Optimization of orders fulfilment in a distribution centre: a case study of schoolbooks

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Abstract: A distribution centre (DC) is the place in which products are received, handled, stored, packaged, and then shipped to satisfy customer's orders. To provide a competitive service level in a DC, an order received must be fulfilled on time and in correct quantities. To improve the efficiency of DC's activities, this study aims to present the redesign of the order fulfilment process within a schoolbooks DC, located in the South of Italy. A crucial issue of this DC refers to the schoolbooks personalized covering process. This problem motivated the reengineering of the DC processes by implementing an automatic sorter, with the purpose of sorting the schoolbooks destined to the various customers. Two scenarios are evaluated: the "AS IS" scenario, which represents the current situation, and a "TO BE" one, in which the implementation of an automated sorter is evaluated. For both, the productivity – in terms of orders per day – and the number of operators required to carry out the different activities were evaluated. The introduction of the automatic sorting system, in addition to tripling productivity and increasing the efficiency of the schoolbooks DC, also made it possible to significantly reduce the number of operators employed during each work shift. The results of the TO BE configurations can represent useful indications for operations managers, allowing to identify alternative strategies to enhance the efficiency of the targeted company.

Keywords: Distribution centre, efficiency optimization, order fulfilment, logistics, process automation.

1. Introduction

To fulfil customer's requirements and differentiate from competitors, distribution centres (DCs) are confronted with a wide range of challenges while planning their operations. A DC is a critical node in providing high customer service level in a supply chain network (Urzúa, et al., 2019); this is because DC activities like receiving, storage, order picking and shipping are critical to each supply chain (van Gils, et al., 2018). Receiving activity includes the unloading of products from transport carrier, updating the inventory record, inspection to find if there is any quantity or quality inconsistency (de Koster, et al., 2007). Storage is concerned with the organization of goods held in the warehouse in order to achieve high space utilization and facilitate efficient material handling (Gu, et al., 2007). Order picking is the retrieval of stock keeping units (SKUs) from their location in the warehouse to satisfy the customer's orders (Petersen & Aase, 2004). Shipping is the last warehouse process, and one of the most important, for that matter. While customer experience greatly depends on the shipping process, the process itself depends on the preceding processes to varied extents (Sunol, 2019).

A DC is the place where products are received, handled, stored, packed, and then shipped to satisfy customer's orders (Russull & Taylor III, 2013). To provide a competitive service level at a DC, an order received must be fulfilled on time and in correct quantities (Shuyu, et al., 2019). Order fulfilment involves generating, filling, delivering, and servicing customer orders. The objective of the order fulfilment request is to achieve agility in the order fulfilment process in terms of efficiency, flexibility, robustness and adaptability (Luo, et al., 2019).

To improve efficiency, this paper aims to present the redesign of the order fulfilment process in a DC, and it is organised as follows: section 2 illustrates the context from which this works originates, namely a schoolbooks DC – in particular handling books for primary and secondary schools – located in the South of Italy. A crucial issue of this DC refers to the schoolbooks personalized covering process. This problem motivated the management of the company to consider the reengineering of the DC by implementing an automatic sorter, with the purpose of automatically sorting the schoolbooks destined to the different customers. Section 3 is dedicated to the presentation of the work done in the DC and of the corresponding results. To this end, two scenarios are evaluated: an "AS IS" scenario, which represents the current situation, and a "TO BE" scenario, where the implementation of the automated sorter is evaluated. To automate the sorting process, however, it was also necessary to reorganize the DC area; according to that, two different configurations were developed for the "TO

BE" model. In the first configuration, two physically separated areas were dedicated to intensive storage and product picking activities, while in the second configuration it was hypothesised to expand the DC area currently used by the company for product storage and picking. They are both presented and illustrated for completeness, but only the first configuration was selected and deepened. Finally, section 4 discusses the main findings and concludes by highlighting the main limitations of this work and suggesting potential improvements.

This study was developed on the basis of the request of the management of the company which owns the DC. This company suggested as Key Performance Indicators (KPIs) the productivity, expressed in orders per day, and the number of operators requested to complete the DC activities. These parameters were determined for both scenarios to evaluate the feasibility of the investment. Indeed, some managers and practitioners are still dubious as far as the automation of processes; in this respect, this study aims at demonstrating the efficiency and savings of the automated solution. Moreover, to the best of authors' knowledge, there are no studies in literature which consider the implementation of automatic sorters and take into account these specific KPIs in the industry in question, which is a specific niche market. Hence, in-depth analysis could be appropriate.

2. Context

The publishing industry involves production and dissemination processes to make information (e.g. literature, music, software, and travel aids) available. According to the AIE (2019) (Italian acronym for "Association of Italian Editors") in 2018, the total publishing market in Italy reached 3.170 billion euro. The main indirect sale channels for books are bookshops, online store and large-scale retail store.

As mentioned, this paper focuses on a schoolbooks DC, operating in the South of Italy. The company, one of the only three main players in Italy which operate in this field, receives orders of schoolbooks from its customers and fulfils them by preparing, covering, packaging and shipping items. A crucial issue of this DC refers exactly to the schoolbooks covering process. The information printed on the customized covers, according to the final customer's requests, may include the following details: name and surname, book title, logo or image, barcode and price.
Due to the peculiarity of items in question, production is purely seasonal, and it is scheduled only for five months each year.

In this study, as mentioned above, the aim is to improve the efficiency of the DC, in particular of the order fulfilment process, by reengineering the DC area investigating two different scenarios.

3. Scenarios analysis

In this section, an analysis of two different scenarios – AS IS and TO BE – for an efficient functioning of the DC is provided.

More precisely, the following scenarios are taken into account in this study:

1) An "AS IS" scenario in which there are three different areas:
   - Receiving and shipping;
   - Storage and picking;
   - Order fulfilment.

   In this scenario, intensive storage takes place in an area located 5 km far from the DC. During the night, there is a massive picking of the items to be processed the next day, and they are shipped to the DC. The schoolbooks are temporarily massively stored in an area close to the processing zone following the logic of placing the most numerous codes in the area closest to the processing. Picking takes place in this work in progress (WIP) warehouse.

   Figure 1 shows the DC layout of this scenario.

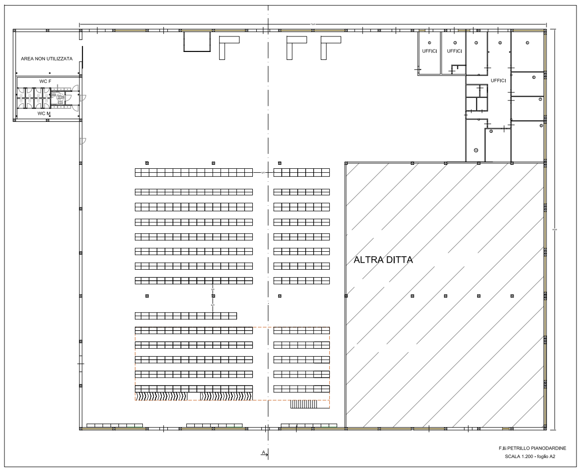

Figure 1: Representation of the DC's layout of AS IS scenario.

2) A "TO BE" scenario which considered the implementation of the automated sorter. To automate the sorting process two different configurations including two different reorganizations of the DC were designed, detailed below. However, only the first configuration, the easiest to be implemented, was developed.
   a) The first configuration is obtained by dedicating two physically separated areas to the intensive storage and product picking activities. Figure 2 shows the layout of the DC in this configuration.

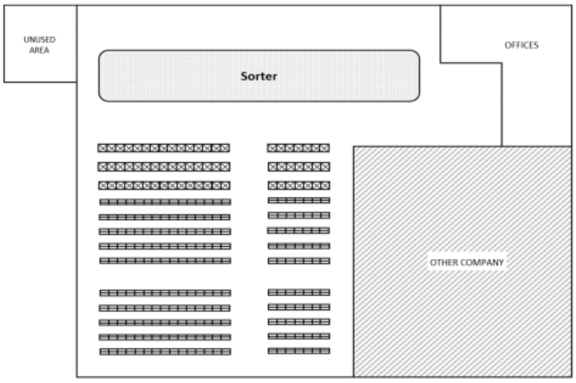

Figure 2: Representation of the DC layout of TO BE scenario – first configuration.

b) The second configuration, on the other hand, envisages extending the DC area currently used by the company for the storage and picking of products, avoiding intensive storage 5 km far from the DC. Figure 3 represents the DC layout in the second configuration.

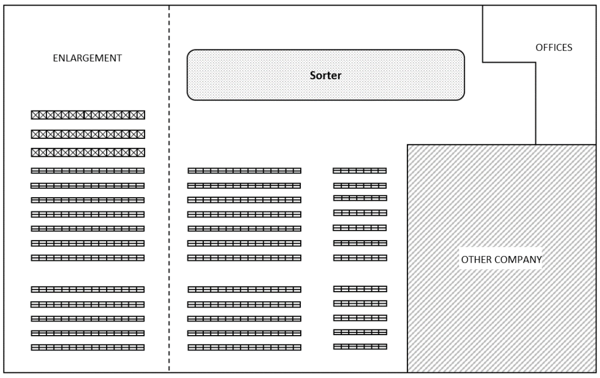

Figure 3: Representation of the DC layout of TO BE scenario – second configuration.

In both TO BE configurations, the following different zones can be identified in the warehouse:

- Receiving;
- Intensive storage;
- Picking;
- Sorting;
- Order fulfilment;
- Shipping.

As already mentioned, for both scenarios (AS IS and TO BE) that will be analysed, the productivity – in terms of orders per day – and the number of operators needed to carry out the different DC activities will be evaluated as performance parameters, following the suggestions of the DC's managers.

3.1 AS IS scenario

The activities carried out within the DC in this scenario can be summarised into five fundamental processes:

- Receiving and storage;
- Picking;
- Scanning and labelling;
- Covering;
- Packaging and shipping.

For the sake of brevity, the detailed presentation of the processes will be limited to a crucial issue of this DC, which is the schoolbooks covering process. For the remaining processes, the results obtained will be presented, omitting the description.

The covers are produced using three machines (figures 4 and 5), not in-line, patented and designed specifically for the automatic production of plastic film covers customized according to the needs of the final customer. These machines offer the possibility of producing covers of different sizes with small adjustments. They can work in two different modes:

1) Using the 3D scanner to measure the book size. In this case the machine generates the covers on the fly;
2) From file. The machine generates the book covers starting from a database containing the sizes of all books to be fulfilled. In this last case, it is necessary to keep the sequence of the covers produced unchanged.

Figure 4: Covering machine.

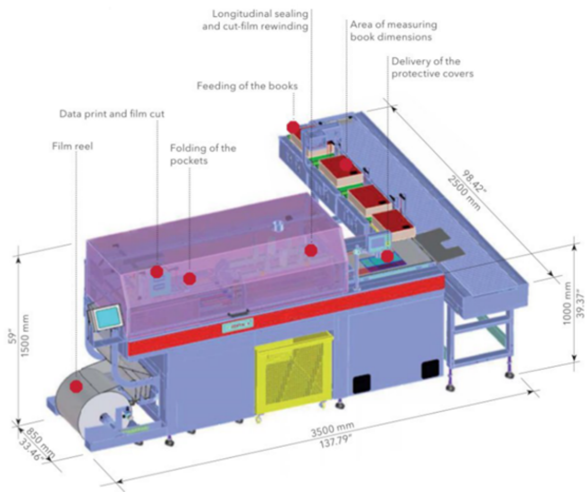

Figure 5: Scheme for covering machine.

To avoid bottlenecks along the lines, resulting in low volumes, the machines generate the customized covers on the fly. The fact, instead, of keeping the sequence unchanged is very expensive for the company and, at the same time, it is risky for the customer. This is why the company has also bought three additional machines to work on the fly in the next season.

As mentioned above, only for the crucial process (covering), the detailed description will be presented; nonetheless, a similar evaluation has been carried out for all the processes carried out inside the DC.

The full list of input data relevant to the productivity evaluation, provided by the company itself, is shown in Table 1.

Table 1: Input data – AS IS scenario.

Description	Numerical value	Unit of measurement
Production lines	11	-
Covering machines	3	-
Working hours per day and line	24	[hours/day]
ISBNs per hour	150	[ISBNs/hour]
Orders per hour and per picker	20	[orders/hour]

The number of books (identified using the International Standard Book Number, ISBN – on average 1 ISBN=1.6 books) that can be picked daily in the AS IS scenario accounts for:

$$150\frac{ISBNs}{h} * 24\frac{h}{day} * 11 = 39{,}600\frac{ISBNs}{day}$$

The number of orders processed per working day can be computed applying the following formula:

$$20\frac{orders}{h} * 24\frac{h}{day} * 11 = 5{,}280\frac{orders}{day}$$

The number of employees needed to carry out the different activities, instead, is showed in the following table:

Table 2: Number of operators – AS IS scenario.

Activity	Operators
Picking	11
Scanning and labelling	11
Covering	33
Packaging and shipping	11
Total number of operators	**66**

As can be seen from Table 2, the activity involving the highest number of operators is the covering process as it is a fully manual process; the remaining processes, instead, require 11 operators overall, one per line. This is the reason why this particular process was prioritized in the analysis.

3.2 TO BE scenario

With the aim to optimize and speed up the picking, sorting and packaging activities, the reengineered scenario was built taking into account the introduction of a machine for the automatic sorting and packaging of schoolbooks.

The automatic sorting system consists of several stations (figure 6). Upstream of the line there is an ergonomic system for the input of items. This system consists of a feeding docks through which the schoolbooks, manually inserted by the operators, are conveyed in ramps to the sorting station (figure 7). The schoolbooks fed in this way enter a modular carousel with pockets (figure 8), which are circulated in continuous mode. Once a book comes close to its assigned exit, the pocket opens at the bottom to drop the book inside a special cart (figure 9). Downstream, on the other hand, there are various packaging stations (figure 10), consisting of a manual sorting and filling area for the shipping units, a weighing plan (figure 11), a taping and binding system and a system for printing the transport documents (figure 12).

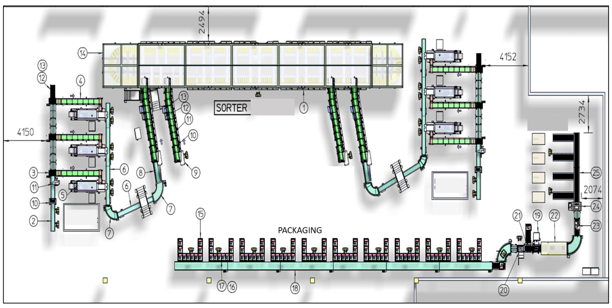

Figure 6: Automatic sorting system.

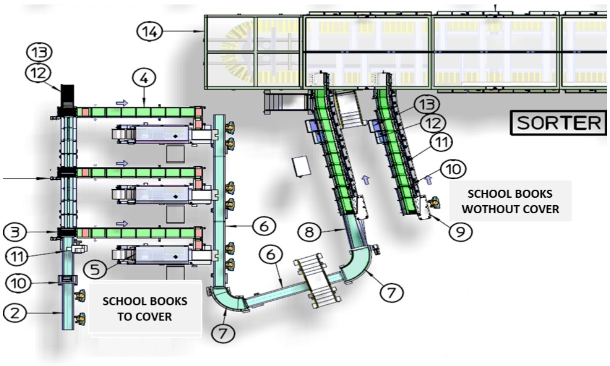

Figure 7: Feeding bays.

Figure 8: Pocket-sorting system.

Figure 9: Manual cart.

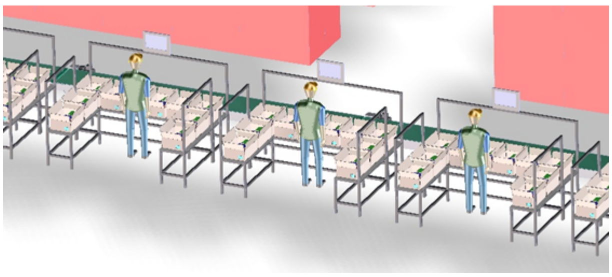

Figure 10: Packaging stations.

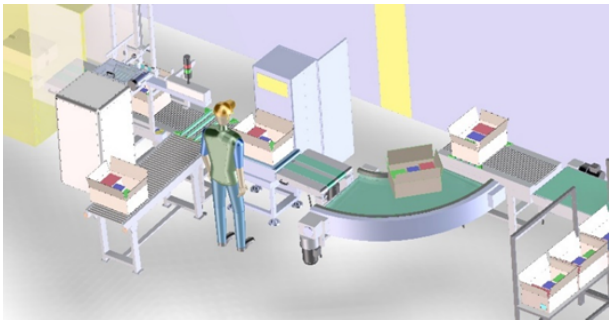

Figure 11: Shipping unit weight control system.

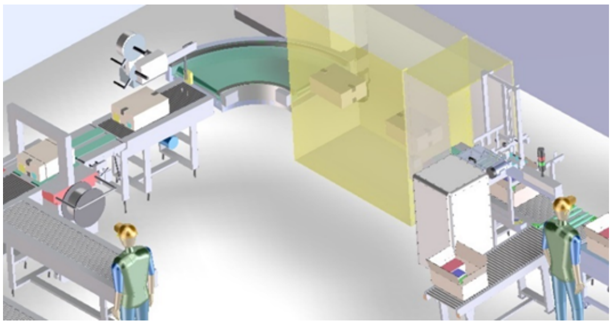

Figure 12: Packaging and labelling system.

The introduction of the automatic sorting system makes it possible to switch to massive picking management, thus allowing for more orders to be grouped together in a single mission. This makes it possible to considerably decrease the routes covered by operators involved in picking activities inside the warehouse. In order to further decrease the travel time of the operators, it is also possible to organise picking activities according to the zone picking. It is, therefore, possible to assign each operator a specific area of the DC where picking can be carried out. By always moving within the same area, the picker, besides travelling shorter, can in this way contribute to reducing errors and consequently increasing productivity.

In the TO BE scenario, therefore, each picking operator in one hour is able to pick up a total of 1,000 ISBNs. The automatic sorting system allows to sort about 5,000 ISBNs per hour (1,000 for each of the 5 operators), for a total of 40,000 ISBNs processed during a normal eight-hour work shift. By scheduling work on three shifts, therefore, the company has the possibility to process about 120,000 ISBNs during a working day, thus satisfying 15-20,000 customers' orders.

The number of operators per shift needed to carry out the different activities is shown in the following table:

Table 3: Number of operators – TO BE scenario.

Activity	Operators
Picking	5
Trolley handling	4
Sorter power supply	4

Covering	12
Packaging and shipping	10
Sorting shipping unit	2
Total number of operators	**37**

As can be seen from table 3, again the activity which requires the highest number of operators is the covering process, but it would be definitely reduced after the implementation of the new machine.

4. Discussions and conclusions

The present paper has focused on the optimization of the orders fulfilment process in a schoolbooks DC, located in the South of Italy; this context is a niche sector which is almost neglected in literature. In particular, a reengineering of a DC with the aim of optimizing the efficiency of internal warehouse processes is proposed. In this study, we have investigated two different scenarios: an "AS IS" scenario, which represents the actual situation, and a "TO BE" scenario, where the implementation of an automated sorter was evaluated, with the purpose of sorting the schoolbooks to be shipped to various customers. For both scenarios, an evaluation of the productivity – in term of orders per day – of schoolbooks DC and the number of operators needed to carry out the different activity is provided as the management of the company has expressively requested to analyse these performance indicators.

The main results obtained through the reengineering of the DC processes, and of the picking activity in particular, are summarised in Table 4, for both the scenarios analysed (AS IS and TO BE).

Table 4: Comparison of the results for picking process.

	AS IS	**TO BE**
Picking	Selective	Massive
ISBNs per hour per operator [ISBNs/hour/operator]	150	1,000
Operators	11	5
Total ISBNs per hour [ISBNs/hour]	1,650	5,000
Total ISBNs per day [ISBNs/day]	39,600	120,000
Orders per working day [orders/day]	5,280	15,600

As can be seen from Table 4, in the TO BE scenario each operator is able to pick up 1,000 ISBNs/hour. The automatic sorting system allows to sort about 5,000 ISBNs/hour; therefore 5 operators are enough to carry out the picking activities. Covering activity, even in the reengineered scenario, is the most critical process. In fact, it is still a manual process and therefore, if not properly organized, it could involve bottlenecks inside the system.

In addition, the considerable increase in the system productivity due to the introduction of an automatic sorting system, together with the expected increase in the demand for customised covers, make it necessary to introduce further covering machines.

A system structured in this way allows the DC, with 3-shift operation, to process 120,000 ISBNs, useful to satisfy about 15,000 orders per day. The introduction of the automatic sorting system allows, therefore, to fulfil in a shift of 8 hours, the same number of ISBNs that in a manual process (AS IS scenario) would be fulfilled during an entire working day.

This kind of system, besides tripling the productivity and increasing the efficiency of the DC, will also allow to significantly reduce the number of operators employed during each shift – approximately 30 saved per shift – as shown in table 5.

Table 5: Comparison of operators' number for the fulfilment order.

Process	**AS IS**	**TO BE**
Picking	11	5
Trolley handling	-	4
Sorter power supply	-	4
Scanning and labelling	11	-
Covering	33	12
Packaging and shipping	11	10
Sorting shipping unit	-	2
Total number of operators	**66**	**37**

In conclusion, the introduction of an automatic sorting machine has several strong points. The reengineering of the process, in fact, allows for a considerable increase in productivity and efficiency of the system and, at the same time, for a decrease in the manpower employed in this purely seasonal activity. On the other hand, the main weak point of the proposed solution is the quite high initial investment for the purchase of automatic technologies and for possible structural interventions for the reconfiguration of the storage area. In addition, introducing automated technologies involves the need for an initial training of the employees, with consequent (possible) reduction in the level of service in the short term. However, the economic point of view has not been deepened, as for the company in question the primary objective was to determine the convenience of the automated system in terms of productivity. Nonetheless, a cost analysis would be the second step of the feasibility study in case of real intention in implementing a solution of this kind.

The investment in automation is also justified in the light of the opportunities offered by the sector. School publishing, in fact, is a niche market segment with low risks and high economic and financial returns. By increasing its productivity and enhancing the level of service offered to the end customer, the company under examination has the opportunity to expand its market share. On the other hand, the school publishing market does not have high growth potential, as the number of students – and therefore of potential buyers – is almost constant over the years. Indeed, estimates of last year (Il Sole24ore, 2019) confirm that school publishing has increased production by 11.8% in 2019. This is an encouraging result, although of course these data depict a pre-COVID-19 situation and could change in 2020 (which however is a very particular year of this century because of the pandemic emergency).

Moreover, the possible spread of digital products and services – which are the only substitute product for schoolbooks – could lead to a radical overhaul of distribution structures. Indeed, a little more than a decade ago, the publishing industry was confined to printed works – traditional books, newspapers, and magazines. With the advent of digital information, the book industry now also publishes in blog, e-book, Web site, and other electronic formats (Vault, 2019). However, in favour of this specific case, as the focus is on books for the primary and secondary school where students are very young, this process is for sure slower.

It should be noted, however, that this study predated the recent pandemic situation, due to COVID-19. For sure, the industry in question, as many other industries, could be affected by this emergency. Just think to the various hypothesis as far as distant teaching and learning which are scheduled for the next school year; may they include books provided in digital format, speeding up the abovementioned process of digitalization also at primary and secondary school? Will consequently production volumes be substantially reduced? In the light of these aspects, for an investment of this kind, the authors believe that waiting for the development of regulations is highly recommended; and then, it might come into play another popular keyword affecting our century, namely the renowned resilience.

References

AIE, A. I. E., 2019. Rapporto sullo stato dell'editoria in Italia 2019. Retrieved from: https://www.aie.it/Portals/_default/Skede/Allegati/Skeda105-4499-2019.10.16/Rapporto%202019_La%20Sintesi.pdf?IDUNI=h5uqveohkvq4s0cdcz3wb2iq6208 [Accessed 21 January 2020].

de Koster, R., Le-Duc, T., and Roodbergen, K. (2007). Design and control of warehouse order picking: a literature review. European Journal of Operational Research, 182 (2), 481-501.

Gu, J., Goetschalckx, M., and McGinnis, L. (2007). Research on warehouse operation: A comprehensive review. European Journal of Operational Research, 177 (1), 1-21.

Il Sole24Ore (2019). Scuola, libri e letture: pochi grandi editori controllano il mercato. Available at: https://www.infodata.ilsole24ore.com/2019/12/18/libri-giornali-lettura-tutti-numeri-delleditoria/

Luo, H., Yang, X., and Kong, X. (2019). A synchronized production-warehouse management solution for reengineering the online-offline integrated order fulfillment. Transportation Research Part E: Logistics and Transportation Review, 112, 211-230.

Petersen, C. and Aase, G. (2004). A comparison of picking, storage, and routing policies in manual order picking. International Journal of Production Economics, 92 (1), 11-19.

Russull, R. and Taylor III, B. (2013). Operations and Supply Chain Management. New Jersey, Wiley.

Shuyu, L., Kajihara, Y., Hakkaku, M., Makoshi, A., and Shinzato, T. (2019). Study of a system for supporting the analysis of distribution processing work at a logistics center - A case study of analyzing picking work in a retail clothing order fulfillment center. Journal of Japan Industrial Management Association, 70 (2 E), 124-135.

Sunol, H., 2019. Warehouse Operations: Optimizing the Shipping Process. Retrieved from: https://articles.cyzerg.com/warehouse-operations-optimizing-the-shipping-process [Accessed 18 February 2020].

Urzúa, M., Mendoza, A., and González, A. (2019). Evaluating the impact of order picking strategies on the order fulfilment time: A simulation study. Acta Logistica, 6 (4), 103-114.

van Gils, T., Ramaekers, K., Caris, A., and de Koster, R. (2018). Designing efficient order picking systems by combining planning problems: State-of-the-art classification and review. European Journal of Operational Research, 267, 1-15.

Vault, 2019. Book Publishing. Retrieved from: https://www.vault.com/industries-professions/industries/book-publishing [Accessed 21 January 2020].