# Improving Warehouse Operation Flows

## The Case Study of Worten

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**Abstract**

In the past years, the retail market suffered constant evolutions specially enhanced by the continuous growing and subsequent preponderance of the internet on our everyday lives. In Portugal, smaller competitors could not accompany these changings remaining the ones with high financial power who, taking benefit of economies of scale, were able to practice lower costs when compared to traditional local retailers. The market became then controlled by a lower number of competitors that, practicing similar costs between each other, focused mainly on customer satisfaction and buying experience, always pursuing to provide the best service level in order to achieve customer loyalty, retention and preference.

In this sense, factors such as the expected increase in demand, space restrictions, the higher range of different products offered and the constant need of reducing costs forced the necessity of redesigning warehouse layouts and operation processes. This paper studies and provides an alternative, reliable, efficient and profitable solution for the configuration of the four main central warehouse operations of the Portuguese specialized retail company Worten.

**Keywords:** Retailing, Logistics, Warehouse Management, Warehouse Design Layout, Simulation, Automation

## 1. Introduction

In the consumer electronics retail market, in which Worten is inserted in, cost reduction and customer´s order fulfilment and satisfaction are the two main business drivers to be accomplished. This Portuguese company operates both in Portugal and Spain, having a main warehouse located in the centre of Portugal with an area of approximately 50,000 square meters, which supplies all the stores in the country.

The constant growth of the online business unit, the pressure to reduce lead times and costs, the omni-channel strategy followed by the company and the expected growth for company´s business areas led to the need of changing the current warehouse layout and redesign its operations in order to improve both capacity and productivity.

## 2. Case Study

### 2.1. Problem Definition

Worten sells a wide range of different products with opposing characteristics in terms of dimensions, volume, storage, handling and holding requirements which go from refrigerators to memory cards, passing by laptops and smartphones. This paper will only focus on the flow of smaller format products, not considering home appliances goods. For smaller format products, there are two main reception flows: PBS (Pick by Store) and PBL (Pick by Line). The PBS flow is characterized by the need of storing products prior to shipping. This need is related with the low suppliers´ service level in terms of both irregularities in the accomplishment of delivery dates and quantities or with suppliers whose delivery times are long. Being the most traditional warehouse flow it is, however, less productive - when an order is placed for these products, batch picking is done: one operator, with the aid of an electric pallet truck, transports two pallets at a time, each one corresponding to a store, and picks the products ordered by those stores, placing them in the corresponding store pallet – and more costly, due to the need of retaining inventory and stopped product at the warehouse. The PBL flow, contrarily, does not require to have inventory at hand and is similar to a cross-docking operation - products are shipped at the same day they are received. Products are sorted by preparation zone at the act of receival and expedited at the end of the same day. This flow is related with high service level suppliers that have various delivery windows during a week avoiding retaining inventory. There are, however, certain exceptions as it is the case of a supplier that delivers on day *x* and *x+2*, and the product is intended to leave for a certain store on day *x+1*. In this specific case, this product might be stored until day *x+1*. In these cases, products are bulk picked – one operator, with the aid of a forklift, picks **all** the products that **all** the stores ordered for that day. Afterwards, these products will be sorted by their corresponding preparation zones. In terms of efficiency/productivity, it is already proved that bulk picking (PBL) is by far preferable to batch picking (PBS), which can be understood by this simple example: considering product A was ordered by stores 1, 2 and 3, for the PBS flow, on operator would have to go to that pick location that has product A stored two times, once this operator can only transport two pallets/stores at a time. In the case of a PBL flow, the operator would have to go only once, because the sorting by store would be done afterwards. Additionally, the pallets prepared in both flows are treated independently even if they have the same store destination. This leads, in some cases, in sending two half-full pallets leaving the warehouse to same store, one from PBL flow and the other from PBS, which has the consequence of a lack of space usage in trucks. In some considerable cases, the products contained in these two pallets could be stored only in one full pallet. Because the transportation partners contracted by the company charge by pallet, along with the fact that bulk picking is much more efficient than batch picking, the junction of PBS and PBL flows becomes a major issue as to reduce transportation costs and improve operational efficiency. Furthermore, the omnichannel strategy defined by the company, the growth of the business in Spain, the desire to satisfy Worten´s marketplace clients and the pressure of the market to reduce lead times, were the main business drivers that led to the need of re-designing the warehouse layout and adapting its operations, in order to improve operational efficiency and reduce preparation costs. The company developed then an umbrella project, defined by the following steps: *Requirements Understanding*: characterize the business necessities (1), *Analytics Understanding*: transpose the necessities to logistics requirements (2), *Layout Preparation*: definition of the new layout proposal (3), *Analysis and Modelling*: simulation of the different scenarios with basis on benchmarks and evaluating the response to the requirements, taking into account the logistics´ operations efficiency and the return on investment (ROI) (4), *Validation*: operational and financial validation of the final proposal (5) and, finally, *Implementation* (6). The purpose of this study being exposed is included in Steps 4 and 5 of the company´s project: develop a simulation model of the Scenario As Is of the four main operations of the warehouse, design and propose a micro-layout and operational procedure alternative of these operations considering the already defined macro-layout of the warehouse, and test it with resort to a To Be scenario simulation model to conclude the operational validation of the proposal. Afterwards, the proposal will be financially analysed after contacts with suppliers take place and, if validated, will be implemented. The present paper will then focus on the warehouse operations *Put-to-Zone* (PTZ), *Put-to-Light* (PTL), *Online* (ONL) and *Put-to-Store* (PTS) which will be located, in the new layout, in the centre of the warehouse (Figure 1), in order to minimize travel distances and times. The operations inside these zones as well as the flows between them will be studied in detail. Currently, in these areas, it is only treated the PBL flow, but the future idea is to integrate also the PBS flow in them, resulting in a Unique Logistic Flow (ULF).

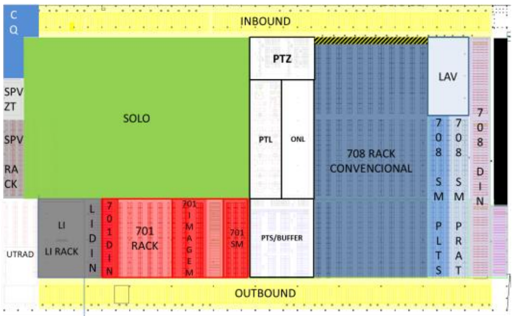

**Figure 1 - Warehouse Layout (To Be)**

The micro-layout of each of the four zones – PTZ, PTL, Online and PTS – will be altered according to the new designed layout proposal, as well as the transportation of goods between these zones, with the possibility of inserting automation in the system.
The problem at hand deserves a careful and conservative approach once not only different zones of the warehouse are being moved from its current locations but also the operations associated will be adapted. The timings and manner of when and how these changings will be made will have to be meticulously studied so that the whole operation does not stop during the implementation of the new layout. The insertion of automation in its operations is believed to be a major step in the technological development of the company which will require a good, precise and effective preparation.

### 2.2. Warehouse Operation flows

PTZ receives as inputs pallets from both reception and/or stock and sorts the articles by corresponding PTL sector. The PTL is then divided in 3 different categories depending on the dimensions of the products – GRA ("GRAnde", *big*), MED ("MEDio", *medium*) and PEQ ("PEQueno", *small*) – which correspond to 7 different sectors (category GRA is subdivided in five different sectors – GRA1, GRA2, GRA3, GRA4 and GRA 5). The 3 categories have various boxes and each of them corresponds to a specific store (in PEQ and MED there are all the 180 stores and in GRA, these 180 are divided in the five sectors, with 36 stores in each sector, once the boxes in which the products are stored have a larger size). In each of the sectors, an operator scans the code of a certain item. The system will turn on lights that have a box assigned corresponding to a specific store and indicate the quantity in units of that product that is intended to be put in that box/store. The operator places the items accordingly and proceeds until the tote is empty. When a box is full, the operator pushes it and another operator is responsible for picking that full box from the opposite side of the rack and transport it to the PTS reception zone. In the PTS section, there are pallets spread on the floor through four corridors with each corresponding to a specific store. Boxes with products inside or separate large products are placed in each store throughout the day and, at the end of the day, the pallets of the stores with delivery window in that day, are collected and sent to expedition. The products might come from different flows: from the PTL sector as closed boxes, from the Online sector if they are intended to stores with delivery window in that day, directly from reception (in the case it is, for example, a pallet fully allocated containing only large products above 6 liters), directly from PTZ and from Stock.
The online operation works in a very particular way due to the short delivery time window that the company proposes to accomplish to its clients: the order arrives to the customer 24 working hours after the placement in the online platform. The customer has two options of receiving the product(s) ordered: at home (home delivery - HD) or in a Store (pick up in store – PIS).

In this section, the products can only be of two types – short or large – such as the orders – mono or multi. A mono order is an order that contains only one item whereas multi orders have more than one. Multi orders might also be only of short products, only large products or a combination of both. This area is then divided in different parts: products arrive from picking to a receiving area and depending on the type of product – large or small – and type of order – mono or multi - the operator moves them to the assigned zone. Operations such as packing and putwall (honeycomb to store articles from multi orders that arrive from picking in different times so that they are packed together) take place and products are taken by hand to the sorting zone. Regarding the sorting zone of the online section, it is divided in two. The small products that arrive to a buffer from a conveyor are sorted in 4 different zones of a Put-to-Light system to a specific store. Close to this put to light system, there are pallets stack on the floor also corresponding to stores where some of them are to be delivered by internal operator (IO) and others by express operator (EO). If the products are to be home delivered or to be picked up in a store that does not have delivery window in that day, they will be transported by EO, otherwise, they are placed in the corresponding pallet store and, at the end of the day, these pallets are taken to the PTS zone of the warehouse to be expedited and posteriorly, delivered by IO.

## 3. Literature Review

### 3.1. Retailing, Logistics, Supply Chain & Warehousing

Zentes et al. (2007) define retail companies as the ones that are primarily involved in the activity of purchasing products from other organisations with the intent of reselling them to a final costumer without the need of transforming them. However, the concept of retailing has suffered considerable changings due to the development of markets and consumer behaviour. Traditionally, a retailer was considered a passive distributor, which was nowadays transformed into an active intermediary that controls the product range offering, carefully selecting products from manufacturers and making them available to consumers (Varley, 2014). The technological advances and the high speed of development of new systems for supporting both retailers and consumers inherent to it (Gunday et al., 2014) have subjected the retail industry to constant changing and adaption to the new trends.

According to Christopher (2016), logistics is defined as the process of strategically managing the procurement, movement and storage of materials, parts and/or finished inventory as well as its respective related information flows, through an organization and its marketing channels with the aim of maximizing the current and future profitability by reducing operating costs through cost-effective fulfilment of orders. The Council of Supply Chain Management Professionals (CSCMP), recognized as the official entity of professional experts in this field of study, describe supply chain management as the active management of all the supply chain activities (https://cscmp.org, consulted in May 2019). Logistics is, then, a subset of the supply chain that serves as a link between manufacturing and selling processes that culminates in the creation of place and time utility (Ismail, 2008). Warehousing has become a core competency, a strategic weapon that companies are using to reinforce their competitive position (Tompkins & Smith, 2008). A warehouse is works as a static unit that aims to better match product availability to consumer demand, facilitating the movement of goods from suppliers to customers by meeting the demand in an accurate, timely and cost-effective manner (Van der Berg, 2011). Gu et al. (2007) add that warehouse management is an integrating part of the supply chain that plays an important role regarding the effective delivery of goods to clients. Warehouse management is based in two main pillars: space and time (Richards, 2018). In the recent years, the *modus operandi* of warehouses has been undergoing considerable changes that make warehouse excellence hard to achieve. These challenges include increased customer service requirements, demands to reduce inventory, need for increased integration of the warehouse within the total logistics system, recent trends for inserting automation, demands to increase warehouse operating efficiency and space utilization, among others. From all these challenges, the last two are extremely relevant once it is the purpose of the present work. The growing competition in the retail market forced companies to continuously improve its processes design in its distribution networks (Gu et al., 2010). Mishra et al. (2011) express that an efficient warehouse management contributes drastically for inventory costs minimization as well as reducing lead times. This largely relies on warehouse processes optimization and layout design. It is then imperative to understand the different warehouse operations and how to measure and quantify warehouse productivity.

### 3.2. Simulation

According to Rouwenhorst et al. (2000) a warehouse might be viewed through three different axes: processes, resources and organization. Products that arrive to warehouse are treated through a series of processes (such as receiving, storing, picking and shipping) and resources refers to all the working material and personnel handled to operate a warehouse (from storage units, such as pallets or carton boxes to computer systems and human operators). The organization includes all the planning and controlling of the warehouse as a system. Despite not being as recent as other scientific papers found, the KPIs defined by Rouwenhorst et al. (2000) were perceived as the ones that were most closely related to the problem at hand. These authors stand out the following as distinguishable for a correct evaluation, keeping in mind that the relative importance of each criterion depends with the types of warehouses being treated: order fulfilment quality (accuracy), response time, storage capacity, investment and operational costs.

Bechtsis et al. (2018) provide an effective review directly related with the purpose of this work by providing a framework for developing highly customised simulation tools that support an effective integration of automation in supply networks. Simulation is a continuously evolving field of research with undoubted contribution to the progress of manufacturing system (Mourtzis et al., 2014). With this, a vast number of software tools are available. AnyLogic was the chosen software to be used in the project to simulate the operations and study its effects once this is the software provided by Worten.

## 4. Methodology

### 4.1 Proposed solution approach

The methodology followed in this work is represented in Figure 2.

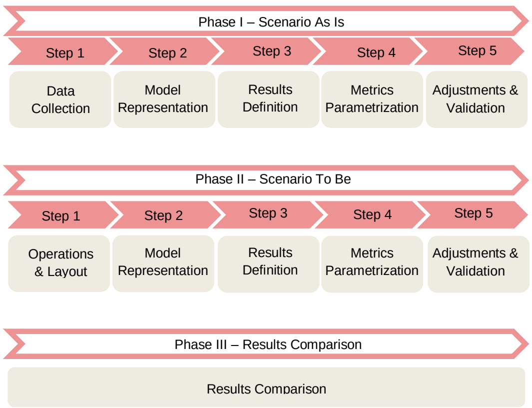


Figure 2 - Methodology

Two different simulation models – As Is & To Be – will be developed in order to evaluate the overall improvement of the system. In scenario As Is, data is collected, the model is represented, the results proposed to achieve are defined and the input metrics are parametrized in accordance with the previously determined results before adjusting and validating the model. In the scenario To Be, it is firstly necessary to study and present an alternative solution to the operations according to their new layout, by developing a 3D model, using Sketchup software, of these warehouse operations zones. The simulation steps follow the same approach of the scenario As Is and finally results of both scenarios are compared.

Before proceeding to the representation of the simulation models themselves it is firstly necessary to define the KPIs of such models. In Chapter 3, they were clearly outlined the KPIs in warehouse management, which, although directly inter-dependent, can be divided in three main groups: Storage capability (volume and mix flexibility, storage capacity), Flows and operations efficiency (order fulfilment quality, throughput, response time) and Profitability (investment and operational costs). After meeting with the company´s boards to establish priorities within the time frame of the whole project, it was defined that the Flows and operations efficiency indicators were the first mandatory desired results to be achieved, followed by Storage capabilities and finally Profitability of this specific project. This was due to the fact that the macro-layout is already defined and approved and once operations zones take its new places, the first approach is to define how they are going to work, followed by the adaption of the storage areas to these new working flows and, finally, validate the financial budget for this overall project. The KPIs defined for the simulation models were then focused on the Flows and operations efficiency, still orienting and bearing in mind that storage capabilities are the next steps for future work on these models. Once the final and main purpose of this project is reducing operational cost they were defined as KPIs of the simulation models the operational efficiency (1), the required number of operators to perform the activities (2) and the operators occupation rate (3). With this, it is intended to prove that with less people (which means less cost) it is possible to improve the operational efficiency, measured by the time it takes to fulfil the demand, through a better integration of the flows between processes/activities of these zones. These KPIs can be divided in the specific and detailed objectives presented as follows: accurate representation of the flows and operations of PTZ, PTL, Online and PTS working zones of the warehouse as they occur today on its corresponding locations (1), propose of a new micro-layout of these zones and test it regarding the corresponding restrictions of their new locations in the warehouse and insertion of the PBS flow and possible insertion of automated systems to remove operational inefficiencies (2), present and compare results of both scenarios concluding, if possible, operational validation of the project (3). On behalf of the restrictions of the model, they were defined the following: the demand is restricted to the information available in internal database of the company (i), in the *As Is* scenario the number of operators used on the model is restricted to the actual number of operators currently working in these functions at the company (ii), in the *To Be* scenario the number of operators is determined by eliminating transporting operators and adding new operators to new functions based on the expected necessities of the scenario (iii), the only source of resources used was the number of workers (machinery was not considered) (iv), once the new micro-layout of each of these zones has not yet been approved, the scenario *To Be* focuses on the increase of capacity but not in additional factors such as stores distribution in PTL sectors, which require further detail study (v). The results of the simulation will be mainly focused on PTZ and PTL operations areas, once these are the ones that will suffer the most changes in terms of layout and operation – apart from the fact that a different location of the operation areas in the warehouse by itself impacts the overall working efficiency, for this first study phase, Online and PTS will be moved to their new locations still maintaining their operating manners. The flows that reach these areas will not be affected other than by the way they reach it. During the development of the work, they were taken as assumptions of the model the distribution of stores in PTL sectors remained the same from the *As Is* scenario to the *To Be (a)* and the conveyors speed in the scenario *To Be* is equal to the one of the unique conveyor in the warehouse at the date of today (b).

### 4.2 Scenario As Is

Once automation has to be programmed to work in all seasons it has, at the worst case scenario, to be able to work in the highest peak season. According to historical data, inside the high demand season, the month that typically represents the greatest sales volume is November, with the month of November of 2018 being the one in which the company registered the greatest sales volume that there is record. By assuring that automation is capable of satisfying the demand in this month, it will be able to work during the remaining seasons. Bearing this in mind, the data collection will correspond to the month of November 2018 – the last highest peak season in Worten's history. This data will be used as input for the simulation experiments of both scenarios. It was proceeded to the model representation, with the definition of the simulation blocks and flows between them. The results proposed to be obtained were then defined - as Zeigler et al. (2000) proposed, one should design a model so that it faithfully captures the system behaviour only to the extent that the objectives of the simulation being studied demands. These could be defined in three different types, shown in Table 1. For the purpose of this work, once it is focused in operational improvements, the Design and Support Results will not be considered once both require the automation suppliers´ integration in the project – the Design Results can only be taken into account after the automation suppliers define the system´s requirements in terms of space to implement the conveyors whereas Support results require automation suppliers´ specifications of which precise values are required (such as flow rates in which operational nodes). With the outputs clearly defined, it is necessary to correctly parameterize the metrics as inputs, this is, correctly measure times, distances and rates of the model. Finally, the necessary adjustments are done, results are obtained, and the model is validated against the real record of occurrences in November 2018.

Table 1 – Definition of the Results

| Type of Result | Scenario(s) | Units of Measure | Purpose |
|---|---|---|---|
| **Comparison** | As Is<br>To Be | Time<br>Occupation rates<br>Number of Operators | Improvement<br>Perfarmance<br>Efficiency |
| **Design** | To Be | Number of pallets/totes<br>Volume | Space Management |
| **Support** | As Is | Units/time | Automation Development |

### 4.3 Scenario To Be

The first step for approaching the To Be scenario was a brainstorm of various operational possibilities, study of market supply availabilities and meetings for discussing the results to decide the best micro-layout proposal. Afterwards, it is proceeded to the representation of the 3D conceptual model of the proposal using Sketchup software, in order to correctly define the number of working stations and development of the operational solution, according to space restrictions and demanded objectives of the project. On the overall, the proposal will pass by inserting conveyors between the linked areas to substitute the transport operators. The remaining steps follow the same approach as Scenario As Is.

## 5 Results Analysis

In terms of operational efficiency, it is measured the time it takes for closing the operations line – at the time trucks start arriving and products have to be expedited, the operations stop and operators start preparing the loading of the trucks. This value will be measured with resort to a daily time plot, where the simulation will output the time it took, in each day, from the moment the operations stopped, until the production was ready to be expedited. For scenario As Is, it was obtained the plot shown in Figure 3 – it is registered a great variation of values throughout the simulation time with a peak recorded in the middle of the month which accounts for the stores supply preparation for Black Friday. An average of 1.69 hours for closing the operations line is registered.

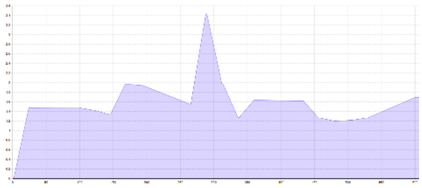

Figure 3 - Close Line Time (As Is)

In a macro-perspective of evaluating the operation zones on its whole (by activity and not by operator), in the As Is scenario, Figures 4 was developed to approach the occupation rates of PTZ and PTL operations areas. From Figure 4, it is concluded that there was an average of 2.54 operators working from the total of 5. However, considering these operations, it is not expected that the automation systems will improve much this occupation rate once it is only from this operation forward that these systems will be implemented. The input flow of this area is uniquely related with the reception schedules of trucks/suppliers and its unload operations that do not belong to the scope of this work. The same reasoning is applied to PTL operations area, where there was an average of 3.27 operators working out of the total of 7 operators from the total shift working time. Roughly 14% of the time there was no operator working, 12% there was only one of the 8 working, 6% two and so on and forth. The highest occupation values are achieved for 5 and 4 (33% and 26% of the total working time, respectively) PTL operators working at the same time.

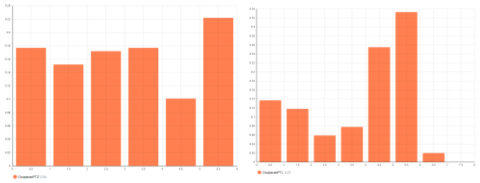

Figure 4 - PTZ & PTL Operators Occupation Rate (As Is)

The simulation results of the scenario As Is also show an occupation percentage of the transport operators of 96%. This discrepancy of occupation rates, between transport operators and PTZ/PTL operators, makes it clear that transport operators are overcharged in relation to the PTZ and PTL areas, which they feed. It is then suggested that a more effective transportation method might result in higher PTZ and PTL occupation rates. After the insertion of the PBS flow in the model of the Scenario To Be, the operations close line time already shows an improvement of inserting automation systems. The values are much more constant, which is related to the assurance of a constant flow rate from conveyors: products no longer await the availability of an operator to be transported; the conveyor already transports them to PTS. Additionally, an average of 1.14 hours for closing the operations line contrasts with the previous 1.69 hours from the Scenario As Is, showing a reduction of 32,6% of time (Figure 5).

Figure 5 - Close Line Time (To Be)

From the run experiment of the To Be simulation model, the results obtained seem to comprove the theory that the automation systems inserted in the flows and operations being studied improve the overall efficiency and productivity of the corresponding zones. Regarding the overall occupation rates of the operators of PTZ and PTL operations area, they were obtained the results presented in Figure 6. In the To Be scenario, apart from the fact that they were added three working stations in the PTZ operations area, in percentage the occupation rate was not much improved, once the automated systems do not affect the occupation rate of these zone operators. As said before, the input flow of PTZ comes from reception and suppliers arriving schedules. The value of an average of 4.47 employees working out of the total of eight (55%) - versus the 2.54 out of five obtained in the As Is scenario (50%) - is related with the insertion of the PBS flow in this operation. Once PBS represents 50% and PBL the other 50% of input work, the flow rate was duplicated whereas the working stations were not. This is believed to explain the short improvement of the occupation rate of PTZ operations area. However, PTL operators' occupation rates were clearly improved on the overall. From the previous average occupation of 3.27 employees (46%) the To Be scenario shows an improvement into 4.75 (68%), representing a gaining of 22% in the operators' occupation rate on its overall. This is related to having the products available in each sector shortly after they have been sorted in the PTZ operations area, with the time these articles waited for a transport operator to be available to place them in the corresponding PTL sectors no longer being lost. The simulation results confirm the expectations.

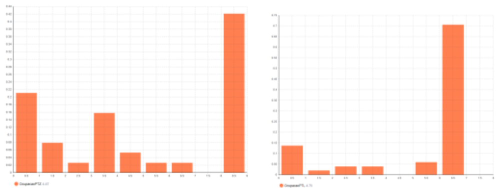

Figure 6 - PTZ & PTL Operators Occupation Rates (To Be)

From the analysis of the decrease of operational time spent in transportation, this is, non-value added time, it achieved a reduction of 53,7% decrease in this time, an increase of 13,5% in value-added time, a reduction of 9 operators needed to perform these operations and a 7.7% higher operators occupancy rate (Table 2).

Table 2 - Results

| Results | Scenario As Is | Scenario To Be | % Change |
|---|---|---|---|
| Non-value Added Time | 26,32 hours | 11,93 hours | -53,7% |
| Value Added Time | 106,68 hours | 121,07 hours | +13,5% |
| Number of Operators | 31 | 22 | -29% |
| Operators occupancy rate | 48,1% | 55,7% | +7.7% |

When investing in equipment, such as automation systems, these should be designed to perform at the maximum capacity required by the operations at its peaks. But, at the same time, it should be considered that if, for example, the high demand season, accounts for a 50% higher operational demand than the medium demand season and 80% higher than the low demand season, it might result on excessive investment that will be only be used half of the year. It is for that reason that a sensitivity analysis takes place in order to study the impact that the operational demand variability used as input to the model has in the overall output results. They were run two additional experiments in the To Be simulation model using as inputs the data referent to the months of February and July, correspondent to a month of low and medium demand season, respectively.

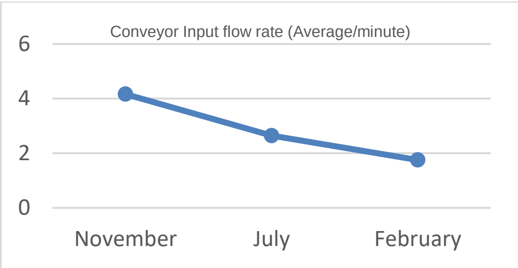


Figure 7 - Automated Conveyor Input Flow Rate

By analysing Figure 7, it can easily be concluded that there is a significant reduction on the input flow of objects to the conveyor. From November to July, there is a decrease of roughly 36% of the occupation rate of the automation systems and from November to February that decrease exceeds 57%. These values might rise the doubt of whether such an investment is profitable and reliable. However, this possibility has already been taken into account when designing the new macro-layout of these for zones. It is expected that the automation system to be inserted in the PTL operations area will represent the greatest part of the expense of the overall project, due to the large dimensions in terms of conveyor meters required, to the numerous sorters required, perpendicular conveyors, boxes elevators, among others. Once the fixed costs cannot be managed, the variable costs, however, can. With variable costs it is meant number of required operators and energy and maintenance costs. The automation systems inserted in these areas allow to be used only when such a demand so requisites. This is, conveyors inserted, for example, can be only working when it is necessary, with the operations not depending on them. Furthermore, there are several external variables that although they do not have a direct impact on these occupation rate values, they do play an important indirect role on the viability of this project: it must not be forgotten that by inserting this automation system and expanding the capacity of some operation zones, it is possible to bulk pick PBS flow instead of batch pick as it is currently done. This, apart from improving directly productivity, reducing picking times and distances and lowering personnel spending suggests that only with a very high efficient transportation system would this intent result. Finally, although there is an evident decrease in occupation percentage, taking into account the lowest value (1,73 objects per minute) by itself, it is definitely still a reasonable input flow for a conveyor.

## 6 Conclusions

After the definition and representation of a new micro-layout proposal for the areas being studied using 3D drawing software tools, as expected, the improvement from As Is scenario to the To Be scenario was confirmed. The sensitivity analysis subsequently performed allows to evaluate the impact of the automation systems in the cycle year, which will aid decision-makers to evaluate the viability and profitability of the solution presented when compared to the cost investment inherent to it. It is concluded that the objectives of the work initially defined were achieved as well as KPIs show the operational improvement and subsequent cost reduction of the overall processes through a maximization of the operators occupation rates and insertion of the PBS flow in these processes by a duplicated operational capacity of the sectors.

The future steps to be taken for the development and final conclusion of the operational validation will come out after a detailed analysis of the stores distribution in PTL sectors as well as the design and support results proposed to extract from the already created and correctly represented simulation model that will serve as a basis for future developments and improvements of each of these operating zones of the warehouse.

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