performance constantly accessed according with well-defined criteria. Among them, the following are commonly mentioned: Investment and Operational Costs, Volume and Mix Flexibility, Throughput, Storage Capacity and Order Fulfillment Quality (Accuracy) (Rouwenhorst et al., 2000); however, Travel Distance and Total Fulfillment Time, i.e. total travel and picking times, are the most used, when referring to traditional warehouses. Moreover, it is known that the operational process concerning order picking represents ≈60% of the overall operating costs in a traditional warehouse, being the most labour intensive process. Order picking is also the most difficult process to manage (Frazelle, 2002; Petersen et al., 2004; Van den Berg, 1999) and it is significantly affected by the storage (Chan and Chan, 2011; Rouwenhorst et al., 2000) and routing policies (Petersen et al, 2004).

Furthermore, discrete-event simulation is found out as a relevant approach to test several combinations of warehousing policies and their impact on the operations performance, since it is widely used in the warehousing context. SIMUL8 software is, then, selected because it is a robust, user friendly tool, which has showed adequate to the implementation of conceptual models and to a powerful what-if analysis. In this way, the «as-is» model is built to represent the current situation. Secondly, the improved new model is also built.

Two hypotheses concerning the Picker-to-Parts Warehousing System Performance are tested in both models. In the new model, the pickers utilization decreases 15%, which was found related to an efficiency improvement, despite the effect of Golden Zone Storage Implementation Strategy could not be isolated. The Total Fulfillment Time also improved by 15%.

Next section presents the literature review. After that, the case study in the GrandVision’s Logistics is reported. On one hand, this serves the purpose of testing the solutions for the sponsor context as a potential contribution to practice, despite the results were not implemented. On the other hand, it represents a contribution to theory testing through the confirmation (or not) of the established hypotheses. Finally, the conclusions section closes the paper.

Setting a theoretical background

Warehouses are strategic infrastructures built to *facilitate the movement of goods through the supply chain to the end consumer* (Rushton et al., 2010). A storage system (Rouwenhorst et al., 2000), order picking system (De Koster, 2007), or just warehousing system (Van den Berg and Zijm, 1999; Van den Berg, 1999) refers to specific combinations of human resources and technology, which allow material handling activities to be accomplished in an effective way. Their operating costs represent about 22% of the overall logistic costs in the USA (Establish, 2005), while in Europe the percentage is around 25% (ELA/AT Kearney, 2004).

Several authors have pointed out a lack of systematic approaches for warehouse design (Baker and Canessa, 2009; Goetschalckx et al., 2002; Rouwenhorst et al., 2000). Moreover, warehouse decisions are regarded as highly complex as often address conflicting performance objectives, e.g. costs, throughput, storage capacity, response times. Thus, tradeoffs have to made (Rouwenhorst et al., 2000).

The flow of items through the warehouse can be divided into distinct phases, which are called processes; the design of the process flow is considered a strategic level decision (Rouwenhorst et al., 2000). Most literature refer four basic processes: receiving, storage, order picking and shipping; nevertheless, some authors go more in detail and include other steps as pre-advice, checking, put-away, replenishment, packing and cross dock (Richards, 2011).

A great number of warehouses are designed to have a reserve or bulk storage area, where products are stored in the most economical way, and a forward or fast pick area, where products are stored in a way which increases picking productivity in 10-20 times (Frazelle, 2002). In this kind of layout configuration inventory must flow cyclically from the reserve area to the fast pick area, a concept defined as replenishment.

The big majority of warehouses employ humans in its activities, and three different order picking systems are found in warehouses: picker-to-part systems, put systems and parts-to-picker systems. *Picker-to-part systems* weight about 80% of all order picking systems in Western Europe (De Koster, 2007). Order picking is the most important process in a traditional Picker-to-Parts or Manual Warehousing Systems (Van den Berg, 1999). It can be defined as *"the process by which products are retrieved from storage to satisfy customer demand"* (Roodbergen and Vis, 2005: 799). Orderpickers travel along aisles collecting items either from bins at low-level storage racks (bin-shelving), or from high-level storage racks. Petersen et al. (2005) suggest that placing higher demand SKUs in the "golden zone" – the area between a picker's waist and shoulders – would significantly reduce total fulfillment time, although it might increase travel distance (*vide* also Saccomano ,1996 and, Jones and Battieste, 2004). Pick carts and container carts are vehicles widely used for low-level picking, whereas high-level picking operations are done by the help of man-aboard lifting trucks or cranes (Van den Berg and Zijm, 1999).

Storage is a major warehouse function and the way material is destined to storage locations is the most important factor affecting the performance of the order picking process (Chan and Chan, 2011; Rouwenhorst et al., 2000). Hence, storage and order picking should be considered a cluster of problems, and decisions regarding its policies should not be taken isolated. According with Petersen et al (2004), order picking performance depends on three main aspects: picking policies, routing policies and storage policies. Different combinations of these policies will result into considerably different operations. Therefore, it is worth taking a closer look to each one of them.

Picking policies concern the number of orders (and therefore items) picked by an orderpicker during a picking tour (Frazelle, 2002). Three basic picking alternatives can be identified: single order or strict order picking, batch picking and zone picking. After having decided the number of orders an orderpicker shall pick in a picking tour, one faces the problem of picking routes, which *"consists of finding a sequence in which products have to be retrieved from storage such that the travel distances are as short as possible"* (Roodbergen and De Koster, 2001:1866). Several routing heuristics and optimal procedures have been developed. Although optimal procedures offer the best solutions, they are often confusing and difficult to explain; while heuristics yield near-optimal solutions and are easier to implement (Petersen and Aase, 2004).

To sum up, order picking is not only the most costly and labor intensive process of a traditional (bin-shelving) warehouse, but also the most complex; hence, its «optimization» for cost-efficiency is usually a major design goal, being the objective maximizing throughput at minimum investment and operational costs.

Case study

Problem Statement

The problem statement can be resumed as shown below:

Given:

- Information on the Warehouse Layout
- A certain set of Human-Resources
- Information of SKU's stored in the Warehouse and its Turnover
- The average number of daily Replenishment Orders
- The average number of daily Replenishment Order Lines,

determine a combination of Storage, Picking and Routing policies, which will bring an improvement to the performance of the Shop Replenishment Operation.

Empirical Findings and Hypotheses

Empirical findings regarding Picker-to-Parts Warehousing System Performance from Petersen and Aase (2004), Petersen et al.(2004) and Petersen et al.(2005) helped to narrow the range of theoretical policy combinations to be tested. As a consequence, this research is focused on the effect of batching, class-based and golden zone policies, under the following hypotheses: (i) A Class-Based Storage Policy will improve GrandVision's Warehouse Replenishment Operation. (ii) A Batching Picking Policy will improve GrandVision's Warehouse Replenishment Operation. (iii) A Golden Zone Storage Assignment Strategy will improve GrandVision's Warehouse Replenishment Operation. Hypothesis (ii), i.e. changing the batching policy and its related impact in the simulation model are out of the scope of this paper. So, it is not tested.

Problem-solving methodology

The selected methodology to test different combination of policies was discrete-event simulation, as it is considered the best modeling approach for operations systems Robinson (2004) and, also, because it is widely used in the warehousing context (e.g. Chan and Chan, 2011; Petersen and Aase, 2004). Moreover, the SIMUL8 software was chosen because it is a very user friendly solution, despite being very powerful.

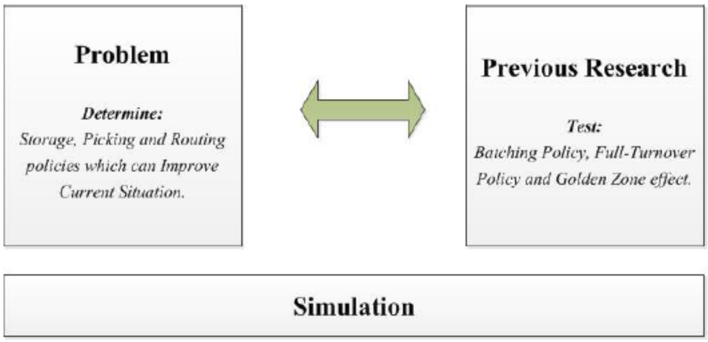

Figure 1 – Conceptual framework

Two models simulating the Shop Replenishment Operation were created, implemented and their results were contrasted to determine a combination of Storage, Picking and Routing policies to improve the current situation (Figure 1). Therefore, a change proposal regarding the SKU storage policy along with the implementation of a golden zone policy is presented as an alternative.

Developing and implementing the conceptual models

Simulation modelling requires an information input in order to emulate the performance of an operating system, as close as possible to the reality. In order to input that information in the simulation software, data was collected, not only from Management maps and from the company information system (ERP), but also by the observation of the replenishment operation, in the field. The required data are, as follows:

- Warehouse layout measures
- Data regarding the size and content of the Replenishment Orders (RO)
- Data regarding turnover of each SKU

- Data regarding picking times.

The first model that is created simulates the ‘as-is’ situation. Therefore, the storage and picking policies actually used were replicated in the model, as close as possible to the reality. The storage policy follows a Class-Based option based on the Type of Product, i.e. Frames and Sunglasses, either Private Label or Branded. In addition, the implemented picking policy is Strict Order Picking. Moreover, Traversal Policy was also considered in the simulation model, despite the routing policy being random, in reality, because this was found out as a good simplification approach. The ‘as-is’ situation is, then, depicted in Figure 2.

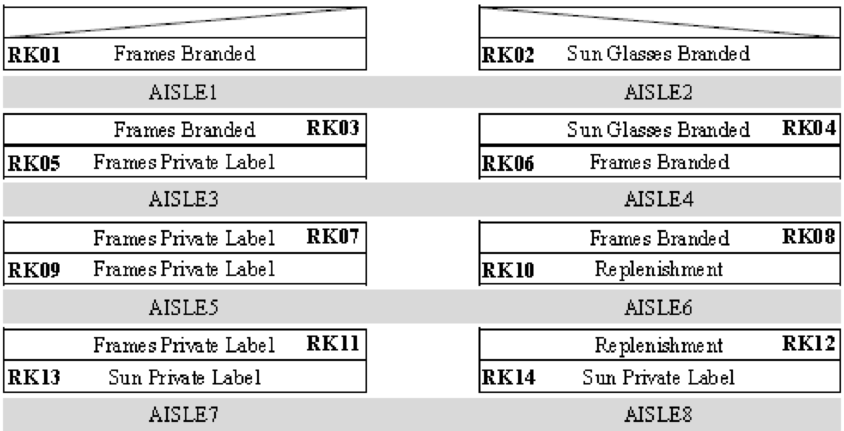

Figure 2 – Model for the current situation

From the analysis of the Turnover of each SKU, one concludes that the SKU “Private Label Sunglasses” is ranked higher, representing 49,5% of the Grand Total, followed by “Branded Sunglasses”, representing 21,8%, “Branded Frames” with 20,1%, and finally “Private Label Frames”, representing 8,6 % (Figure 3).

	Sales '11	%
Private label	82 841	58,1%
Sun Glasses	70 604	49,5%
Frames	12 237	8,6%
Branded	59 855	41,9%
Sun Glasses	31 175	21,8%
Frames	28 680	20,1%
Total	**142 696**	100,0%

Figure 3 – Turnover by type of product

As regards the Storage Policy of the alternative model simulating the Shop Replenishment Operation, it has maintained the consistency of Product Type (Frames and Sunglasses either Private Label or Branded), in order to simplify the picking operation. Nevertheless, the four different Product Type combinations are stored closer to the depot, according with its Turnover. So, this can be considered as a Class-Based Storage with two sorting dimensions, i.e. Type of Product and Turnover. Moreover, a within-aisle storage implementation strategy was chosen. Finally, the Golden Zone was also assumed in the improved model. Therefore, products with higher Turnover are located between waist and shoulders (Figure 4).

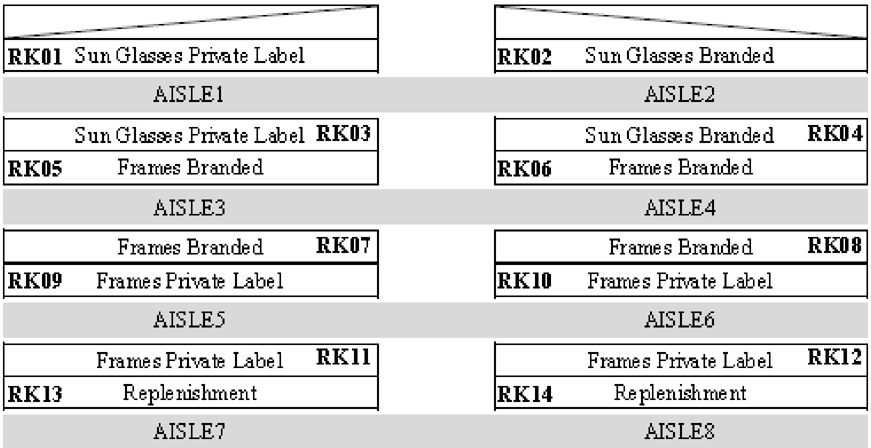

Figure 4 – Alternative storage policy

The next step is to use the SIMUL8 software to implement these conceptual alternatives. Figure 5 presents the result of this implementation. Despite the whole set of details could be found in Moreira (2013), a short explanation will be given in the next paragraphs to enable a broad overview of the depicted schema, as follows:

 - **Work Entry Point** – According to empirical data, a number of replenishment orders (RO), with a certain number of order lines and quantities of each SKU is created each morning. The RO are the Work Items of the model.

 - **Pickers** – There are 3 pickers available; in the model, they are the resources responsible for completing the RO. They should collect one RO, pick all items in it and then repeat the process until there are no other RO available to be picked.

 - **Routing Work Center** – At the front aisle, cross aisle and rear aisle there are work centers, which conduct pickers according to the established traversal routing policy. These routings are done by the means of programmed labels that analyze what is the next rack from which pickers should collect an item.

 - **Rack Work Center** – At each aisle there are two rack work centers. Labels are inserted in a storage spreadsheet file; in this way, the work item is tested when passing in the work center and pickers take the corresponding time to pick the amount of items in the corresponding rack. In addition there are also Golden Zone labels, distinguishing products which are stored or not in this special area.

 - **Work Exit Point –** the pickers collect an order, till there are no more orders to collect, when finishing to pick up another one.

 - Traversal Route first stage.

 - Traversal Route second stage.

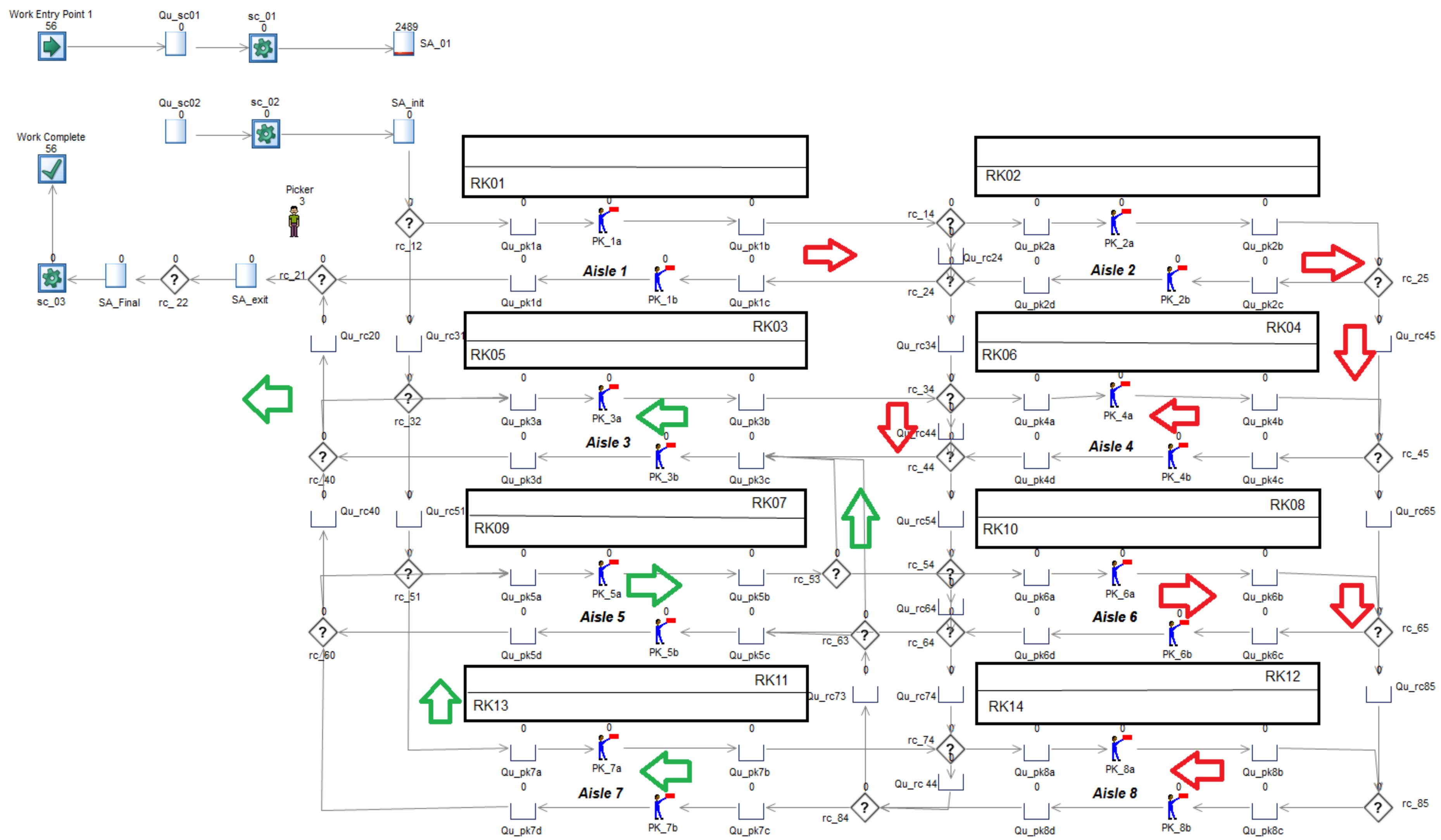

Figure 5 – Implementation of the conceptual models with the SIMUL8 software

Results

If one compares the new situation with the current one ("as-is") for the same amount of entered and processed Replenishment Orders, it might be concluded that the resource utilization decreased from ≈65% to ≈55% of the pickers' working day (Figure 6), representing an improvement of 15% in the warehouse operation. It should be noted that resources utilization was taken as a good measure of the operation efficiency. Therefore, the simple alteration of the storage policy, along with a Golden Zone policy implementation, brings in a significant increase in warehouse performance.

Before ("as-is" situation)

	Utilization %	Minimum Use	Current Use	Average Use	Maximum Use	Traveling %
Picker	64,743	0	0	1,942	3	0

After

	Utilization %	Minimum Use	Current Use	Average Use	Maximum Use	Traveling %
Picker	55,151	0	0	1,655	3	0

Figure 6 – Resource utilisation

The change brought an improvement of 15% on Total Fulfillment Time. Therefore, the simulation models confirmed the hypothesis (i) of improvement, i.e.

(i) A Class-Based Storage Policy appears to improve GrandVision's Warehouse Replenishment Operation

Although it was implemented in the simulation models, the effect of Golden Zone Storage Implementation Strategy was not measured, as it was not possible to isolate its effect. Moreover, the test of changing the batching policy is out of the scope of this paper.

Conclusions

This research has tested the performance of rival warehousing policies concerning the picking process by developing a model and implementing it with SIMUL8, a discrete-event simulation software. Hypotheses were set by fine tuning the outcomes of the literature survey with simplifications based on empirical evidence of other studies. The estimated benefits coming out of the simulation models are not far from the studies of Peter and Aase (2004), where improvements that range from 17% to 22% are referred.

A relevant contribution to practice is that GrandVision's management can assess the benefits from the proposed changes for its Shop Replenishment Operation ahead of their eventual implementation. Moreover, as the research results match the data patterns coming out of the literature, this is a sign of literal replication and so, of stronger internal validity of the model (Yin, 1994; Vilas Boas et al., 1998). This case study also performed a confirmatory role (Eisenhardt, 1989) by enabling the empirical test of the hypotheses previously set, which is a contribution to research.

Limitations and assumptions

Simulation modelling remains a representation of the reality, although there was a hard work of several months spent in collecting empirical data from the field to support this research. A reason for this concerns the assumptions and simplifications considered during the modelling process that cause limitations to the obtained results. Those are as follows:

- Travel Times within Aisles were not considered as there was one Work Center per each aisle;
- The Routing Policy in current situation was assumed as S-Shaped, when in reality it was random;
- Sales Turnover was selected as a slotting measure, which can raise two issues. Firstly, despite everything pointing out that for most of the SKUs, Sales Turnover and Warehouse Shipment Turnover match, it is known that there are some products, called obsoletes, which are sent to the shops but not sold. Secondly, as popularity is based in the number of hits of an SKU in picking lists, Sales Turnover represents a ratio per unit of time. The difference between this two slotting measures can more important, if there is a good amount of cross-docking operations taking place, as the largest portion of stock of some SKUs are only in transit through the warehouse. These are not stored for Picking Operations.
- Sales Turnover was considered as an average of the entire year period, which ignores the effect of seasonality, especially present in sunglasses.

In addition, the following limitations are also identified:

- What-if analysis regarding batching policies, order size and demand distribution was not done.
- Trials were not run in the simulation, thus the results present are only referred to a single case.
- I was not possible to isolate the effect of Golden Zone Storage Implementation Strategy.

All these assumptions and limitations provide an empirical gap that suport a requirement for deeper future work.

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