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OPTIMAL DISTRIBUTION BETWEEN BOX AND PALLET AUTOMATIC WAREHOUSE STORAGE

Case Study

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JEL Classification
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Abstract

Warehouse management has witnessed widespread and rapid development in recent years. This is due to the increasingly complex logistics processes as well as to the dynamic and spectacular development of warehouse design and operation. The smooth functioning of the stock and the warehouse plays a very important role in the life of every production company, so it is imperative to continuously review processes and to apply new procedures to increase efficiency. Results: When storing the phase products, the speed of the internal material flow processes, including the rate of storage, must always be proportional to the output of warehouses. Likewise, the storage capacity of the warehouse must correspond to the input needs of the areas it supplies. The constantly changing needs can be balanced by inserting buffers. In addition, storage capacities must be prepared in advance for changing space needs. Thus, in one year, the 64-36% removal ratio between the previous 2 warehouses changed to 56-44%, due to changing trends. This requires regular monitoring of the forecasts and management of the inventory strategy to be followed. Conclusion: During our research we have found that by updating the data quarterly, we can ensure the proper distribution of stock and optimum utilization of warehouses.

INTRODUCTION

The market is constantly changing, and the ability to adapt is vital for both industrial and service companies alike. A company's position on the market is largely determined by its competitiveness, its customer focus, the quality it offers, and its flexibility and innovation (Takács-György & Toyserkani, 2014). These objectives can only be achieved through cost-effective management, and the quality of warehousing processes can significantly influence this (Fronczek, 2017).
The reason for the extensive development of warehousing systems is that there is a great need for resources to deal with material handling, storage and warehousing. Inventory systems continue to play an important role in the logistics supply chain, and although one of the most important goals of logistics development is inventory efficiency and inventory reduction, most of the logistical costs of companies are incurred here (Chico et. al., 2017; Nica et.al., 2017). Therefore, there is a need to pay close attention to the efficiency of warehousing activity, which must be organised according to the following key principles: individual unit loads, selecting the most suitable individual unit load form and size, good utilization of the area, minimizing movement performance, checking and directing the flow of material and information, and creating safe, protected and environmentally friendly conditions, at the lowest possible total cost (Gelei, 2013). According to Novák (2008), the warehouse's operations are constantly changing, introducing new tools and systems for more efficient work.
At the Nyíregyháza factory of LEGO, the Danish toy manufacturing company, there are currently two automated warehouses, which have been in operation since 2014 - one box based and one pallet-based. The storage capacity of the two warehouses is about 80,000 pallets of semi-finished products. Of these, 44 600 pallets are stored in the palletized automatic warehouse, and 35,000 pallet sets (511,000 boxes) in the box based automated warehouse. During storage, efforts should be made to ensure that the utilization of the two warehouses is nearly the same. However, it is also important that the phase products that are typically used in palette quantities be stored in the **palletized automatic warehouse** (hereinafter referred to as "**pallet warehouse**"), whereas box-based products with lower utilization rates be stored in the **box based automated warehouse** (hereinafter referred to as "**box warehouse**").

LITERATURE REVIEW

Importance of storage in the supply chain

Storage of individual parts or products means interruption of material flow. However, it cannot be completely eliminated because storage is able to create a balance between material flow and material demand in terms of quantity and/or timing. At the same time, it provides security against the risk of unforeseen events, allows the development of choice, provides a means of speculating on price increases, and enables certain products to mature, i.e. to enhance their quality.
Traditionally, the concept of a warehouse can be defined as that part of a company's logistics system (and/or supply chain) that stores products (raw materials, sub-assemblies, semi-finished or finished products) at and/or between points of production and use, and provides information about them (e.g. product status, characteristics) (Stock & Lambert, 2001). The most important goal of stockholding is to balance the differences between supply and demand. This is because it is almost impossible to accurately synchronize demand with supply (Rushton et al., 2010). Warehousing is a subsystem that – using its own equipment and facilities - promotes the consistency of inventories, aligns flows and, where necessary, balances stocks. These tasks are carried out at warehouses. Warehouses are not only places where internal processes take place, but also feature external relationships (Prezenszki, 2004). We use warehouses to store goods for various lengths of time so that customer orders can be easily met (Attwood & Attwood, 1992).
Thanks to continuous development which, in practice, means the logistics system and the practical appearance of the supply chain, the role of warehouses has been expanded. In addition to the storage of products and the transfer of information, emphasis is also placed on activities related to goods manipulation, something which has previously been a minor aspect, but has now become particularly significant (Gelei, 2007; Kliestikova et. al., 2017). With regard to the sophistication of today's modern technology, improvements in the operation of warehouses show a major change, which also allows companies to save costs due to the constant changes in their economic life. In addition, it promotes market competitiveness and extends many new service activities (Tcherneva, 2016).
The development of business entails new leadership, management and technology processes, and if these prove to be effective, more and more businesses adopt these methods. It is necessary to search for reserves that have not yet been exploited. A supply chain which is able to coordinate these activities enjoys a competitive edge against disorganized chains (Vörös, 2010). The warehouse is an essential component of the supply chain and when considering potential choices for key decisions the business should be considered in a wider sense (Rushton et al., 2006). We need to look at market or industry trends, corporate goals, the business plan defined by the company, the previously developed supply chain strategy, and any other strategy, as well as consumer service levels, and finally, also factors outside the company

(Moravcikova et. al., 2017). Taking this into consideration when designing warehousing can contribute to successful operation (Rushton et al., 2006; Lancaric et. al., 2016).

Inventory and storage costs are dependent on the value of the product and the amount of time the product has spent in the warehouse. This all adds extra costs which increase proportionately (Süle, 2014). The warehouse is a major player in the logistics system, its so-called soul, and has a direct impact on the entire corporate structure. Over the past decade or decades, warehouse management has undergone considerable development, thanks also to the complex and continuously updated logistics processes. Additionally, rapid technological change is contributing to development, which also increases the high level of operation (Kliestik et. al., 2018).

Storage is activated several times in the entire logistics process. It fulfils the collection and distribution function, combining 3 individual subsystems (use of materials, production, and distribution) into a processes. This enables the implementation of an integrated material and information flow and the creation of an optimal supply chain (Prezenszki, 2004). Warehousing has two important functions: one is storage, the other is supply. Storage is responsible for the conservation of finished products, while supply means deliveries on the basis of consumption and sales (Némon, 2013). In order to satisfy the customer needs, the supply function prevails over the storage function.

From a warehousing point of view, based on the general logistic process model encompassing the path of the raw material from producer to user, it can be stated that the storage process fulfils its collecting and distributing function multiple times in the whole process, combining the sub-processes of raw material production, finished product production and distribution, making integrated material and information flows possible (Prezenszki, 2010). The management of the warehousing operation includes the problems that arise behind the daily operating processes and ensures the existence of framework pre-conditions (Demeter et al., 2009; Balcerzak et. al., 2017). Logistic performance measurement of warehouse processes is a very difficult task because each company needs to define and apply metrics that fit well into the profile of the company and faithfully reflect the performance they want to measure. This decision is of the utmost importance, as we will have to adjust our warehouse system and its operating principles to this performance expectation (Oláh 2016; Oláh et al., 2016).

Stackable, static storage systems

Storage operations are strongly influenced by continuously occurring major changes in production and service processes, which are mainly caused by the search for quality against volume. For a workable layout, it is necessary to calculate the requirement for storage, which can serve several purposes in the case of a large warehouse. It is important to identify the different warehouses activities that affect the planning of the warehouse layout, determine the space requirement, the ideal layout for each activity, and then match the space requirements to the individual constraints.

MATERIALS AND METHOD

The problem under investigation is LEGO Group specific, so we used the LEGO Group's internal documents and the systems used by the LEGO Group. The corporate governance system analyzed reports from the "SAP R3" reports of PP (Production Planning) modules, to establish what product codes were needed in the past few months and what production and delivery needs are expected in the coming months. The warehouse management system is a so-called "SAP" interface linked to a "COMBI 2.0" system. This is the LEGO Group's own system that has been developed within the SAP Framework in the ABAP programming language, and its logic is entirely based on functions defined by the LEGO Group. Thus, historical data on inventory movement (2015-2016) was obtained from the "COMBI 2.0" system. The settings for the automated warehouse parameters for item numbers were also made in the "COMBI 2.0" system. For this, we used the documentation of the "COMBI 2.0" system and the documentation of the "SAP R3 PP" module.

RESULTS

In December 2015, the warehouse management system acquired a new function in order to better distribute the inventory of automated warehouses. The essence of the function is to set a ratio number for each product code that shows the maximum percentage of a given product that can be stored in the boxed warehouse, taking into account the total inventory of the two automated warehouses. The system is based on the ratio at which a so-called "batch job" carried out four times per day transfers the boxes containing the products into the pallet warehouse, if at least 1 full palette can be built. A "batch job" works on the basis of predefined parameters. It only packs full (packed to an exact quantity) or overfilled (containing more than the number of units in the package) boxes, at a rate of 120 pallets every 6 hours. Determining the ratios and the first uploading was carried out by the LEGO Group's warehouse management system development team at the same time as the system was introduced.

When calibrating the automated "batch job", you can change many settings:

• You can specify one or more product codes or packets if you want to retrieve a specific product or box size.
• You can determine the maximum number of automatic retransfer tasks for each palette which can be generated by a "batch job".
• It is possible to set as a parameter the types of boxes to be included in the calculation.
• It is possible to determine how many palletizing stations can operate at the same time on retransfers.
• It is also possible to set the height of the blocks built by the palletizing robots.

In March 2016, we investigated the relevance of the ratios uploaded in December 2015. This task had become more necessary in many respects, as from the first quarter at one of the factory outlets we had returned from pallet-based to box-based shipments. In addition, a number of new product codes had been added to the system in 2016, with no appropriate ratios yet established. Therefore, their total quantity was stored in the box warehouse, which was the default setting for the new item numbers.

To make the calculation, the warehouse management system development team also helped us, because they had previously determined the ratios. The development team used a complex spreadsheet software (hereinafter referred to as spreadsheet) for calculations, which determined the ratios in several steps. These required a significant amount of data that included historical data from March 2016, both in production and outbound terms, plus production and delivery forecasts from March 2016 for all the materials that can be stored in the boxed warehouse. The amount of data thus collected exceeded 320,000 rows in the file. The downloads included the product code and the amount consumed or predicted to be consumed. For all these, a further download was needed to determine their packaging specifications.

The data received was added together on the spreadsheet file and the ratios were determined here (Table 1). With the help of the formulas we used, we collated how many bookings had been or would be made, according to the downloads, and on this basis, the total that was, or would be required for the box warehouse. Comparing this to the total amount of bookings, we obtained the maximum proportion of the product to be stored in the box warehouse relative to the total inventory. This percentage became our current ratio for the product in the coming months. The ratio calculation with spreadsheet was already causing a problem at these points. With hundreds of thousands record files totalling nearly 50 MB, it took a very long time to calculate the data. There was one occasion when we could not calculate with spreadsheet in one and a half hours. At that time we made improvements to what other options might be able to accelerate the calculation, as the capacity of the spreadsheet software was not sufficient.

To upload the ratios, we used the warehouse management system transaction to change the master data settings for the product codes (Table 2). Prior to updating the ratios we downloaded master data for all product codes, and updated the ratios of the changed product codes in the saved data. This resulted in a change in the ratios of 5 864 product codes.

An important parameter for the upload file is that there is a minimum stock for each product that can be stored in the boxed warehouse, which is always automatically placed in the boxed warehouse, representing 2 pallets of material. Due to the changed ratios, after uploading, the previous 1 300 pallets of transferable materials became 7 190 pallets, which was 86,884 boxes, or 17% of the total capacity of the boxed warehouse (Table 3). The update was completed on April 15, 2016.

In April 2016, the average number of pallets increased threefold for the remainder of the month. The utilization of the box warehouse decreased by 3.1% at the end of the month. The average rate dropped from 89.7% to 80% after the update.

In Figures 1-2 it can be seen that the rate of product delivery did not change, but in the second half of the month the proportion of delivery orders performed was reversed in favour of the palette store.

The August 2016 update was less spectacular. To make it easier to calculate in the excel table, we acquired a more powerful computer, a workstation that we hoped would significantly shorten the duration of the calculation. Unfortunately this did not happen. Calculation of the expanded 350,000-line data set, covering two years of accumulated data, also presented a problem for the workstation. There are 11 162 product ratios, although, of course, not all of them have changed. The average rate decreased from 80% to 79%. After the ratio was upgraded, production service ratios again did not change much, similar to what had occurred previously. The delivery ratios, however, were adjusted to what we experienced after the April update, with the service ratio between the two warehouses changing from 65-35 to 52-48, continuing to favour the boxed warehouse.

The number of transferred pallets does not show as much change as in April 2016 (Figure 3). On a monthly basis it can be observed that the daily average was 500 palettes (Figure 4).

At the end of November 2016 update, we continued to think about how to accelerate the calculation. So we used a database server to perform the calculations. The database server fulfilled the hopes we had placed in it. The previous several hour wait disappeared. We found that the calculation from the 365,000 series data set took little more than 1-2 minutes. The calculation of the database server was much more accurate than the previous spreadsheet versions; the ratios were defined to two decimal places. However, corrections were made for 3 496 product codes. The changed average ratio was 82.12%. The average ratio of the total number of product codes was 83.87% (Figure 5-6). Consequently, the ratios changed by 4.87% towards the box warehouse, from the previous average of 79%. This is due to the fact that the historical delivery data that comes from pallet-based shipments is beginning to run out, and the box-warehouse specific data is highlighted. Nonetheless, after the update, the amount of pallets that can be transferred from the box warehouse rose to 3 500 (Figure 7).

Production supply rates were hardly changed. However, the delivery rates, unlike the previous ones, did not tilt towards the pallet warehouse, but the 56-44% box-pallet ratio (Figure 8) moved to a 64-36% ratio (Figure 9).

CONCLUSIONS AND RECOMMENDATIONS

During our research, we found that continually updating ratios is certainly justified, as production and delivery needs vary from month to month, not to mention the newly introduced product codes that enter the system quarterly.

By updating the data quarterly, it is possible to ensure an adequate distribution of stocks and optimum utilization of warehouses. If this does not happen, due to shifting ratios, the utilization of the two warehouses also shifts. In addition, we ensure the utilization of palletizing robots is also more evenly distributed, since we carry out the pallet construction on the basis of the quarterly forecasts before the delivery request is made, taking into account any free capacity. That is why it is important to use a strategy of demand-based forecasting to deal with the ever-changing volume of demand with its accompanying high level of storage and material handling needs. Basically, because of their differences warehouses cannot be conceptualised on one plan - each company makes its processes efficient by means of unique storage techniques. This is largely dependent on management policy, local conditions, and technological equipment. Storage and warehousing can be closely linked to the protection without loss of inventories in terms of quality and quantity, while providing information and value-added activities. These have now been expanded to meet customer-specific needs and additional goods-manipulation activities.

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ANNEXES

Table 1. Material use data

Article number	Type	Reserved quantity	Palette quantity	Size	Box type	Demand	Whole palette	Remaining demand	Rounded off	Complete demand	Box warehouse (%)	Palette warehouse (%)
4279734	delivery	16500	264000	16500	P25	0.602	0	0.0625	1	1	100 %	0 %
6005405	delivery	6842	82104	6842	P33	0.0833	0	0.0833	1	1	100 %	0 %
6071236	delivery	8195	131120	8195	P25	0.0625	0	0.0625	1	1	100 %	0 %
6064120	delivery	62400	93600	7800	P33	0.666	0	0.666	8	8	100 %	0 %
4256347	delivery	54600	67200	4200	P25	0.0625	0	0.0625	1	13	100 %	0 %
306541	delivery	54600	312000	13000	P16	0.0625	0	0	1	2	100 %	0 %
421402	delivery	51200	25600	1600	P25	0.0625	2	0	2	32	100 %	100 %
6078439	delivery	163200	40800	3400	P33	0.0625	4	0.5	3	48	100 %	100 %
6064228	delivery	66000	40800	11000	P33	0.0625	0	0.0625	2	6	100 %	0 %
6097569	delivery	12000	72000	6000	P33	0.666	0	0.0625	3	2	100 %	0 %

Source: Authors' own research, 2017

Table 2. Ratio calculations

Product code	Box type	Number of orders	Quantity of orders (boxes)	Quantity released from the box warehouse (boxes)	Box warehouse performance (%)	Palette warehouse performance (%)	Quantity released from the boxed warehouse (boxes)	Quantity released from the palette warehouse (palettes)
383201	P33	40	413	149	36%	64%	12.416	22
4600612	P25	39	1818	250	14%	86%	15.625	98
6015356	P16	29	986	266	27%	73%	11.083	30
1237586	P33	30	750	58	31%	69%	4.833	11
241926	P33	50	720	104	35%	65%	13.5	16
241226	P33	163	337	150	40%	20%	8.78	12
4249019	P33	38	1899	450	65%	25%	4.96	17
4508215	P16	76	3	3	78%	85%	15.7	49.9583
6109812	P33	1	288	176	100%	48%	19.4	0
6147010	P25	21	900	420	61%	39%	11	15

Source: Authors' own research, 2017

Table 3. Master data uploading file

Product code	Ratio number	Minimum number of palettes in the box warehouse
9327	80	2
9339	67	2
14586	100	2
9566	91	2
73737	80	2
74011	92	2
74156	100	2
74230	84	2
74333	100	2

Serial labels	Total number of palettes	Total number of boxes
P16	439	10536
P25	1360	21760
P33	2865	34380
P50	2526	20208
Total	**7190**	**86884**

Source: Authors' own research, 2017

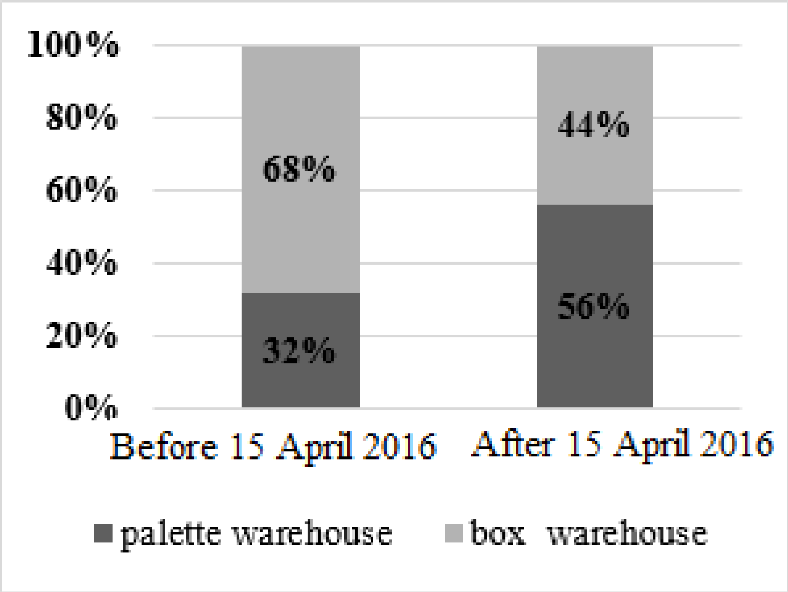

Figure 1. Percentage distribution of product servicing between the palette and box warehouse before 15 April 2016, and in the two weeks after
Source: Authors' own research, 2017

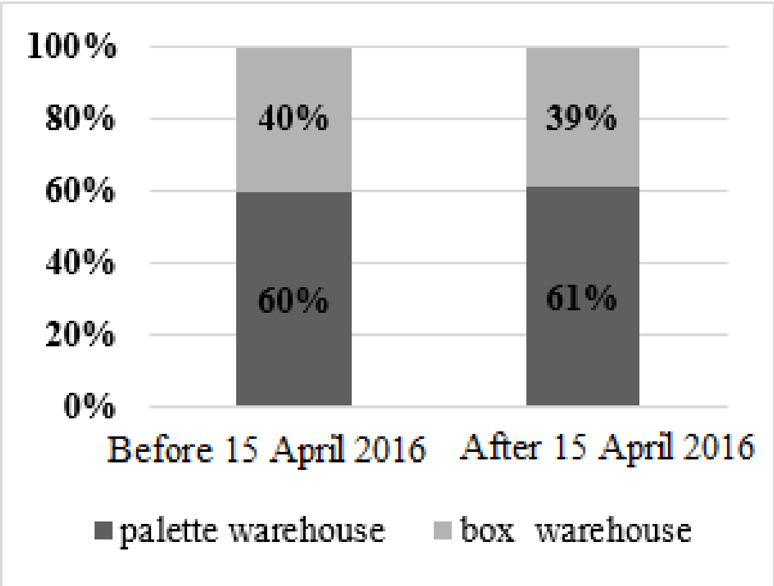

Figure 2. Percentage distribution of product servicing between the palette and box warehouse before 15 April 2016, and in the two weeks after
Source: Authors' own research, 2017

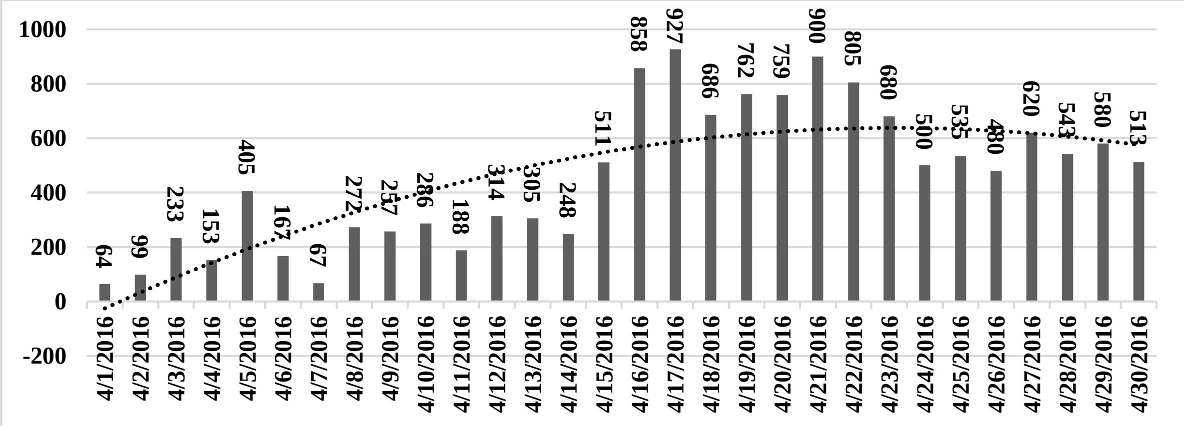

Figure 3. Number of palettes transferred from the box warehouse to the palette warehouse in April 2016
Source: Authors' own research, 2017

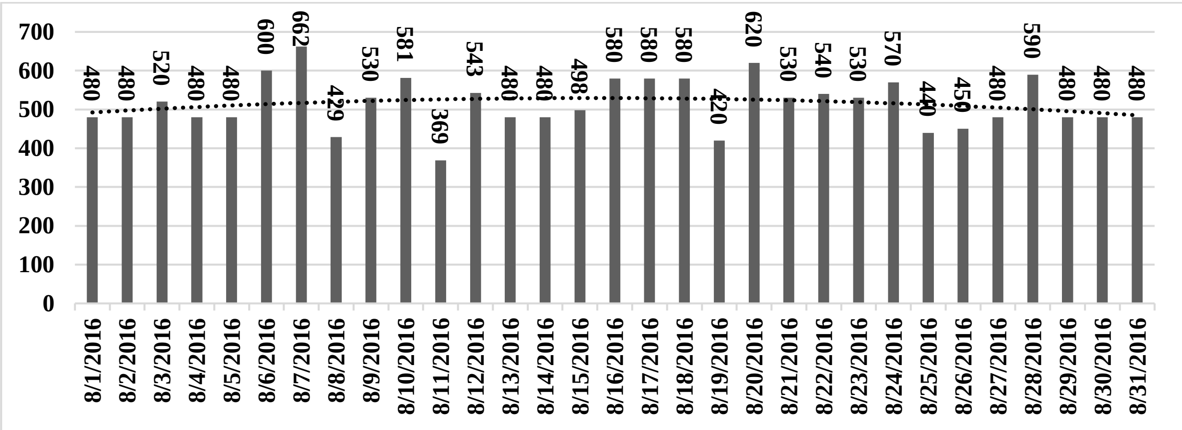

Figure 4. Number of palettes transferred from the box warehouse to the palette warehouse in August 2016
Source: Authors' own research, 2017

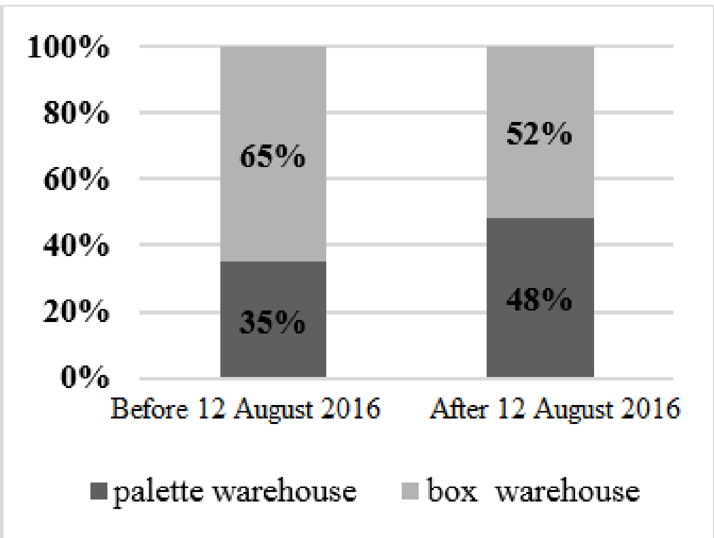

Figure 5. Percentage distribution of preparations for delivery between the palette and box warehouse before 12 August 2016, and in the two weeks after
Source: Authors' own research, 2017

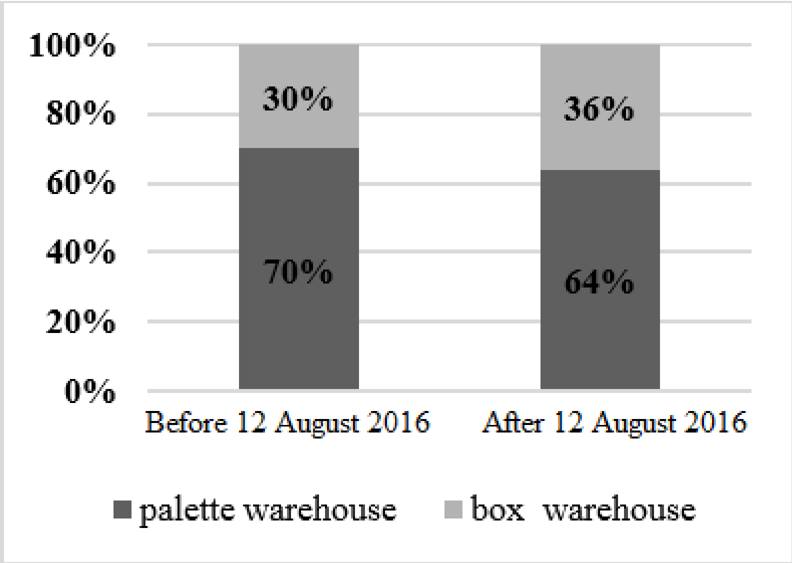

Figure 6. Percentage distribution of product servicing between the palette and box warehouse before 12 August 2016, and in the two weeks after
Source: Authors' own research, 2017

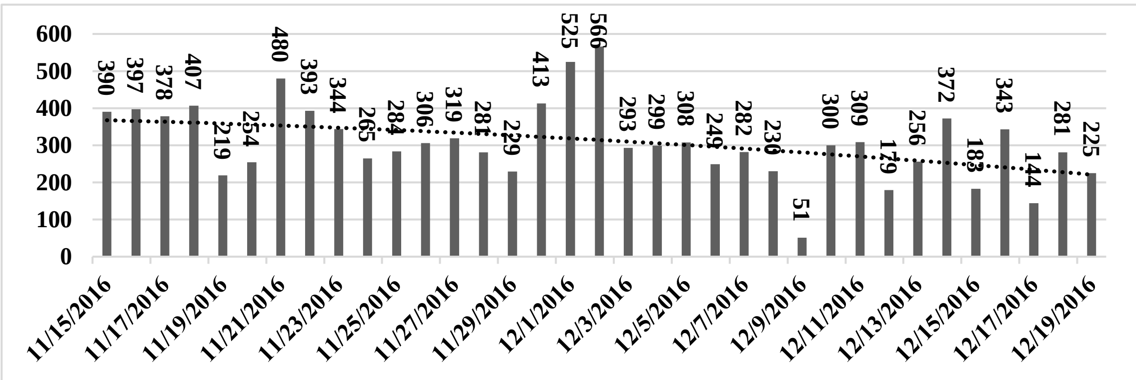

Figure 7. Number of palettes transferred from the box warehouse to the palette warehouse in November-December 2016
Source: Authors' own research, 2017

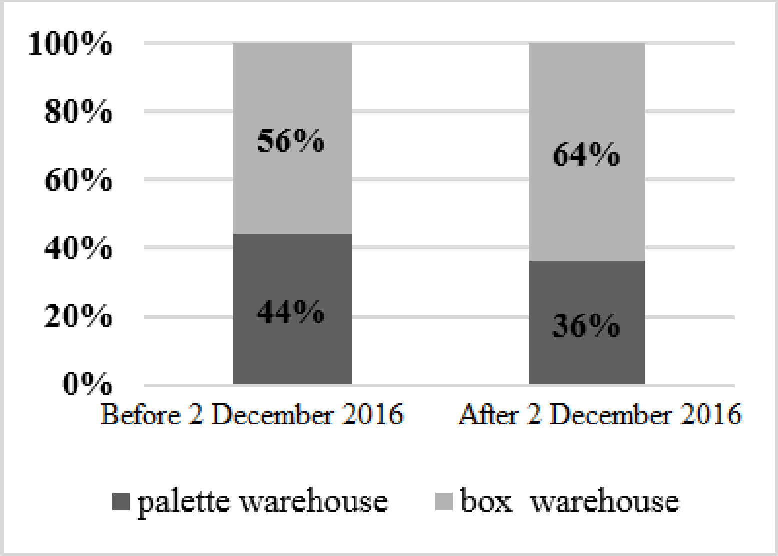

Figure 8. Percentage distribution of delivery preparations between the palette and box warehouse before 2 December 2016, and in the two weeks after
Source: Authors' own research, 2017

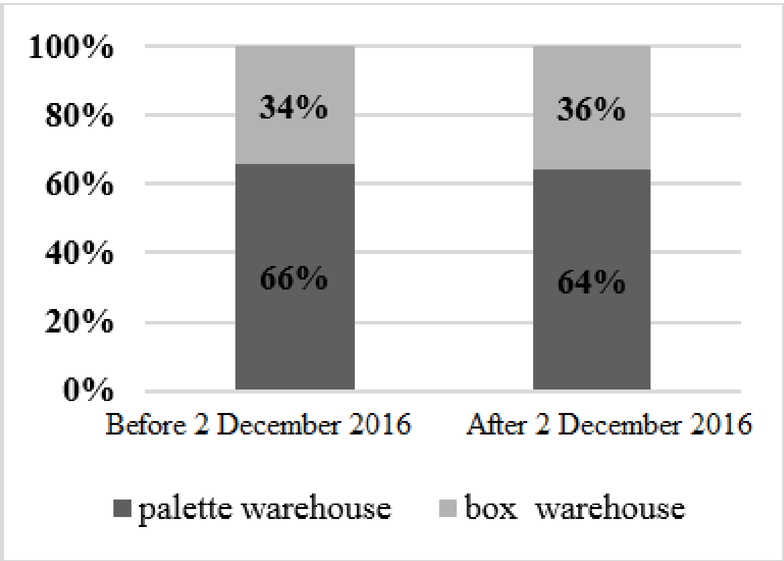

Figure 9. Percentage distribution of product servicing between the palette and box warehouse before 2 December 2016, and in the two weeks after
Source: Authors' own research, 2017