Information System Proposal to Improve Warehouse Operations in a Production System

Araştırma Makalesi/Research Article

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***Abstract*—**The purpose of lean thinking is to get rid of as much waste as possible. Eliminating wasteful activities such as transport, overproduction, waiting, defects, overprocessing, inventory and movement is one of the most important prerequisites in a successful company. This concept is an integral part of lean thinking, and it helps increase profitability. Material picking costs constitute approximately 55%-60% of the total costs related to warehouse operations [1]. The purpose of this article is to develop an information system that finds the shortest path for the responsible personnel to collect the materials required for production from the stock addresses in the warehouse, determines the number of picking boxes required for these materials, and provides the material sequences within the box (in-box sequences). With this developed information system, it will be possible to reduce material picking costs by eliminating wasteful activities such as transport, waiting and movement. The implementation of the developed information system is carried out in a company that produces electromechanical products in Ankara. With the Material Picking Information Systems (MPIS) presented in this article, up to 50% improvement has been achieved in terms of the distance and time spent by the personnel and the model has been validated.

***Keywords*—** information system, warehouse management, determining of material picking route, determining of material picking box quantity

Bir Üretim Sisteminde Depo Operasyonlarını İyileştirmeye Yönelik Bilgi Sistemi Önerisi

***Özet*—** Yalın düşüncenin amacı, mümkün olduğunca fazla israftan kurtulmaktır. Taşıma, aşırı üretim, bekleme, uygunsuz malzemeler, aşırı işleme, envanter ve hareket gibi katma değeri olmayan faaliyetleri ortadan kaldırmak, başarılı bir şirketin en önemli ön koşullarından biridir. Bu kavram, yalın düşüncenin ayrılmaz bir parçasıdır ve karlılığı artırmaya yardımcı olur. Malzeme toplama maliyetleri, depo operasyonları ile ilgili toplam maliyetlerin yaklaşık %55-60'ını oluşturmaktadır [1]. Bu makalenin amacı, sorumlu personelin üretim için gerekli malzemeleri depodaki stok adreslerinden toplaması için en kısa yolu bulan, bu malzemeler için gerekli olan toplama kutusu sayısını belirleyen ve kutu içindeki malzeme dizilimlerini sağlayan bir bilgi sistemi geliştirmektir. Geliştirilen bu bilgi sistemi ile taşıma, bekleme ve hareket gibi israflı faaliyetler ortadan kaldırılarak malzeme toplama maliyetlerinin düşürülmesi mümkün olacaktır. Geliştirilen bilgi sisteminin uygulaması Ankara'da elektromekanik ürünler üreten bir firmada gerçekleştirilmiştir. Bu yazıda sunulan Malzeme Toplama Bilgi Sistemleri (MPIS) ile personelin harcadığı mesafe ve zaman açısından %50'ye varan iyileştirme sağlanmış ve model valide edilmiştir.

***Anahtar Kelimeler*—** bilgi sistemi, depo yönetimi, malzeme toplama rotasının belirlenmesi, malzeme toplama kutusu miktarının belirlenmesi

1. INTRODUCTION

Reducing the cost provides an improvement in the product price for the businesses and this provides an advantage in the marketplace. Reducing the costs in storage and material transfer movements reduces the product cost and this provides a competitive edge.

Any organization or companies have one or many warehouses. These warehouses considered most important and complex part which responsible for:

- Minimizing costs.
- Increasing the customer service level [2].

The warehouse management system purpose is the materials arrangement, management and controlled.

The preparation and distribution of raw materials, parts, semi-materials, and products for manufacture or sale is one of the core business of warehouse management. Material picking activities account for 55 percent to 65 percent of total costs associated with warehouse operations [1]. Rapid and accurate material preparation operations for the production line or customers ensure that not only does the production line or customer not have to wait for supplies, but that warehouse labor is also used effectively. The fundamental operation of a warehouse is the safe storage (stocking) of materials and their transit (handling) from one location to another. The warehouse activities for the preparation of raw materials, parts, semi-materials, and products for production or sale from the warehouse, which is one of the handling operations, begin with the picking activity of goods in the warehouse stock areas. This procedure accounts for the majority of warehouse activities. Improvements in material selection will have a direct impact on the overall operation as a big improvement.

In this article, a Material Picking Information System (MPIS) has been developed for responsible personnel who will collect the materials required for production from the warehouse, which determines the number of picking boxes (how many boxes are required for the materials), finds the order in which the materials will be collected by the shortest route, and lists how these materials are placed in the boxes.

Determining the material picking order is expressed as a Traveling Salesman Problem (TSP) problem and a solution method based on evolutionary algorithms presented by MS Excel Solver is used to find the shortest path (shortest material picking order). CLP Spreadsheet Solver, which is developed by Erdoğan [3] and which solves the container loading problem based on the large neighborhood search algorithm, is used to find the number of the picking box, calculate its size, and determine the material arrangement within the box.

The developed information system is implemented in a company that produces electromechanical products in Ankara. In the current system, the number of boxes, the shortest material picking order and the arrangement of the material in the box (in-box sequences) are realized with the experience and intuition of the responsible personnel. With the proposed MPIS, an improvement of approximately 50% has been achieved in the distance traveled and the time spent by the personnel for material collection.

With the Material Picking Information Systems (MPIS) presented in this article, up to 50% improvement has been achieved in terms of the distance and time spent by the personnel and the model has been validated.

Here, there are analytical models used by the information system, but the study has not been called a decision support system (DDS). A DSS usually deals with semi-structured or unstructured decisions and often provides decision support to tactical and operational level managers. However, the reports produced in this study are daily routine reports and reports at non-strategic levels. For this reason, the developed system can be considered as a management information system even though it uses an analytical model.

2. WAREHOUSE MANAGEMENT

In the literature, storage issues are classified as warehouse design and warehouse operations. Warehouses are an essential component of any supply chain. Their major roles include: buffering the material flow along the supply chain to accommodate variability caused by factors such as product seasonality and/or batching in production and transportation; consolidation of products from various suppliers for combined delivery to customers; and value-added-processing such as kitting, pricing, labeling, and product customization [4].

Warehouse design encompasses the overall structure, scaling and dimensioning, department layout, equipment selection, and operating strategy. Receiving and shipping, as well as storage and order picking, are all part of the warehouse operation.

Warehouse management encompasses the principles and processes involved in running the day-to-day operations of a warehouse. At a high level, this includes accepting and organizing warehouse space, scheduling labor, managing inventory and fulfilling orders.

2.1. Literature

Traditional discrete optimization issues such as the traveling salesman problem (TSP) and the bin (box) packing problem (BPP) are examples of warehouse challenges. Due to their NP-hard nature, these two issues are simple to formulate yet difficult to solve. BPP is frequently used to determine where products should be stored in a warehouse or on a pallet. Order picking is the most labor-intensive function in the warehouse. Many studies on order selection policies have been published [5].

Armstrong, Cook, and Saipe (1979) devised an order picking algorithm that uses a mixed integer linear programming model to reduce overall picking time [6]. For precise programming, they employed artificial orders. Field picking procedures for the distribution center have been studied. There are numerous published studies that highlight the utility of the heuristic algorithm in warehouse picking [7-9]. The goal of their study was to reduce the overall material pickup route.

Ratliff and Rosenthal (1983) provided a picking route algorithm for a warehouse system with two cross aisles, front and back [10], that minimizes picking time. Using a basic step structure, they created a reliable process for selecting a picking route.

Daniels et al. (1998) formulated a model for simultaneously determining the assignment and sequencing decisions, and compared it to previous models for order picking. They discussed the complexity of the order picking problem and established an upper bound on the number of feasible assignments. They presented a tabu search algorithm and experimentally tested [11].

De Koster et al. (2007) presented a literature overview on typical decision problems in design and control of manual order-picking processes. They focused on optimal layout design, storage assignment methods, routing methods, order batching and zoning [12].

Tsai, Liou, and Huang (2008) proposed a batch picking model that considers not only travel cost but also an earliness and tardiness penalty to fulfil the current complex and quick response oriented environment and solved this model using a multiple-GA method for generating optimal batch picking plans [13].

Lin, Kang, Hou, and Cheng (2016) suggested a model that incorporates order grouping and order choosing into one model. They used the Particle Swarm Optimization (PSO) technique to create a model for order grouping and choosing [14].

Erdoğan (2017) used the big neighborhood search heuristic technique to create an MS Excel VBA macro. This research aids in determining the quantity of each box type and the method for placing them in the appropriate boxes [3].

As seen by the literature, efforts to identify the optimal solution continue, as corporations seek the most appropriate solutions in order to gain a competitive advantage. There are many studies on warehouse operations (material collection route, bin packing, etc.). In this regard, especially review articles can be examined [4,5,12,15]

3. METHOD

3.1. Definition of the Problem and System Expectations

Preparing raw materials, parts, semi-finished products, and finished items for manufacturing or sale, referred to as stock materials, is one of the daily routine operations in the warehouse system with parallel aisles and starting and ending points in the same location. In these routine activities carried out, the determination of the picking route is based on the intuition and experience of the warehouse personnel. For this reason, losses of time and wastes will occur in material collection activities based on intuition and experience. Due to the fact that the responsible personnel cannot fully determine the amount and dimensions of the picking box they need before starting the picking activity, the warehouse personnel return to the picking starting point many times during the collection activity and take a new picking box or replace the existing box with a different size box. These repetitive transactions increase the time and labor losses of the enterprise.

3.2. Description of Current System and Limitations

In the company where the implementation is realized, the existing storage (warehouse) system has a width of 26 meters (m) and a length of 16m. There are five parallel lanes, four perpendicular aisles, and 72 designated stock locations. Each warehouse consists of 6 floors (level) and the warehouse has a total height of 5 m. Warehouse corridors are 2 m wide. The width of the stock areas is 2x2 m. In the coding of stock adress, as shown in Figure 1, the first subscript indicates the column number, while the second subscript represents the shelf row number. The sketch of the Warehouse System is given in Figure 2.

The shortest material picking path, number of picking boxes x, and box positioning simulation are all scheduled to function with 20 different materials to be picked from stock regions in the warehouse system. The purpose for this is to avoid the solution time being extended due to the MS Excel Solver infrastructure that will be used in the proposal. Different software infrastructures are anticipated to be able to boost this variety and solution time. There will be 72 different sorts of materials at each inventory location in the system's infrastructure.

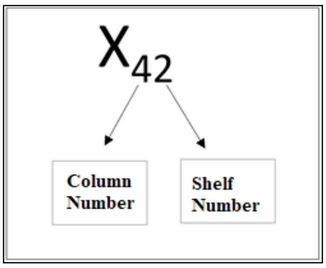


Figure 1. Stock address coding

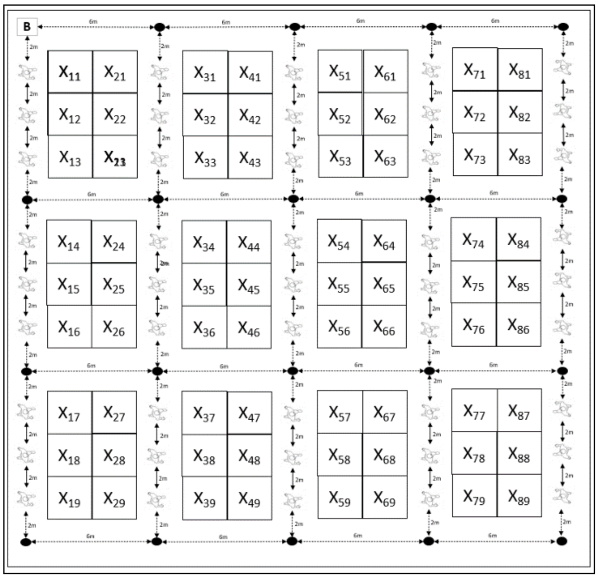


Figure 2. Warehouse’s map

Personnel who will begin picking materials from point (B) given in top left corner in figure 2 will return to point (B) once the picking is completed.

The required number of amount of boxes, the stuff of the box, and how it will be positioned will be displayed to warehouse personnel using simulation in proposed information system.

The materials and quantities of the picking list will be combined into a single lot, and the picking will be completed. In other words, all quantities of a substance to be selected should be in a single box. There are 3 types of picking box used in the warehouse: (0.40m x 0.60m x 0.28m), (0.60m x 0.80m x 0.32m) and (0.61m x 0.81m x 0.52m). Values in parentheses represent width, length and height, respectively. Pallets are used to convey materials that do not fit into any of the picking boxes. There are 5 picking boxes for each type and a total of 15 picking boxes. Figure 3 shows models of picking boxes.

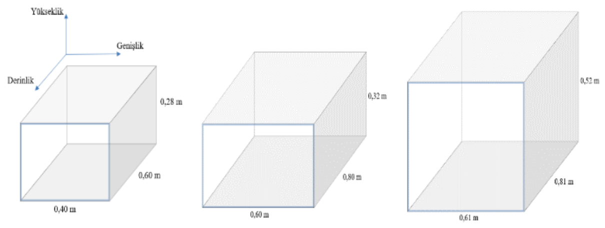


Figure 3. Picking boxes types

In the creation of the information system, Data Flow Diagrams (DFD) are used. DFDs are a widely used tool in the development of structural systems that gives a graphical depiction of the system. Any complicated system can be described using DFDs by utilizing four symbols: external entity, data flow, data store, and process. DFDs are drawn as context diagram, 0-level diagram, and sub-level diagrams [16].

3.3. Creating Context, 0-level, and Sub-level Diagrams

The Context Diagram of the system given in Figure 4 was designed with the system's constraints and expectations in mind. Picking box types information, warehouse location and distance between locations, material stock location information, material size information, sequence information according to pieces, required shipping box and in-box layout calculation request, 3D in-box layout request, and report are requests for the Material Picking Information System. The sequence of picking materials from stock locations, the number of boxes, the 3D in-box layout list, and other reports that indicate the shortest path are among the outputs of the MPIS. The external entities are warehouse supervisors and warehouse operators. The warehouse supervisor is the warehouse's administrative officer and is in charge of the warehouse's operations. The warehouse supervisor's key responsibilities include planning and arranging the day's activities. Warehouse operators are the employees who carry out the actions outlined in the warehouse supervisor's plan.

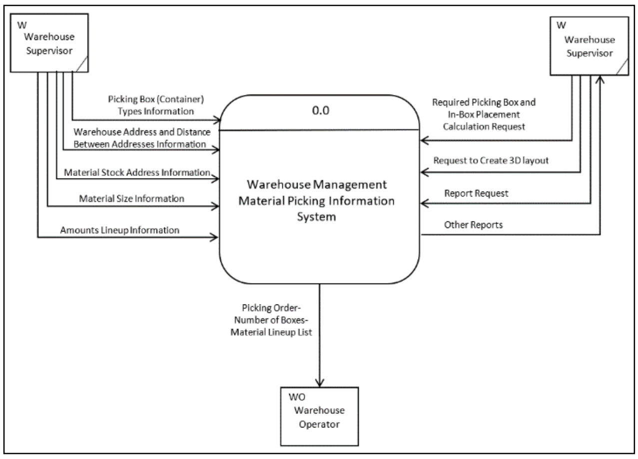


Figure 4. Context diagram

3.4. Creating 0-Level (Overview) Data Flow Diagram

0-level or overview diagram is given in detail in annex (a). The system has 9 processes and nine datastores. Sub-level diagram of the process 2.0 is shown in annex (b).

3.5. Creating System Data Stores and Data Model

In order to provide data entries such as trasport/picking box type data, material stock location data, material size data, warehouse location-distance data, box sequence data, and warehouse operator data, the user interface given in Figure 5 is designed.

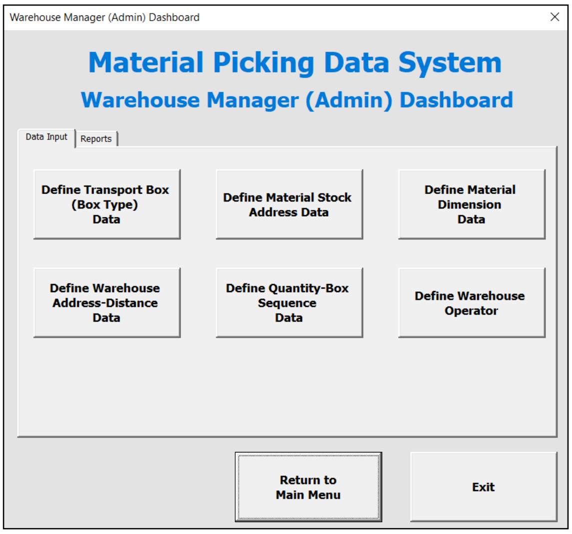


Figure 5. Data entry interface

The Entitiy Relationship (ER) Diagram and data model created for MPIS are given in figure 6 and figure 7 respectively.

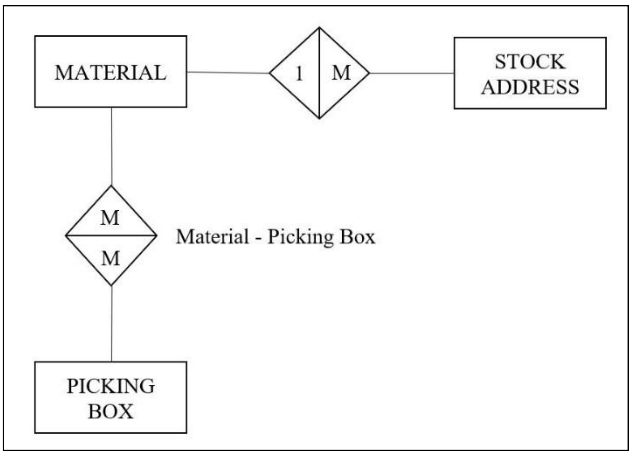


Figure 6. ER Diagram of the system

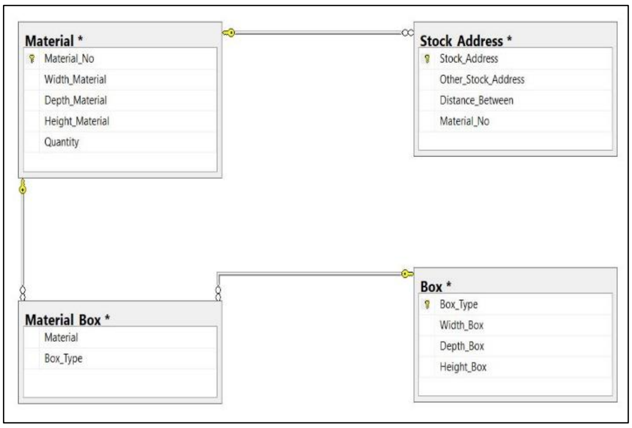


Figure 7. Data Model of the system

3.6. Solution Method

3.6.1. Calculating the Shortest Path

It is aimed to reach a solution by applying the the Traveling Salesman Problem (TSP) model to find the shortest picking path in the process 5.0 in the 0-level DFD. Practical applications of the TSP are in the field of distribution and transport logistics. In addition to optimal solutions, heuristic and genetic algorithms can be applied to solve TSP. Although TSP is easy to formulate, it is among the NP-hard natured problems.

The TSP can be formulated as an integer linear program. Several formulations are known but two notable formulations are the Miller–Tucker–Zemlin (MTZ) formulation [17] and the Dantzig–Fulkerson–Johnson (DFJ) formulation [18]. The DFJ formulation is stronger, though the MTZ formulation is still useful in certain settings.

Here, nodes (e.g.cities) are labeled with the numbers 1, …, n and define: $X_{ij}\epsilon\{0,1\}$: X_{ij} expresses whether to go from point i to point j. It takes the value 1 in case of going, and 0 in the otherwise. Take $C_{ij}>0$ to be the distance from city i to city j. Then TSP can be written as DFJ formulation the following integer linear programming problem [18]:

$$min \sum_{i=1}^{n} \sum_{j\neq i,j=1}^{n} c_{ij}x_{ij} \qquad (1)$$

$$s.t.$$

$$\sum_{i=1,i\neq j}^{n} x_{ij} = 1 \qquad j = 1,\dots,n; \qquad (2)$$

$$\sum_{j=1,j\neq i}^{n} x_{ij} = 1 \qquad i = 1,\dots,n; \qquad (3)$$

$$\sum_{i\in Q} \sum_{j\neq i,j\in Q} x_{ij} \leq |Q| - 1 \quad \forall Q \subset \{1,\dots,n\}, |Q| \geq 2 \qquad (4)$$

TSP; It is the problem of determining the least costly tour that goes through n cities, passes through each one only once and returns to the starting point, and the objective function can be expressed as given in function (1)

Equation (2) and equation (3) are constraints to ensure that each point is visited once.

The last constraint (Equation (4)) of the DFJ formulation ensures no proper subset Q can form a sub-tour, so the solution returned is a single tour and not the union of smaller tours. Because this leads to an exponential number of possible constraints, in practice, it is solved with delayed column generations. There are many exact algorithms (dynamic programming, branch-and-bound algorithm, Integer programming, cutting plane, etc.) and heuristics and approximation algorithms (greedy algorithms, Saving heuristics, meta heuristics etc.) for the TSP problem [15,19,20,21,22,32].

In this article, MS Excel Solver was used to find the material collection route in the TSP problem. The MS Excel Solver that will be used to solve the problem includes the "Evolutionary Solver" option. This solution method is based on genetic or evolutionary algorithms. MS Excel Solver offers a good or near-optimal solution for TSP in possible conditions. MS Excel Solver was chosen because it is a widely used freeware. However, Container/Cargo Loading Problem (CLP) Spreadsheet Solver, which will be used in planning the required number of boxes and in-box placement, is based on MS Excel and works in harmony with each other in both programs.

A distance matrix (Stock Locations Distance Matrix) of 73x73 size is created showing the distance between the stock locations needed to find the shortest path. Using the "Index" formula, which is one of the Excel formulas, the distance between two stock locations is drawn from the "Stock Locations Distance Matrix" with the help of the formula. The "Index" formula is applied in line with the constraint given for the picking of 20 kinds of materials specified within the system limitations. In the TSP to be implemented in MS Excel Solver, an additional constraint has been entered for the warehouse personnel to return to the starting point. MS Excel Solver TSP application screen is given in Figure 8.

The user interface designed for the user to select materials and run MS Excel Solver is given in Figure 9. This part covers the 4.0 and 5.0 processes on the 0-level DFD.

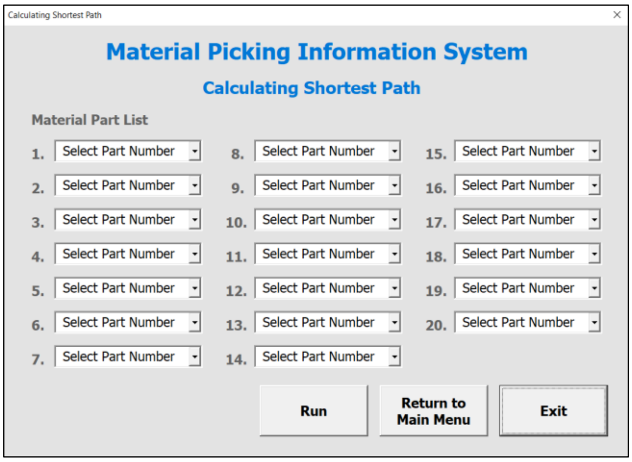


Figure 9. Shortest path calculation interface

As an example, a material picking list is created as in Table 1. The solution was reached in 70 seconds with a computer with Microsoft Windows 10 operating system and Intel(R) Core (TM) i5-8265U CPU @ 1.60GHz, 1800 Mhz, 4 Cores, 8 Logical Processors. A shortest picking route/path has been found as a solution. The shortest picking route is as follows.

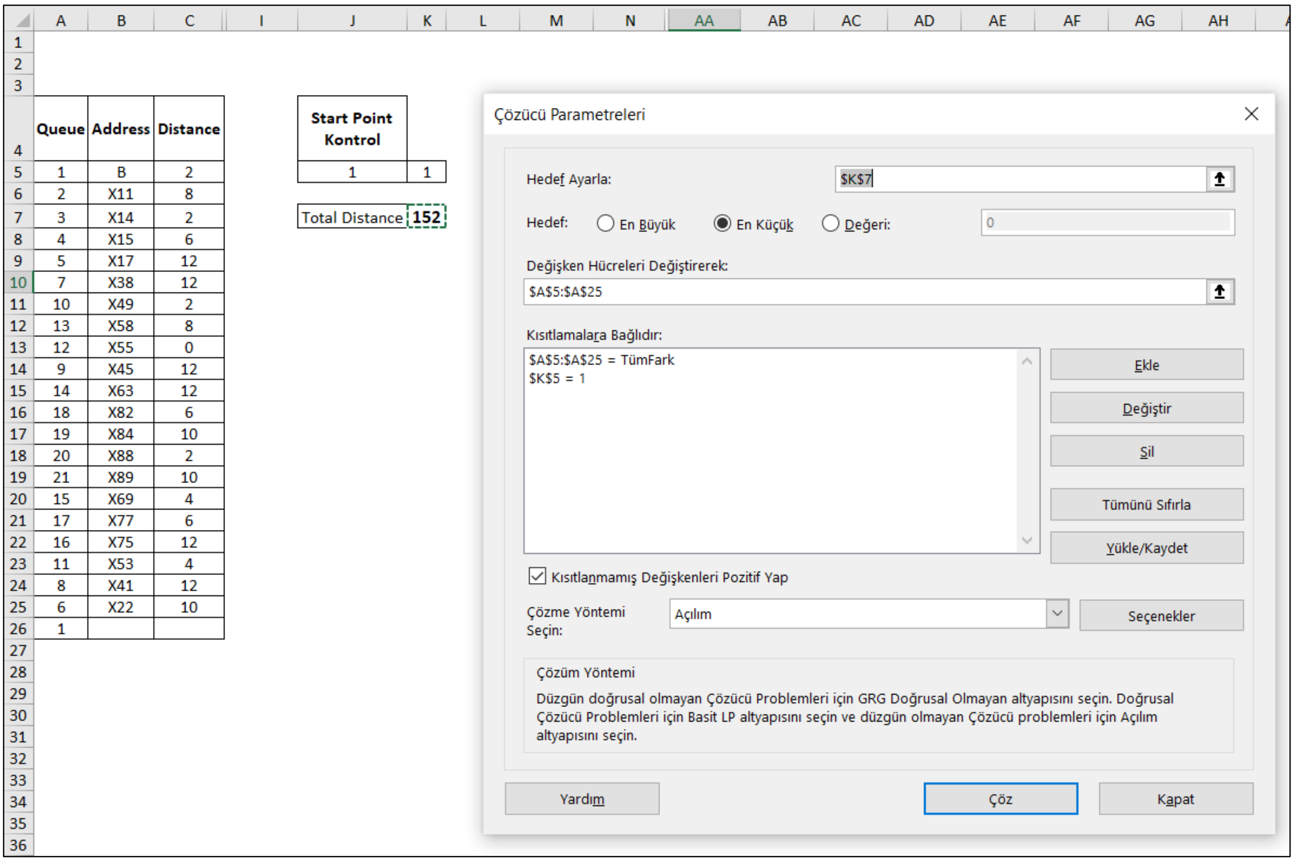


Figure 8. MS Excel Solver TSP application screen

B → X15 → X17 → X38 → X29 → X36 → X45 → X46 → X66 → X76 → X74→ **B**

The representation of the shortest path found on the warehouse sketch is as in Figure 10.

Table 1. Material Picking List

Material Part Number	**Stock Address**
P/N - 5	X15
P/N - 7	X17
P/N - 18	X29
P/N - 24	X36
P/N - 26	X38
P/N - 32	X45
P/N - 33	X46
P/N - 51	X66
P/N - 58	X74
P/N - 60	X76

The result report screen created with the MS Excel Visual Basic for the information system is given in Figure 11. This report will be listed to the warehouse operators and they will perform material collection according to this list. Total distance of this route is calculated as 90 m.

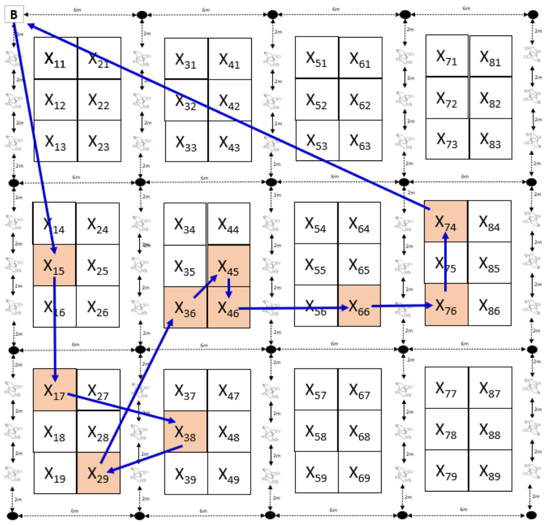
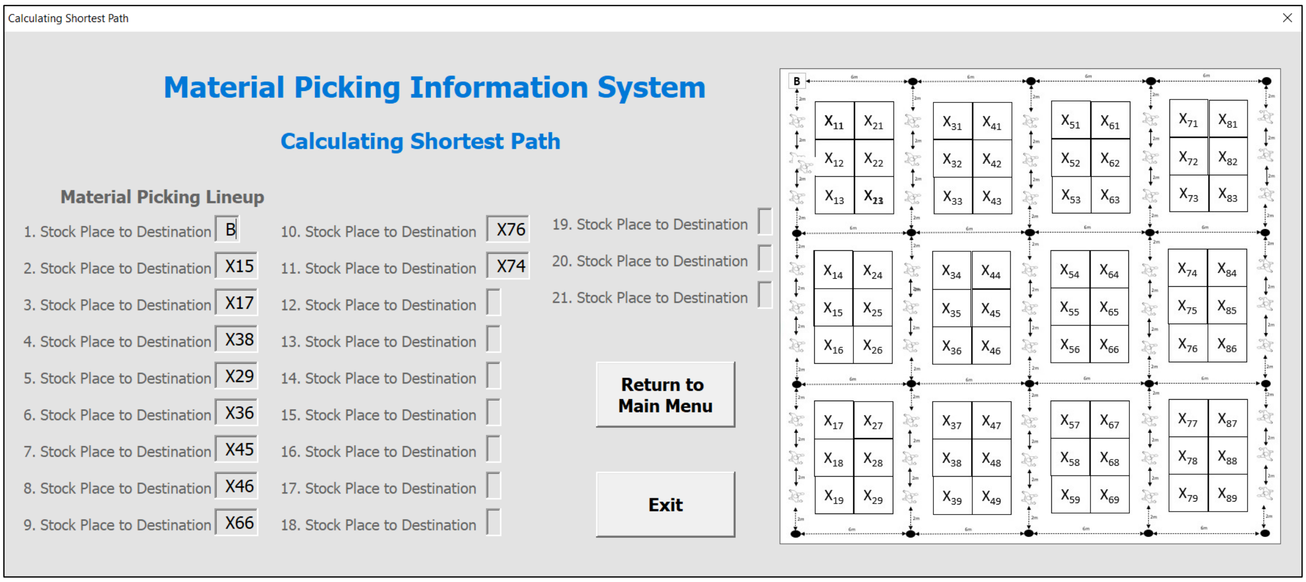


Figure 10. The shortest path on the warehouse sketch

Figure 11. The result report on the information system



3.6.2. Calculating Picking Box Requirement

The problem of placing items of various volumes in boxes of various volumes in order to minimize the number of boxes used is known as the container loading problem (CLP)/3D bin packing problem. The another problem to be solved in this study is to place the materials in the box by minimizing the number of boxes.

CLPs belong to the NP-hard nature due to the dimensions of the boxes and the varying capacities of the containers. For this reason, it is not possible to solve the problem optimally as the problem size grows, so it is a necessity to use heuristic algorithms. The closed mathematical form of the container loading problem is given below:

$$\max \sum_{i=1}^{n} v_i \, p_i$$

$s.t.$

$$0 \le x_i \le W - w_i \qquad (1)$$
$$0 \le y_i \le L - l_i \qquad (2)$$
$$0 \le z_i \le H - h_i \qquad (3)$$

$$W, L, H, w_i, l_i, h_i, n \in Q^+$$
$$x_i, y_i, z_i \ge 0$$
$$p_i \in \{0,1\}$$
$$i = 1,2, \dots, n$$

Here Q^+: Positive integer, W, L, H: Container dimensions, w_i, l_i, h_i: Box dimensions, n: Total number of boxes, pi: Binary code showing whether box i satisfies the constraints, $v_i = w_i.l_i.h_i$: i Indicates the volume of the box. In addition, the boxes will not overlap each other and will be supported by the container floor or other boxes.

There are many studies on the CLP/3D bin packaging problem in the literature. For some of these references, see [23-31]. The MS Excel workbook “CLP Spreadsheet Solver” is an open-source tool for representing, solving, and visualizing the results of Container Loading Problems developed by Erdogan [3] is used to calculate the amount and size of the required picking box and to determine the layout within the box. He implemented the Large Neighborhood Search heuristic within the CLP Spreadsheet Solver. An outline of the algorithm is given below [14]:

- **Step 1 (Initialization)**: Sort the items with respect to their priority, size, and profit. Sort containers with respect to their size and cost.
- **Step 2 (Constructive step):** Use the First-Fit-Decreasing heuristic to pack the items into the containers.
- **Step 3 (Perturbation):** Randomly remove items from containers, and randomly empty a number of containers. Sort the containers in decreasing order of the volume packed into them.
- **Step 4 (Reoptimization):** Use a constructive heuristic to repack the removed items into the containers.
- **Step 5 (Solution update):** If the new solution is better than the best-known solution, update the best-known solution. Otherwise, revert back to the best-known solution. If the time limit is not exceeded, go to Step 3.

The large neighborhood search algorithm used in Excel CLP Spreadsheet Solver is positioned as meta-heuristic in the literature. Meta-heuristic is a high-level problem-free algorithmic framework that provides a set of guidelines or strategies for developing heuristic optimization algorithms [32].

In the system, it is necessary to combine the materials to be collected on the basis of quantity so that they do not separate from each other. For example; Suppose 30 pieces of "P/N - 5" material are to be collected. We see that this amount is factored into 2-5-3. For this reason, these 30 items have been made into a single lot with the 2-5-3 arrangement. Dimension properties of 72 kinds of materials are recorded in meters as width-depth-height. An interface is designed to select the materials to be collected and enter their quantities. Within the limitations of the system, a data entry has been developed for 20 types of material selection. The interface design in accordance with the 6.0 process shown on the 0-level DFD is as in Figure 12.

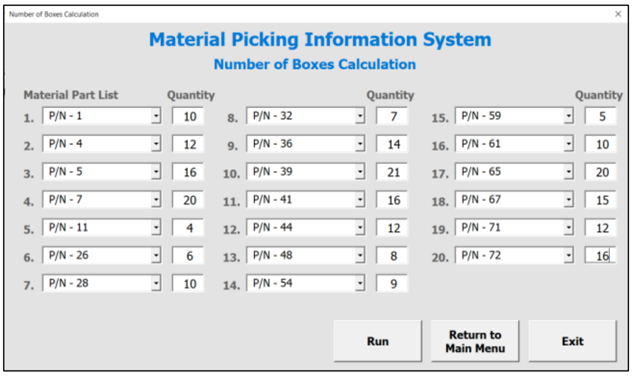


Figure 12. Number of boxes calculation interface

The solution was reached in 45 seconds with a computer with Microsoft Windows 10 operating system and Intel(R) Core (TM) i5-8265U CPU @ 1.60GHz, 1800 MHz, 4 Cores, 8 Logical Processors. After the solution, the result report that will guide the user in the Material Picking Information System has been created with an interface as in Figure 13.

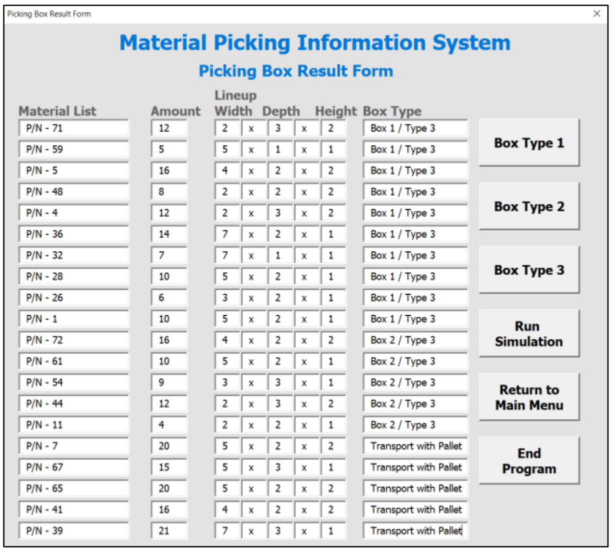


Figure 13. Picking box requirement and in-box placement result interface

In MPIS, a 20-second simulation is performed that shows the material sequences in the picking box (in-box placement) one by one. The result is presented to the warehouse operator as part of the 7.0 process in 0-level DFD. According to the Sample Report, 2 of the type 3 material picking boxes (0.61m. x 0.81m. x 0.52m) are found to be sufficient and the result is reached. The layout image of the materials inside the box created by the Information System is given in Figure 14.

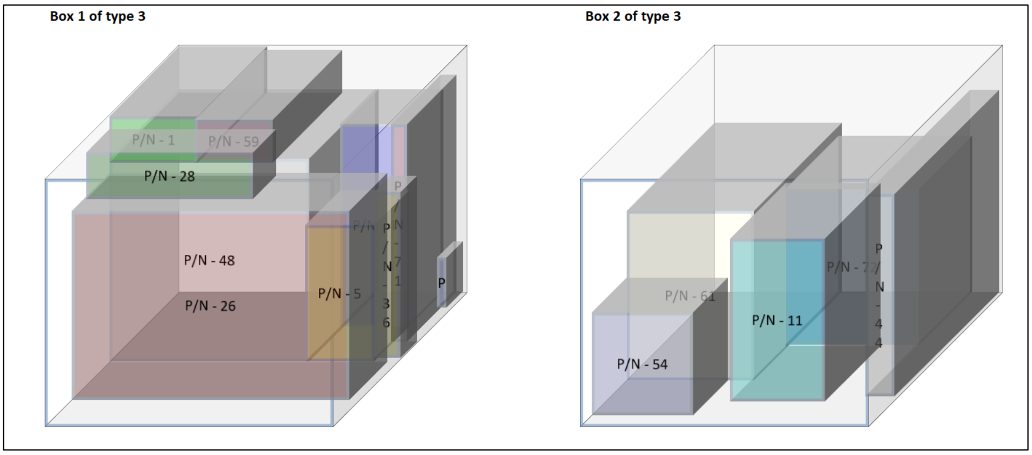


Figure 14. The layout image of the materials inside the boxes

3.6.3. Sequential Calculation of Shortest Path and Picking Box Requirement

The shortest path and the number of picking boxes calculated separately in the previous headings are run sequentially here, and it is aimed to meet the user expectations by adding the shortest path function first and then the picking box need calculation function. Even if the use of this method increase the solution time, it can fully meet the user's needs. It took 70 seconds to find the shortest path, 45 seconds to calculate the required for the picking box, and 20 seconds to simulate the box. Thus, the solution could be reached in 135 seconds with approximately 25000 sub-problem solutions. The solution is presented to the warehouse operator as shown in Figure 15. Thus, the user can get information and waste can be prevented.

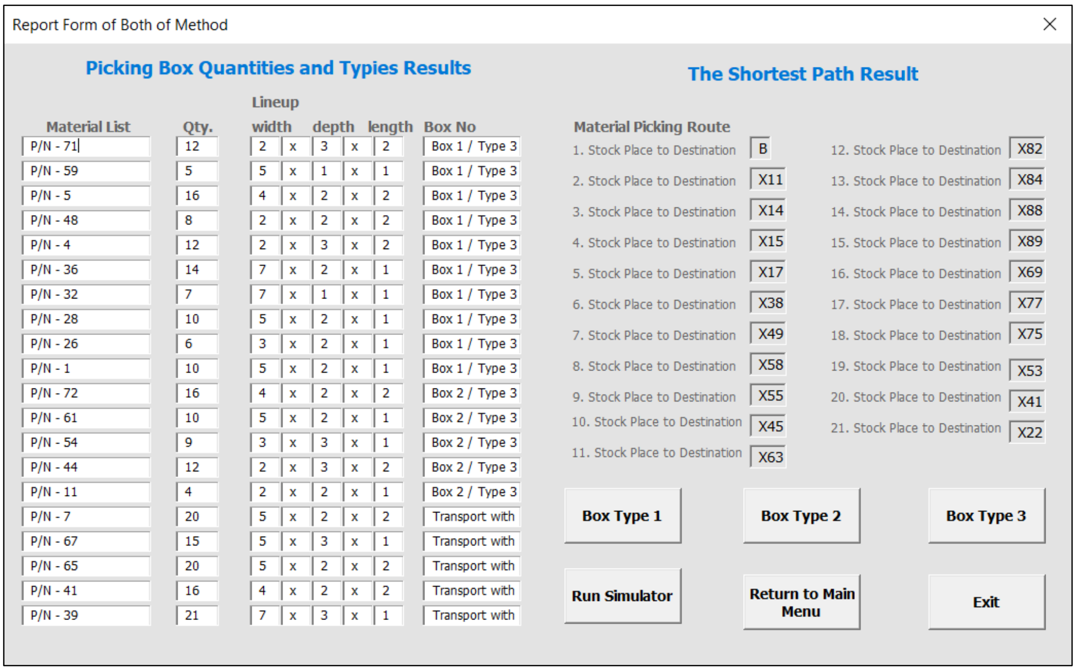


Figure 15. Result form interface for calculating shortest path and number of picking boxes

3.6.4. Reporting to the Warehouse Officer (Manager)

The "Warehouse Manager Interface" in the main menu of the information system (MPIS) has been developed so that the Warehouse Officer can manage the work and information system during the day. With this interface, many reports such as Box Type Report, Warehouse Address Distance Report, Material Inventory Addresses

Report, Material Dimension Report, Piece-Box Arrangement Report, Warehouse Operators Report, Materials to be Purchased and Quantity Report, Number of Required Boxes and Placement Report and Shortest Path Report, can be obtained. The visual of the Material Dimension Report, which is one of these reports, is given in Figure 16.

3.7. Validation of proposed MPIS

Implementation of the developed information system is carried out in a company that produces electromechanical products in Ankara for the verification of the proposed MPIS. In order to verify the MPIS and see its performance, it is compared with the existing system where warehouseoperations is traditionally done. The comparison is made over 10 different material collection work orders. The material collection processes performed by the personnel without using MPIS, with their experience and intuition, and the material collection processes using MPIS for the same work order are compared in terms of number of return to the starting point, total distance traveled (m) and Total time spent (min). Comparison results are given in Table 2.

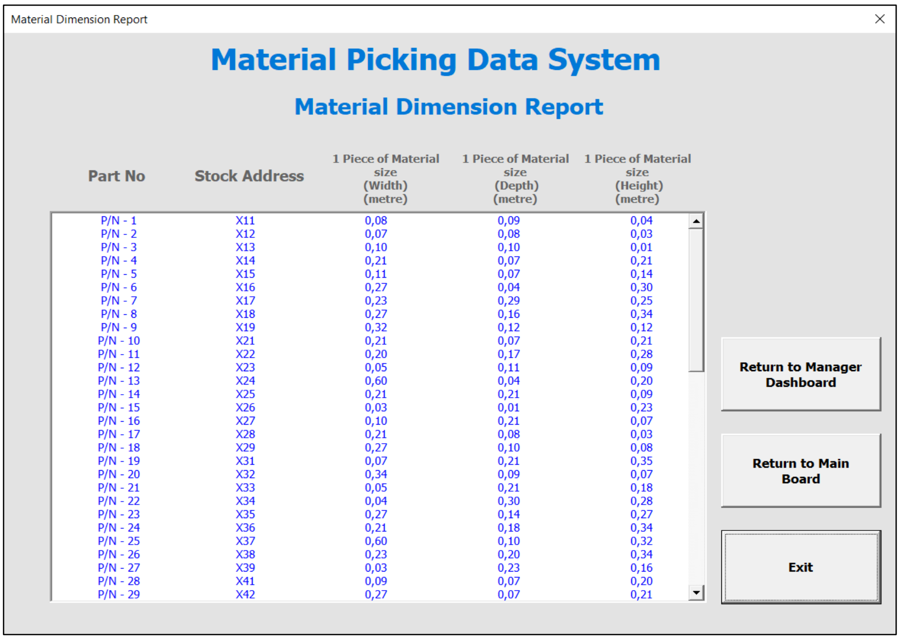


Figure 16. Material dimension report

Table 2. Comparison of Current and Proposed System

Work order ID	# of material items to be collected	# of stock address point to be visited	# of return to the starting point		Total distance traveled (m)		Total time spent (in minute)	
			Without Using MPIS	Using MPIS	Without Using MPIS	Using MPIS	Without Using MPIS	Using MPIS
10455	11	11	0	0	124	74	83,6	45,1
10456	10	10	1	0	152	126	90,2	41
10457	20	20	1	0	196	126	166,2	82
10458	20	20	0	0	160	126	152	82
10459	3	3	0	0	48	148	22,8	12,3
10460	18	18	1	0	148	148	151	73,8
10461	16	16	3	0	220	48	164,2	65,6
10462	15	15	2	0	192	74	142,4	61,5
10463	17	17	1	0	160	74	143,4	69,7
10464	6	6	0	0	52	48	45,6	24,6
Total	**136**	**136**	**9**	**0**	**1452**	**992**	**1161,4**	**557,6**
Average value per unit					10,68	7,29	8,54	4,10

As can be seen in Table 2, 136 items of materials were collected from 136 stock addresses. When MPIS was not used, a total of 9 return to the starting point occurred during the activity. When MPIS is used, this value is 0, meaning that there was no return to the starting point. With the use of MPIS, the total distance traveled has decreased from 1452m to 992m. When these values are proportioned to a total of 136 items of material, 10,68m and 7,29m per item are obtained, respectively. That is, the total distance traveled decreased by 3,39m per unit. Similarly, the total time spent decreased from 1161,4 min. to 557,6 min. When these values are proportioned to a total of 136 items of material, 8,54min and 4,10min per item are obtained, respectively. That is, the total time spent decreased by 4,44min per unit. In summary, with the use of MPIS, it can be seen that approximately 50% improvement has been achieved in the material collection and preparation activities of the company

4. CONCLUSION

Many businesses focus on reducing their costs because they cannot raise their product prices to sustain the economy of their businesses. Taking into account all the costs carried out in the warehouse, the cost portion of 55%-

65% consists of the activities of collecting and preparing the materials from the warehouse from the stock areas. Reducing these costs means increasing profitability. Reducing these costs means increasing profitability. This is the main objective of the study carried out in this article.

In this article, Material Picking Information System (MPIS) that finds the shortest path for the responsible personnel to collect the materials required for production

from the stock addresses in the warehouse, determines the number of picking boxes required for these materials, and provides the material sequences within the box (in-box sequences) is developed. With MPIS, it will be possible to reduce material picking costs by eliminating wasteful activities such as transport, waiting and movement.

Implementation of the developed information system (MPIS) is carried out in a company that produces electromechanical products in Ankara for the verification of the proposed MPIS. In order to verify the MPIS and see its performance, it is compared with the existing system where warehouse operations is traditionally done (In the current system, the number of boxes, the shortest material picking order and the arrangement of the material in the box (in-box sequences) were realized with the experience and intuition of the responsible personnel). The comparison is made over 10 different material collection work orders. The material collection processes performed by the personnel without using MPIS, with their experience and intuition, and the material collection processes using MPIS for the same work order are compared in terms of number of return to the starting point, total distance traveled (m) and Total time spent (min). With the proposed MPIS, an improvement of approximately 50% has been achieved in the distance traveled and the time spent by the personnel for material collection.

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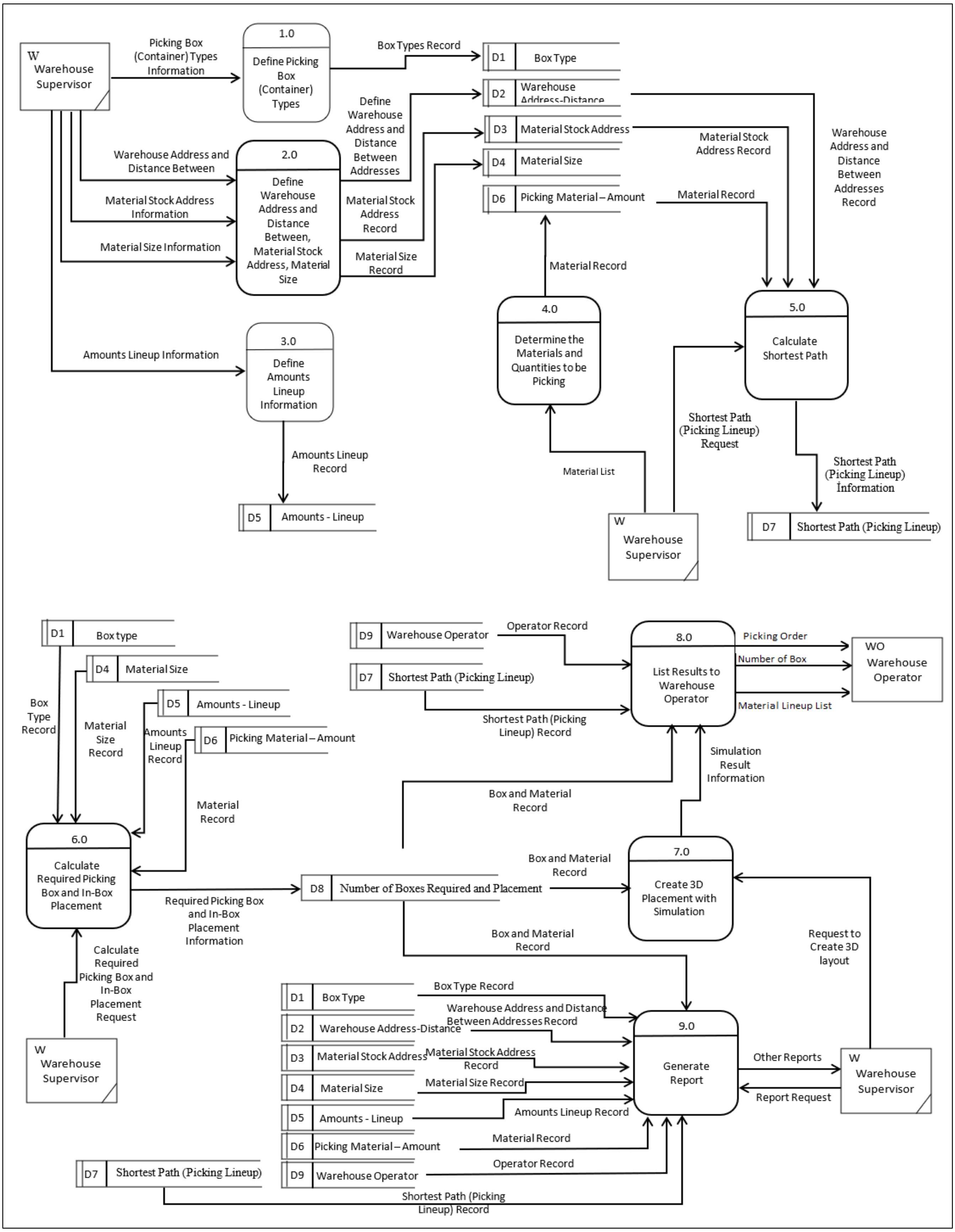
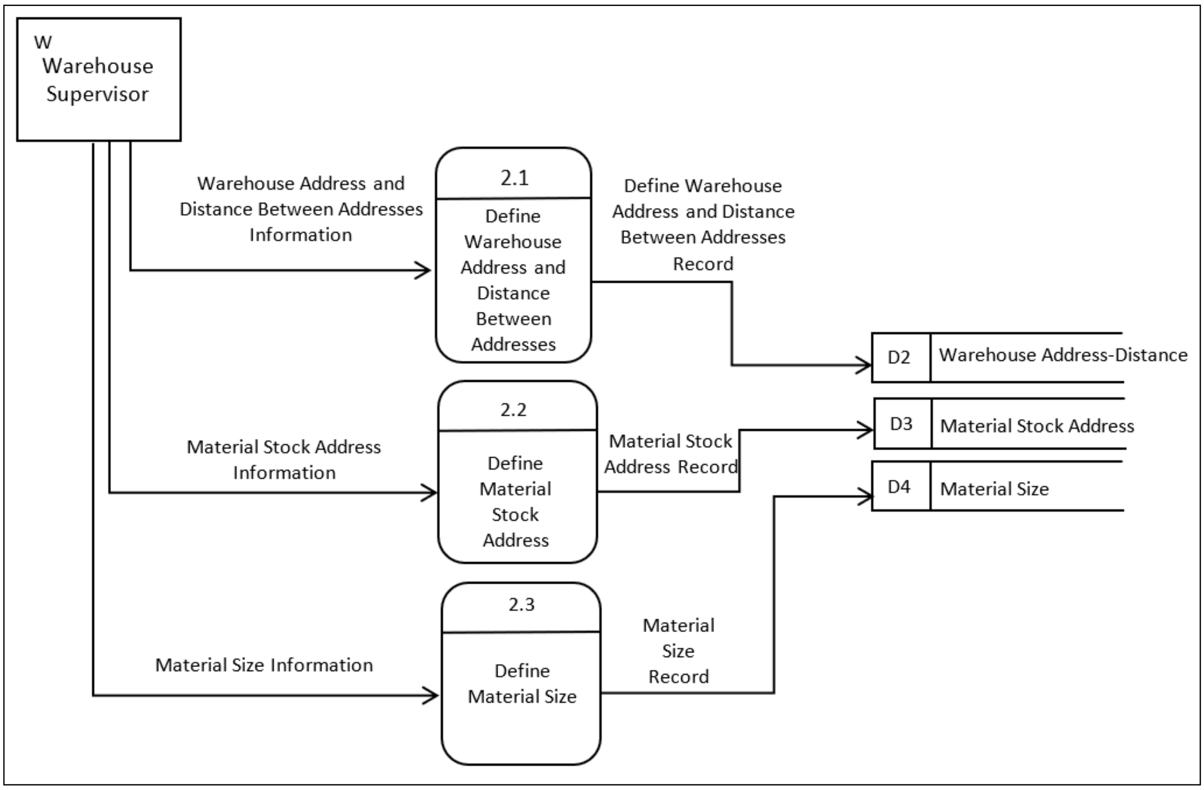
ANNEX



(a) 0-Level Data Flow Diagram



(b) The Sublevel Diagram of Process 2.0