Applying Mathematical Model for Pickers to Orders Problem at the Warehouse of Panda Retail Company

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Abstract. The problem at Panda warehouse came from delaying many orders being ship to the stores. The delay caused by a shortage in the required number of pickers to orders at times of high demand. On the other hand, at times of low demand, some pickers are idle for long periods. As a result, Panda Retail Company lose the customer’s loyalty, especially in the current competitive market, due to failing their needs at the right time besides excessive pickers’ costs due to their idle times. In this paper, a Mixed Integer Linear Programming (MILP) model proposed to optimize the number of required pickers to orders. The model applied with four scenarios of solution to cover the realistic constrains at Panda warehouse. Results showed a maximum saving in the annual pickers’ costs by 27% in addition minimize the number of full-time pickers by 50% with such help from outsourced pickers. The paper, also, pointed out recommendations to the company to sustain its competitive advantages in the retail market.

Keywords: Order picking, Warehouse management, Mathematical programming, Workforce scheduling.

1. Introduction

Warehouses are a vital component of a company’s supply chain. They typically used as a means of storing items, whether those items are parts for manufacturing processes or finished goods. In addition, they can hold items that are not fully ready for consumption, or items a customer does not presently need but requires quick access to when the need arises. The main task of warehouses is to deliver the customer orders at the right time, in the right quantity and quality to the right place. Warehouses are profit-oriented enterprises, so their goal is to provide the highest service standard at the lowest possible cost and by the highest utilization of their resources. Order picking considered one of the most time-consuming operations in pickers to orders warehouses. The order picker facilitates the transition of products in storage to move them on to eager buyers. Studies showed order picking accounts for around 50% of a warehouse’s labor costs. Georgia Tech reports that the number can be as high as 63%. With the rise of e-commerce, order picking has become more important. Why? Because while other operations in the warehouse can be automated, order picking largely remains manual. Technology can be brought in to help the pickers, but that technology cannot replace them [1]. It is reasonable to say the order picker may be the most important person in a warehouse.
Most warehouses focus on speed as the most important consideration of an order picker’s workday. The faster an order picker works; the more products can be shipped out at a given time. At Panda Retail Company, customers expect to find their basic needs whenever they visit their stores. The warehouse processes are an integral part of meeting the customer expectations by ensuring the availability of the items on the store’s shelves. Failing to meet their customers demand will not only affect the company’s overall profitability, but will also risk their customer’s loyalty, especially in a very competitive market. Therefore, the main objective of this paper is to find the required number of pickers (permanent and outsource) at Panda’s warehouse that increase the productivity of the work and reduce the annual pickers’ costs. In the light of that, the paper divided into 6 sections in which section 2 showed how pickers to orders subject addressed in the literature. Section 3 illustrated the problem facing Panda’s warehouse followed, in section 4, by a proposed mathematical model to solve this problem within realistic constraints. This model evaluated, in section 5, from both sides (1) Savings in the number of required pickers and (2) Savings in their annual costs. In section 6, recommendations given to sustain Panda competitive advantages in the retail market.

2. Literature Review

An analysis is done to find the growth rate of scientific publications related to warehouses orders picking problems besides their solutions that suggested by researchers. The analysis applied for the 3268 research articles found in Science Direct Database [2] along the period time from year 2000 to year 2019. Figure 1 demonstrates an increase in the published articles over the last nine years compared with the first ten years. The annual rate of increase during the first ten years (from year 2000 to year 2009) was 5.8% while it was 17.7% during the next nine years (from year 2010 to year 2018). This means the orders picking at warehouses are recently rich topic from scientific and practical researchers’ point of view.

Based on the literature review, warehouse picker-to-orders scheduling investigated from different points of view to cover the classifications of order picking systems and problems [3, 4]. The majority of warehouses employ humans for order picking in which the travel time is an increasing function [5]. Consequently, the travel distance is often considered as primary objective in warehouse design and optimization [6, 7]. Two types of travel distance are widely used in the order-picking literature: the average travel distance of a picking tour (or average tour length) and the total travel distance. The researchers proposed analytical [8-11], simulation [12-14], mathematical programming [15-17], and other approaches [18, 19] to treat the order-batching problem, batch assigning and sequencing problem, and picker routing problem separately or simultaneously. The primary objective was to minimize the picker traveling time. However, the problem faces Panda Retail Warehouse (which is minimizing the number of pickers based on the variability of customer demands within some constraints) not covered in the literature extensively except Alfares [20] and Musaoglu [21].

3. The Problem Facing Panda’s Warehouse

Panda has a massive warehouse located in King Abdullah economic city that covers 100,000 square meters and serves the west region of Kingdom of Saudi Arabia with a total 70 branches from the south to the north. The layout of the warehouse, as portrayed in Fig. 2, mainly consists of four areas which are:

- Storage Area: This area includes vertical
aisles that consists of racking system up to ten pallets in height

- Picking Area: After the picking process occur, the pallets are moved to the picking area to be packed, wrapped and labelled

- Dispatching Area: The packed pallets are moved to the dispatching area right next to the out bound dock

- Outbound Area: The pallets are loaded from the dispatching area to the trucks through the outbound docks.

Figure 3 shows the dispatching area and the aisles of the racking storage system. The locations in the floor are the primary locations. Each item has only one primary location and any additional pallets of an item will be stored in a secondary location which is the higher locations. In the dispatching area, the pallets are prepared to be loaded in the trucks, each line of pallets is for a specific outbound dock.

The fast-moving items are placed in a primary location closer to the dispatching area to ease the picking process for them since their demand is higher than the other items.

Panda is considered a Fast-Moving Consumers Goods (FMCG) retailer. This put a pressure that the availability of the items on shelves for customers to buy is the first priority. Panda’s warehouse has a problem corresponding to the inconsistent items demand over the year. Due to the nature of the FMCG sector, the demand differs throughout the year with two high seasons which are (1) Two months preceding the actual date of Ramadan to ensure that customer demands in Ramadan are available regularly and (2) Three or four months before the end of the year (known as Mega Promotion Period) to achieve the targeted sales volume (see Fig. 4). This causes the warehouse team to be extremely overloaded during the high season and many pickers to be idle during the low season.

Fig. 1. Distribution of the research articles on warehouse orders picking problems over the years 2000 to 2019.
Fig. 2. Typical warehouse layout.

Fig. 3. The picture shows the racklings and the dispatching area at Panda’s warehouse.

Fig. 4. Image of the fluctuant number of the daily-shipped pallets for the year 2019.
As a result, the inconsistent demand leading the warehouse to delay shipments of the items during the high season and losing sales opportunity and to overpay for the pickers during the low season with very low utilization. In addition, any shortage in the required items leads to unsatisfied customers who go directly to competitor retailer companies. As a result, Panda will lose its market share and correspondingly its market reputation. Hiring more or fewer pickers does not solve this problem efficiently. In this paper, this problem taken into consideration with suggested mathematical model and different scenarios to solve it.

4. Proposed Model Formulation

Mixed Integer Linear Programming Model (MILP) is proposed to solve the problem under study. The following three phases are suggested to apply and to validate this model:

Phase #1: Data Collection: In this phase, the variable data for the MILP model will be collected such as number of yearly shipped pallets, the number of pickers currently available in Panda warehouse, picking times, and average wages of full and part-time pickers. The part-time pickers are generally considered as outsource pickers.

The source of the required data are: (1) The database system at Panda Retail Company, (2) An interview with the warehouse operation manager, (3) Human resource department for full time pickers, (4) Outsourced companies in the Saudi retails that supply manpower for part-time pickers, and (5) Manipulation of the collected data.

Phase #2: Model Formulation: Here, the model will be formulated as Mixed Integer Linear Programming with an objective function of minimizing the number of required full and part-time pickers that satisfy the daily demand of shipped pallets. The pickers to orders problem at Panda’s warehouse can be defined as shift manpower scheduling with the following characteristics:

- A cycle consisting of m periods.
- During period i, bi pickers are required.
- There are m shift patterns.
- Each picker is assigned to exactly one shift pattern.
- The cost of assigning a part-time picker to shift j is cpj.
- The cost of assigning a full-time picker in a work period i is cfi.
- Consider ai=1, if period i is a work period in pattern j and 0, otherwise.
- Let the decision variables Xj such that Xj is the number of part-time pickers assigned to shift j.
- Let the decision variable Yi is the number of full-time pickers assigned to period i.

So, the mixed integer linear programming formulation is:

\[
\min \sum_i^n c_f_i Y_i + \sum_j^m c_p_j X_j \\
\text{St.} \\
Y_1 + a_{11}X_1 + a_{12}X_2 + \cdots + a_{1n}X_n \geq b_1 \\
Y_2 + a_{21}X_1 + a_{22}X_2 + \cdots + a_{2n}X_n \geq b_2 \\
\vdots \\
Y_m + a_{m1}X_1 + a_{m2}X_2 + \cdots + a_{mn}X_n \geq b_m \\
Y_i \in \{1, 2, 3, \ldots\} \text{ for } i = 1, \ldots, m \\
X_j \in \{0, 1, 2, \ldots\} \text{ for } j = 1, \ldots, n
\]

Phase #3: Model Validation: The model will be applied and the results will be compared
with the current situation in Panda warehouse. The following criteria are considered to measure the effectiveness of the proposed mathematical model: (1) The overall cost of pickers to parts (average yearly wages), (2) The total ideal time of pickers to parts over the period under study, and (3) The tardiness of picking orders over the same period.

5. Application of the Proposed MILP Model

As illustrated before, the proposed Mixed Integer Linear Programming Model (MILP) consists of three phases to solve the problem under study. These phases applied as shown below:

**Phase #1: The Data Collected and Manipulated:** Here, class “A” items in the warehouse are considered only as it represents 70% of sales volume. The daily-shipped pallets, for both single-item orders and multi-item orders, in the period from January until December collected with 158794 pallets in the year 2019 (see Fig. 4). The two high demand periods excluded from this study because in these two periods, Panda Retail Company depends mainly on the outsourced pickers. Therefore, the main problem faces Panda is outside these two periods. On other words, the study covered the period for January and February in addition to the period from May to August of the year 2019. Based on the information taken from the Panda’s warehouse operation manager, currently, the warehouse picking process held by 20 full-time pickers. This number of full-time pickers is not sufficient to meet the daily fluctuation in the number of shipped pallets. Therefore, the pickers overloaded in the days of high demand besides there are delays in the shipped pallets to stores or the pickers are idle in the days of low demand. From physical observations, the total time to pick a single-item pallet is 0.67 minutes and to pick multi-item pallet is 20 minutes. The monthly cost for full-time pickers is 3000 SR and the weekly salary for part-time pickers is 900 SR in the months that outside the high demand periods. By manipulating the collected data, the number of pallets shipped daily segregated by a ratio of 33% to single item pallets and 67% to multiple items pallets, because the picking time is different for both types. Also, the total number of pickers needed daily calculated taking into consideration that the actual working time at Panda’s warehouse is one shift with 8 hours and 7 days a week. Figure 5 displays graphically in blue color, the number of pickers required daily for the period under study. As a constant 20 full-time pickers are holding the existing picking process, the red color area in Fig. 5 represents the number of idle pickers over the period under study of the year 2019. When the number of pickers on a certain day is required more than 20 pickers, this means there are shortage of shipping the pallets to stores and it is require hiring more number from outsourced companies as part-time pickers. Panda’s operation manager.

**Phase #2: The Model Formulation:**
The MILP model has the following characteristics:

- The objective function of the model is to minimize the number of required full and part-time pickers while the constraints is to satisfy the daily demand of shipped pallets.

- The cost for full-time pickers for the period under study = 3000x6 = 18000 SR.

- The policy between the Human Resource (HR) department at Panda Retail Company and the outsourced companies is: “the companies has to supply manpower for part-time pickers in fixed weekly periods from Sunday to Saturday over the year based on the demand from the HR department”. This means the part-time pickers are working in cyclic
periods of 7 days each. Based on this constraint, the data collected before the first Sunday and after the last Saturday in June of the year 2019 neglected.

- The weekly salary for part-time pickers in non-seasonal periods = 900 SR.
- The warehouse has to have at least 15 full-time pickers at all times.
- The model is constructed in days-on and days-off. Days-on are represented by 1s and days-off are represented by 0s.

Within the above characteristics, the MILP model formulated based on the following four proposed scenarios:

- **The first scenario** is to continue with the same policy between Panda Retail Company and the outsourced companies for part-time pickers. In other words, the part-time pickers will be hired once weekly in groups from Sunday to Saturday. Table 1 Shows the MILP model corresponding to this scenario.

- **The second scenario** is to supply part-time pickers in overlapped groups daily. This assumes, the first group works for 7 days starting from Sunday; the second group works 7 days starting from Monday; and so on. Table 2 shows the MILP model corresponding to this scenario.

- **The third scenario** is the same as the first scenario to continue with the same policy between Panda Retail Company and the outsourced companies for part-time pickers. In addition, releasing the condition of 15 full-time pickers at all times and reduce it to only 10 full-time pickers.

- **The fourth scenario** is the same as the second scenario to supply part-time pickers in overlapped groups daily. In addition, releasing the condition of 15 full-time pickers at all times and reduce it to only 10 full-time pickers.

**Phase #3: The Model Validation:**
OpenSolver 2.9.0 software is used to solve the four MILP models that constructed in phase (2). This software is an Excel VBA add-in that extends Excel’s built-in Solver with more powerful solvers. It is developed and maintained at the Engineering Science department, University of Auckland, VZ. Recent developments are courtesy at MIT. Table 3 summarizes the comparative results between the current solution of the problem under study and the proposed four solutions found from the four scenarios of hiring the part-time pickers in terms of:

- The total annual pickers’ costs.
- The number of full-time pickers required for the shipping demand in year 2019.
- The average number of pickers daily required.
- The average number of daily idle pickers.

Table 3 leads to the following savings to Panda warehouse management:

- The annual pickers’ costs are reduced approximately by 15%, 16%, 20% and 27% using scenarios 1, 2, 3 and 4 respectively.
- The number of full-time pickers is reduced by 25% in the first and second scenarios since this number is within the limits that Panda’s warehouse needs. However, the number of full-time pickers was reduced by 50% in the third and fourth scenarios based on a recommended suggestion by the researcher.
- The number of full and part-time pickers needed daily is reduced by 15%, 15%, 25% and 30% using scenarios 1, 2, 3 and 4 respectively.
- The average number of idle pickers daily is reduced by 23%, 31%, 39%
and 46% using scenarios 1, 2, 3 and 4 respectively.

Figures 6, 7, 8 and 9 display graphically the number of pickers required daily, the number currently assigned daily to Panda’s warehouse, and those required daily based on the four proposed scenarios to minimize the number of daily idle pickers and correspondingly minimize the total full-time and part-time pickers’ costs.

![Image of the number of pickers required daily for the year 2019.](image)

**Fig. 5.** Image of the number of pickers required daily for the year 2019.

**Table 1.** MILP formulation for the 1st Proposed Scenario: Supply part-time pickers only once a week with a minimum of 15 full-time pickers allowed daily.

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Table 2. MILP formulation for the 2nd Proposed Scenario: Supply part-time pickers in overlapped groups daily with a minimum of 15 full-time pickers are allowed daily.

| Constraint No. | Day       | Date       | Cost (SR) | X1 | X2 | X3 | X4 | X5 | X6 | X10 | X11 | X12 | X13 | X14 | X15 | X16 | X17 | X18 | X19 | X20 |
|---------------|-----------|------------|-----------|----|----|----|----|----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1             | Sunday    | 06-01-2019 | 9000      | 1  | 1  | 0  | 0  | 0  | 0  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | ≥10 | 10  | 0   | 0   |
| 2             | Monday    | 07-01-2019 | 9000      | 1  | 1  | 1  | 0  | 0  | 0  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | ≥5  | 5   | 0   | 0   |
| 3             | Tuesday   | 08-01-2019 | 9000      | 1  | 1  | 1  | 0  | 0  | 0  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | ≥3  | 3   | 0   | 0   |
| 4             | Wednesday | 09-01-2019 | 9000      | 1  | 1  | 1  | 0  | 0  | 0  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | ≥3  | 3   | 0   | 0   |
| 5             | Thursday  | 10-01-2019 | 9000      | 1  | 1  | 1  | 0  | 0  | 0  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | ≥5  | 5   | 0   | 0   |
| 6             | Friday    | 11-01-2019 | 9000      | 1  | 1  | 1  | 0  | 0  | 0  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | ≥4  | 4   | 0   | 0   |
| 7             | Saturday  | 12-01-2019 | 9000      | 1  | 1  | 1  | 0  | 0  | 0  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | ≥7  | 7   | 0   | 0   |
| 8             | Sunday    | 13-01-2019 | 9000      | 1  | 1  | 1  | 0  | 0  | 0  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | ≥8  | 8   | 0   | 0   |
| 9             | Monday    | 14-01-2019 | 9000      | 1  | 1  | 1  | 0  | 0  | 0  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | ≥5  | 5   | 0   | 0   |
| 10            | Tuesday   | 15-01-2019 | 9000      | 1  | 1  | 1  | 0  | 0  | 0  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | ≥7  | 7   | 0   | 0   |
| 11            | Wednesday | 16-01-2019 | 9000      | 1  | 1  | 1  | 0  | 0  | 0  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | ≥3  | 3   | 0   | 0   |
| 12            | Thursday  | 17-01-2019 | 9000      | 1  | 1  | 1  | 0  | 0  | 0  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | ≥5  | 5   | 0   | 0   |
| 13            | Friday    | 18-01-2019 | 9000      | 1  | 1  | 1  | 0  | 0  | 0  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | ≥4  | 4   | 0   | 0   |
| 14            | Saturday  | 19-01-2019 | 9000      | 1  | 1  | 1  | 0  | 0  | 0  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | ≥7  | 7   | 0   | 0   |
| 15            | Sunday    | 20-01-2019 | 9000      | 1  | 1  | 1  | 0  | 0  | 0  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | ≥8  | 8   | 0   | 0   |
| 16            | Monday    | 21-01-2019 | 9000      | 1  | 1  | 1  | 0  | 0  | 0  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | ≥5  | 5   | 0   | 0   |
| 17            | Tuesday   | 22-01-2019 | 9000      | 1  | 1  | 1  | 0  | 0  | 0  | 0   | 0   | 0   | 0   | 0   | 0   | 0   | ≥7  | 7   | 0   | 0   |

Table 3. Comparative results between the current solution and the proposed solutions.

<table>
<thead>
<tr>
<th>Item of comparison</th>
<th>Findings of the current solution</th>
<th>Scenario #1 (supply part-time pickers in groups once weekly with fixed 15 full-time pickers)</th>
<th>Scenario #2 (supply part-time pickers in groups daily with fixed 15 full-time pickers)</th>
<th>Scenario #3 (supply part-time pickers in groups once weekly with fixed 10 full-time pickers)</th>
<th>Scenario #4 (supply part-time pickers in groups daily with fixed 10 full-time pickers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The pickers’ costs</td>
<td>380,000 SR</td>
<td>305,100 SR</td>
<td>303,300 SR</td>
<td>289,800 SR</td>
<td>263,700 SR</td>
</tr>
<tr>
<td>The number of fixed full-time pickers</td>
<td>20 pickers</td>
<td>15 pickers</td>
<td>15 pickers</td>
<td>10 pickers</td>
<td>10 pickers</td>
</tr>
<tr>
<td>The average number of full and part-time pickers needed daily</td>
<td>20 pickers</td>
<td>17 pickers</td>
<td>17 pickers</td>
<td>15 pickers</td>
<td>14 pickers</td>
</tr>
<tr>
<td>The average number of idle pickers daily</td>
<td>13 pickers</td>
<td>10 pickers</td>
<td>9 pickers</td>
<td>8 pickers</td>
<td>7 pickers</td>
</tr>
</tbody>
</table>

Fig. 6. Comparison between the number of pickers daily worked and those proposed using scenario #1 for the year 2019.
Fig. 7. Comparison between the number of pickers daily worked and those proposed using scenario #2 for the year 2019.

Fig. 8. Comparison between the number of pickers daily worked and those proposed using scenario #3 for the year 2019.

Fig. 9. Comparison between the number of pickers daily worked and those proposed using scenario #4 for the year 2019.
6. Conclusions and Recommendations

The problem at Panda warehouse came from delaying many orders shipped to the stores that directly affect the availability of the stores. The delay caused by the lack of pickers to orders at times of high demand. On the other hand, other days when the warehouse gets a smaller number of orders from the stores, some of the workers are idle for long periods. Panda Retail Company schedules their workers in their warehouse manually. They do not use scientific techniques or software to allocate their resources. As a result, Panda Retail Company loose the customer’s loyalty, especially in the current competitive market, due to failing their demands at the right time. This besides excessive picker costs due to their idle times. A Mixed Integer Linear Programming model based on the cyclic scheduling approach is proposed and applied with four scenarios of solution. The results showed savings in the annual pickers’ costs between 15% and 27%, savings in the number of full-time pickers between 25% and 50%, and savings in the average daily idle pickers between 23% and 46%.

In the light of these results, the following recommendations made:

- Extend the study to include all the FMCG retailers in Saudi Arabia to compare them together to have the major common issues that could affect the performance of the warehouse during the picking process.
- Extend the study to cover all areas that affect the performance of the warehouse in Panda Retail Company, from the moment of receiving the goods in the warehouse until delivering these goods to the branches.
- Extend the study to cover the performance of each individual picker, based on the skills and experience of the picker. Therefore, each picker will have a different picking time.

References

Maan Radi et al.


تطبيق نموذج رياضي لحل مشكلة ملتقطي الطلبات في مستودع شركة بنده للتجزئة
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المستخلص. جاءت المشكلة في مستودع بنده من تأخير العديد من الطلبات التي يتم شحنها إلى المتاجر. التأخير حدث نتيجة عرقت العدد المطلوب من الطلبات لمنطقين في أوقات الطلبات المرتفع، من ناحية أخرى، في أوقات انخفاض الطلبات يكون بعض المنطقين خاملين لفترات طويلة، ونتيجة لذلك، فقدت شركة بنده للتجزئة وراء الميول، خاصة في ظل التنافس بين الشركات المناقسة، بسبب فشل احتياجاتهم في الوقت المناسب إلى جانب التكاليف الزائدة للملتقين بسبب أوقات خمولهم. في هذه الورقة العلمية، تم اقتراح نموذج البرمجة الخطية المختلطة (MILP) لتحسين عدد المنطقين المطلوبين للطلبات. تم تطبيق النموذج مع أربعة سيناريوهات من الحل لتغطية القواعد الواقعية في مستودع بنده. وقد أظهر النتائج الحد الأقصى من التوفر في تكاليف المنطقين السنوية بنسبة 27% بالإضافة إلى تقليل عدد المنطقين بدءاً من التوفر في تكاليف المنطقين السنوية بنسبة 50% بمساعدة من المنطقين الخارجيين. وأشارت الورقة أيضاً إلى توصيات للشركة التي تساعد على الحفاظ على مزاياها التنافسية في سوق التجزئة.

كلمات مفتاحية: إنشاء الطلبات، إدارة المستودعات، البرمجة الخطية، جدولة القوى العاملة.