FACULTY OF ENGINEERING
DEPARTMENT OF INDUSTRIAL ENGINEERING

IE 4920 SYSTEM ANALYSIS REPORT

A Warehouse Management Decision Support System for TOTOMAK

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Izmir, 2023

The system, process, or product addressed in this project;

has multiple components and includes various subsystems ☐

concerns more than one discipline ☐

requires solving complex problems for its analysis and design ☐

This project has been designed under the following realistic constraints and conditions (all or that apply) which are discussed in a separate paragraph in the conclusion section.

Economic Considerations ☐

Environmental Considerations ☐

Sustainability ☐

Applicability ☐

Ethical Considerations ☐

Social and Political Considerations ☐

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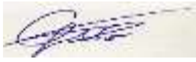
Prof. Dr. Levent Kandiller

We hereby certify that this project is our own work, except where indicated by a reference.

Burak Kurt 

Güner Şirin 

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Abstract
Warehouse management is considered as one of the essential components of a supply chain. Inadequate storage space and inefficient available storage are common problems in designing warehouses. In this project, an effective warehouse management policy is needed because of having limited space for finished goods. The complementary solution is to ensure that the highest-selling inventory is easily accessible by placing it at the most accessible point. Position of the finished goods and deciding the sequence of routes to perform the fastest loading and unloading work are critical factors in reaching maximum efficiency. This project aims to provide easy access to stored goods and minimize the travel time between the picking and the placing positions to avoid inefficient routes and disruptions by strategically planning the warehouse layout design and running each operation in the best sequential manner.

***Keywords*— warehouse management, ABC analysis, quadratic assignment problem, assignment problem**

I. INTRODUCTION

This project was processed warehouse management practices in Totomak Machinery and Spare Parts Company, a specialized exporter of machinery and spare parts. Warehouse management involves organizing and controlling storage and shipping operations to optimize efficiency, reduce costs, and increase revenue. It encompasses inventory tracking, process integration, and operational streamlining. Effective warehouse management enables companies to manage their supply chain, ensuring timely product availability and cost-effective shipping. Warehouse management systems provide benefits like improved inventory control, increased efficiency, and reduced costs. Totomak lacks a specific product placement policy and aims to implement a "First in, First out" (FIFO) approach. The study includes macro and micro analyses of the company, problem identification, literature review, and proposes a quadratic assignment problem approach and assignment problem models as the solution method.

Totomak was founded in 1950, has grown into a leading manufacturing company with a strong focus on exports. It started as a small workshop and later moved to a larger facility in Izmir, Turkey. Totomak expanded its product range and began supplying OEM parts to a truck manufacturer. In 1990, the company relocated to a new factory in Izmir and successfully achieved its target of exporting 85% of its products. Over the years, Totomak continued to expand, acquiring a new factory building and establishing a presence in Mexico. With a workforce of 880 employees, Totomak has become a leader in its industries, exporting 95% of its products to various regions worldwide. The company aims to meet the expectations of its business partners and become a preferred and competitive supplier through its machining experience and research and development efforts. It holds important certifications in quality management and information security. Totomak recorded steady sales growth from 2017 to 2019, totaling 20 million euros. Sales declined in 2020 due to the pandemic but rebounded rapidly in the subsequent period, reaching a peak in 2022.

Totomak utilizes approximately 29,750 tons of raw materials annually, including gray/ductile cast iron, aluminum, long steel, and steel alloy. Machining processes such as sawing, turning, milling, grinding, gun drilling, and high-pressure washing are employed to shape and cut the materials. Additionally, Totomak has established Assembly and Test Lines for specific components, such as oil pumps, Integrated Gas Modules (IGM), Diesel Conduct Manifolds (DCM), and Test Selected Manifolds (TSM).

Totomak data was used in this study to examine their warehouse management techniques. The data includes information on shipped materials, demand lists, warehouse layout, and square measurements. Through the application of ABC analysis, Pareto analysis, quadratic assignment problem analysis, and assignment problem methods, the study aims to identify and understand the challenges faced by Totomak in warehouse management.

The study employed Pareto analysis, applying the 80-20 rule, to identify critical factors influencing warehouse management. Analysis of sales data revealed that a small number of products (48) accounted for a large portion (80%) of the total quantity, while a larger number of products (140) contributed less (20%). This analysis aided in pinpointing the key factors impacting warehouse management and informed the development of a targeted solution. By prioritizing the most significant factors, the study aimed to effectively address the underlying causes of the warehouse management problem.

Nowadays, the company is moving to a new warehouse. It is considered that moving to a larger warehouse instead of the current warehouse. The layout of the new warehouse is shown in **Figure 1**. warehouse 4 will not be used. The company thinks of it as a waste dump. It is developed that work in the main warehouse. Which is divided into 3 parts. Warehouse 1 is generated with the production line, Warehouse 2 is the main part of the warehouse. Warehouse 3 is the delivery part. The company is planning to make the shelf system like a cross array or H shape array in the warehouse.

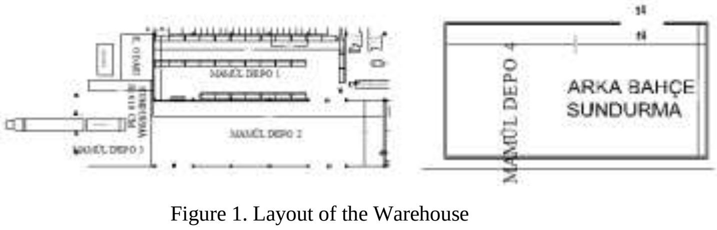

Figure 1. Layout of the Warehouse

II. PROBLEM DEFINITION

The company is relocating to a new warehouse due to inefficiencies at the current Izmir location, which have led to financial losses and hindered FIFO implementation. The project aims to enhance warehouse management efficiency by reducing unnecessary forklift operations and devising an algorithm to optimize product placement. Issues identified include inadequate data collection, unstructured pick and place operations, absence of a FIFO picking policy, unknown SKU locations, and manual forklift routing. The fishbone diagram in **Figure 9** presents detailed solutions to these issues.

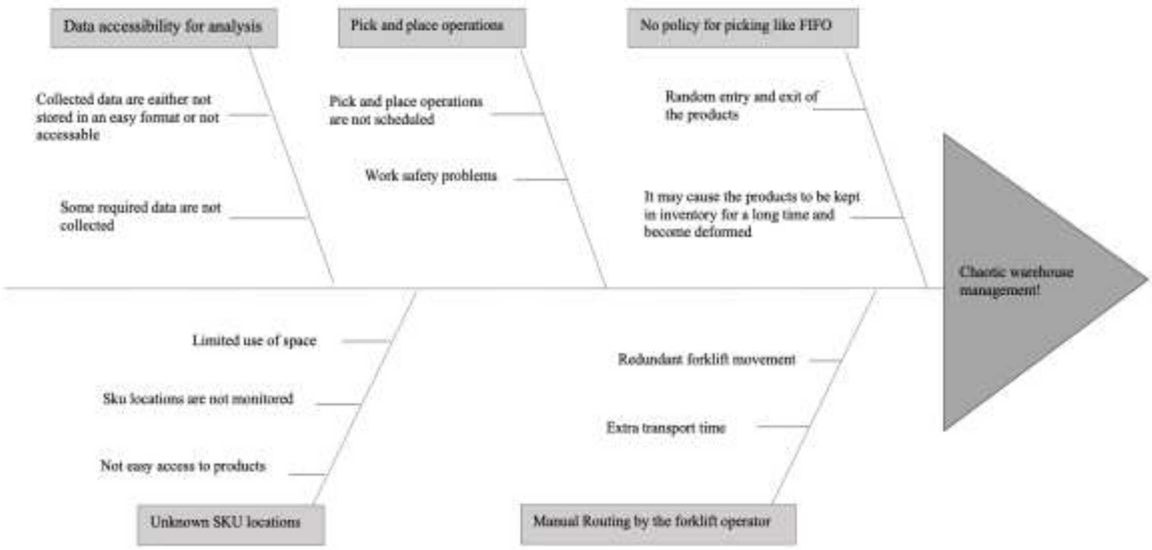

Figure 2. Fishbone Diagram

Following an analysis of company operations, several issues were identified, including inaccessible data, lack of scheduled operations, manual forklift operations, no FIFO or LIFO policies, and unknown SKU locations. Key performance indicators (KPIs) were established to address these issues, using industrial engineering methods. A two-stage mathematical model was then developed to improve warehouse layout and management and to evaluate the success of the implemented solutions based on these KPIs.

III. LITERATURE REVIEW

Considering the contributions made in this study and the scope of this subject are highly extensive, the literature review is examined under four headings including warehouse management, ABC and Pareto analyses, assignment problem, and quadratic assignment problem based on the topic discussed in the previous part above.

The literature demonstrates the critical role of warehouse layout in minimizing travel distance, with Caron et al. [1] highlighting that layout design can impact total travel distance by over 60%. Thus, ensuing analyses will focus on determining the optimal item placement within shelves.

Research [2] demonstrates the effectiveness of ABC grouping and inventory control decisions in establishing optimization models, drawing on the Pareto analysis principle. This principle, established in the 17th century, indicates that a majority of activities are not critical, with 20% of inventory products accounting for 80% of usage.

Various heuristics and algorithms, including the Hungarian method, the auction algorithm, and the proposed method, have been developed to address assignment problems [3]. Introduced by the German mathematician Konig, the Hungarian method is an effective technique for identifying optimal solutions without direct reference, focusing on minimizing opportunity costs.

Further contributions to the field include the work of Li and Smith [4], who applied stochastic congestion to traffic circulation systems and developed an algorithm for Quadratic Assignment Problems. Ji (1997) extended the application of the Hungarian Method by proposing an alternative based on $2n \times 2n$ matrix levels, where operations are performed until an optimal solution is achieved.

This part of the report provides us an important insight before proceeding to the next step which is the modeling approach. It helps us to understand our problem better and see the related methods to solve.

IV. Model Formation

In this context, required data for project analysis, such as the list of shipped materials, demand list, warehouse layout, and square measure, is received from Totomak. Based on the data we obtained from the company, we used ABC analysis, Pareto analysis, quadratic assignment problem analysis, and assignment problem methods to understand and diagnose the company's problems in terms of warehouse management.

Figure 3 show that ABC Analysis is applied to find the most important products which are needed to be placed on accessible shelves. Products are categorized by their sales weights, and the products with high frequency are defined as group A, constituting 50% of the orders.

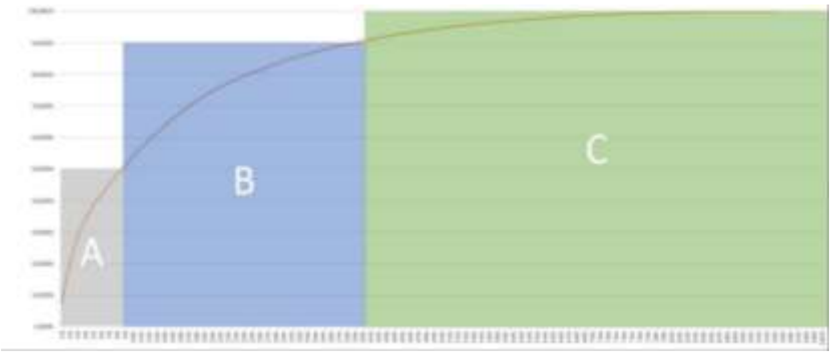

Figure 3. ABC Analysis 2023 for Sales

In the orders for the year 2023, group A consists of 16 products, with product codes X56, X132, X50, X150, X127, X168, X70, X66, X67, X115, X187, X47, X46, X90, X3, and X11, in order of frequency. These products make up 50% of the orders in 2023. Group B consists of 58 different products, and group C consists of 114 products. The remaining five products are unrecorded orders.

In our Pareto analysis, we used the 80-20 rule, also known as the Pareto principle, as a basis for our work. This principle states that, for many events, roughly 80% of the effects come from 20% of the causes. Our analysis of the company's sales data revealed that 48 products accounted for 80% of the total quantity, and 140 products accounted for only 20% of the total quantity. On the other hand, five products did not contribute to the total. Based on this information, we were able to identify the key factors that were contributing to the warehouse management problem and develop a solution that focused on addressing these underlying causes. By utilizing the Pareto principle and focusing on the most impactful factors, we were able to come up with a more effective solution for the warehouse management issue. Studies in ABC analysis were verified using with Pareto analysis.

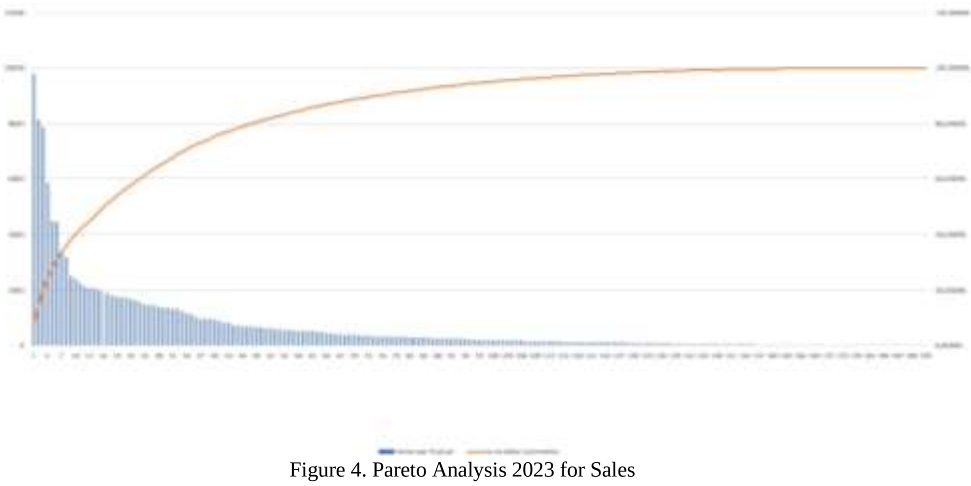

Figure 4. Pareto Analysis 2023 for Sales

Two models have been created by the Totomak company to solve the issue of disorganized warehouse management. The first model, which is tactical in level, deals with the six-month shelf allocation in accordance with the demand list of the company. This goal of this model is minimize total handling duration caused by product placement over the specified time period. The second model, which is situated at the operational level, aims to reduce the number of forklift sorties and the overall distance traveled during routine pick-up and placement tasks. These models were created with the intention of improving warehouse productivity and streamlining logistical processes.

The essential parameters for the models, turnover, safety stock, and maximum available to promise (ATP), have been determined. The process of parameter creation is elaborated upon below.

Parameters of Model l

The six-month demand list for Totomak company starting from May has been compiled.

TABLE I.

NUMBER OF PRODUCTS

Demand: Weeks (Number Of Products)							
Item	12.05.2023	19.05.2023	26.05.2023	2.06.2023	9.06.2023	16.06.2023	. . .
X2	12	47	24	-	36	-	. . .
X3	24	12	36	12	12	-	. . .
X4	12	12	12	36	12	12	. . .

The table displays the number of products that can fit on a single pallet.

TABLE II.

NUMBER OF PRODUCTS ON A SINGLE PALLET

Item	Number of Product / Pallet
X2	6
X3	12
X4	4

The table, which is based on a product-by-product analysis, has been updated to reflect the number of each product that can fit on a single pallet, resulting in the creation of a pallet-based table.

TABLE III.

NUMBER OF PALLETS

Demand: Weeks (Number Of Pallets)							
Item	12.05.2023	19.05.2023	26.05.2023	2.06.2023	9.06.2023	16.06.2023	. . .
X2	2	8	4	-	6	-	. . .
X3	2	1	3	1	1	-	. . .
X4	3	3	3	9	3	3	. . .

For each product, the week with the highest demand has been identified and added to the safety stock amount, resulting in the determination of the maximum available to promise (Max ATP) quantity. Once the total demand for each product has been determined, the frequency of turnover can be obtained by dividing it by the Max ATP value.

TABLE IV.

TOTAL DEMAND FOR EACH PRODUCT

Item	Max Weekly Demand	Safety Stock	Max ATP	Total Demand	Turnover
X2	8	2	10	20	2
X3	3	1	4	8	2
X4	9	3	12	24	2

In order to allocate shelves, Totomak company conducted shelf measurements in their warehouse, and a distance matrix was created based on the distances between the base point and the beginning of each shelf, accounting for the distance from the base point to the location start point.

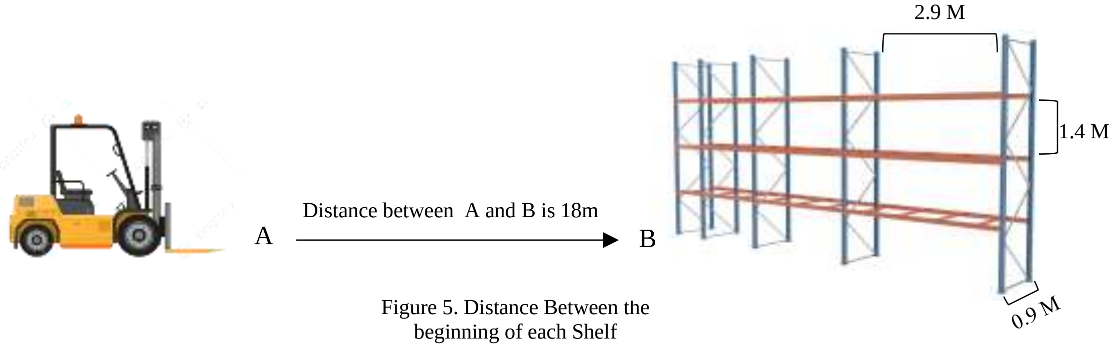

Figure 5. Distance Between the beginning of each Shelf

Sets of the model are as below.

S	Stock Keeping Unit $s \in S = \{1,2,\dots,\vert S\vert\}$
l	Location: $l \in L = \{1,2,\dots,\vert L\vert\}$

Input parameters of the model are as below.

t_s	Frequency of turnover
$a(s)$	Number of locations to be reserved for SKU's
d_l	Distance between the base and the location l wrt forklift movements

Decision variables are defined as follows.

x_l^s	Whether location l is reserved for SKU s

Based on the definitions above, the formulation of the problem is as follows.

$$Min \sum_l \sum_s t_s . d_l . x_l^s \qquad (1)$$

Subject to:

$$\sum_l x_l^s = a(s) \qquad \forall s \qquad (2)$$

$$\sum_l x_l^s \leq 1 \qquad \forall l \qquad (3)$$

$$x_l^s \in \{0,1\} \qquad \forall s, l \qquad (4)$$

To solve model 1 in the Python application, three different methods were attempted. The first method involved solving the mathematical model formulation using a general problem solver (GPS). The second method utilized a heuristic approach. The heuristic solution involved sorting items in descending order of turnover values and cloning items according to their ATP values. Next, locations were sorted in ascending order of distances. The final step was to match the minimum distance with the cloned item that had the maximum turnover. Lastly, the problem was solved using the Hungarian method. All three methods were tested on a toy problem consisting of 10 products, All codes were executed on Acer nitro i7 9th generation 16gb ram and based on the conducted experiments, pandas, scipy, numpy libraries are used in python code. The results are shown in the following table.

TABLE V.

COMPARISON OF METHODS OF MODEL 1

MODEL 1								
OBJECTIVE FUNCTION					TIME(CPU sec)			
PROBLEM	GPS	**Hungarian**	Heuristic	%GAP(H)	PROBLEM	GPS	**Hungarian**	Heuristic
1	4290,10	4290,10	4589,62	6,98%	1	0,00235	0,00023	0,00171
2	11566,44	11566,44	12464,99	7,77%	2	0,00211	0,00019	0,00179
3	7276,34	7276,30	7875,37	8,23%	3	0,00017	0,00025	0,00131
4	4942,04	4942,04	5241,56	6,06%	4	0,00268	0,00019	0,00156
5	16235,03	16235,03	17732,61	9,22%	5	0,00267	0,00021	0,00131
6	5593,98	5593,98	5893,50	5,35%	6	0,00224	0,00024	0,00176
7	12596,86	12596,86	13794,92	9,51%	7	0,00178	0,00024	0,00155
8	14552,68	14552,68	15750,74	8,23%	8	0,00121	0,00030	0,00189
9	19494,72	19494,72	20992,29	7,68%	9	0,00317	0,00021	0,00162
10	19873,20	19873,20	21670,29	9,04%	10	0,00264	0,00023	0,00161
				7,81%	**Average**	**0,00210**	**0,00023**	**0,00161**
				9,51%	Worst	0,00317	0,00030	0,00189

Both GPS and the Hungarian method were found to produce optimal results for the toy problem consisting of 10 items, but the Hungarian method was observed to be faster. The heuristic method, while producing results faster than GPS, failed to find the optimal solution. As a result, the Hungarian method was chosen for solving the problem at the actual scale.

After creating the distance and location matrices, a distance matrix was constructed for all products to solve the problem as an assignment problem. Each product was cloned as many as its Max ATP value. The distances between locations were multiplied by the turnover value of each product to obtain the distance matrix for all products and their respective locations. To solve the assignment problem, a square matrix is required. If the matrix is not square, dummies must be added.

TABLE VI.

DİSTANCE MATRİX OF MODEL 1

		DISTANCE	65	63.6	62.2	60.8	59.4	58	56.6	. . .	102,1
TURNOVER	ITEM	SHELF NUMBER	1	2	3	4	5	6	7	. . .	1320
3,15789474	X2	1	205,263158	200,842105	196,421053	192	187,578947	183,157895	178,736842		322,421053
3,15789474	X2	2	205,263158	200,842105	196,421053	192	187,578947	183,157895	178,736842		322,421053
3,15789474	X2	3	205,263158	200,842105	196,421053	192	187,578947	183,157895	178,736842		322,421053
3,15789474	X2	4	205,263158	200,842105	196,421053	192	187,578947	183,157895	178,736842		322,421053
3,15789474	X2	5	205,263158	200,842105	196,421053	192	187,578947	183,157895	178,736842		322,421053
3,15789474	X2	6	205,263158	200,842105	196,421053	192	187,578947	183,157895	178,736842		322,421053
3,15789474	X2	7	205,263158	200,842105	196,421053	192	187,578947	183,157895	178,736842		322,421053
3,15789474	X2	8	205,263158	200,842105	196,421053	192	187,578947	183,157895	178,736842		322,421053
3,15789474	X2	9	205,263158	200,842105	196,421053	192	187,578947	183,157895	178,736842		322,421053
3,15789474	X2	10	205,263158	200,842105	196,421053	192	187,578947	183,157895	178,736842		322,421053
3,15789474	X2	11	205,263158	200,842105	196,421053	192	187,578947	183,157895	178,736842		322,421053
3,15789474	X2	12	205,263158	200,842105	196,421053	192	187,578947	183,157895	178,736842		322,421053
3,15789474	X2	13	205,263158	200,842105	196,421053	192	187,578947	183,157895	178,736842		322,421053
3,15789474	X2	14	205,263158	200,842105	196,421053	192	187,578947	183,157895	178,736842		322,421053
3,15789474	X2	15	205,263158	200,842105	196,421053	192	187,578947	183,157895	178,736842		322,421053
3,15789474	X2	16	205,263158	200,842105	196,421053	192	187,578947	183,157895	178,736842		322,421053
3,15789474	X2	17	205,263158	200,842105	196,421053	192	187,578947	183,157895	178,736842		322,421053
3,15789474	X2	18	205,263158	200,842105	196,421053	192	187,578947	183,157895	178,736842		322,421053
3,15789474	X2	19	205,263158	200,842105	196,421053	192	187,578947	183,157895	178,736842		322,421053
⋮											⋮
0,0001	DUMMY	1320	0,0065	0,00636	0,00622	0,00608	0,00594	0,0058	0,00566	. . .	0,01021

The problem was solved using the Hungarian method on a Python application. The pandas, scipy, and numpy libraries were used to solve the problem. The results are presented in a summarized format.

Product 1 is assigned to shelf 1043 with a distance of 279.157
Product 2 is assigned to shelf 490 with a distance of 283.894
Product 3 is assigned to shelf 1099 with a distance of 281.052
Product 4 is assigned to shelf 501 with a distance of 281.052
Product 5 is assigned to shelf 455 with a distance of 280.736
.

Product 1312 is assigned to shelf 965 with a distance of 282.540

Total Distance:338515.086

Parameters of Model 2

Sets of the model are as below.

S	Stock keeping units s ∈ S ={1,2,…,|S|}
k	Number of sorties k ∈ K

Input parameters of the model are below.

$l_{(i)}$	Distance of location of the item i
$d_{0,l_{(j)}}$	Distance between the starting poing and placing product j
$d_{l_{(i)},0}$	Distance between the picking product i and turning to the starting point
$d_{l_{(i)},l_{(j)},}$	Distance between the picking product i and turning to the starting point

Decision variables are defined as follows.

x_i^k	1, SKU i is picked in sortie k; 0 otherwise
y_i^k	1, SKU i is placed in sortie k; 0 otherwise
z_k	1, if job is done in sortie k

Based on the definitions above, the formulation of the problem is as follows.

$$\left(\sum_j d_{0,l_{(j)}} + \sum_i d_{\boldsymbol{l}_{(i)},\mathbf{0}}\right) + min \sum_i \sum_j d_{\boldsymbol{l}_{(i)},\boldsymbol{l}_{(j)}} . x_{ij} \qquad (1)$$

Subject to:

$$\sum_i x_{ij} = 1, \qquad \forall j \qquad (2)$$

$$\sum_j x_{ij} = 1, \qquad \forall j \qquad (3)$$

$$x_{ij} = 0 \ or\ 1, \forall i, j. \qquad (4)$$

Objective function (1) Minimizes the distance that forklifts will take to pick and place the products. Constarint (2) guarantees that a product will be picked for every sortie. Constraint (3) guarantees that a product will be placed for every sortie. Range of the decision variable (4).

Prior to solving the real-life problem in Model 2 using a Python application, a toy problem was devised as a preliminary step. Toy instances: 20 items (10 picked, 10 placed) and 100 locations.

The toy problem was subjected to three solution methods: the general problem solver formulation (GPS), the Hungarian method, and the heuristic method. All codes were executed on Acer nitro i7 9th generation 16gb ram and based on the conducted experiments, pandas, scipy, numpy libraries are used in python code. The results obtained from these methods were then compared to identify the most appropriate approach. The comparative analysis is presented in the following table.

TABLE VII.

COMPARISON OF METHODS FOR MODEL 2

MODEL2								
OBJECTIVE FUNCTION				TIME				
PROBLEM	GPS	Hungarian	Heuristic	%GAP(H)	PROBLEM	GPS	Hungarian	Heuristic
1	61,33	61,33	65,33	6,58%	1	0,0522	0,0087	0,0002
2	128,66	128,66	154,00	19,70%	2	0,0109	0,0043	0,0002
3	88,66	88,66	106,00	19,64%	3	0,0144	0,0032	0,0001
4	149,33	149,33	185,33	24,11%	4	0,0183	0,0024	0,0003
5	108,66	108,66	108,67	0,01%	5	0,0162	0,0035	0,0001
6	115,33	115,33	122,00	5,78%	6	0,0223	0,0013	0,0002
7	82,66	82,66	84,00	1,62%	7	0,0209	0,0077	0,0005
8	274,66	274,66	313,33	14,08%	8	0,0135	0,0041	0,0001
9	95,33	95,33	99,33	4,20%	9	0,0143	0,0076	0,0002
10	85,33	85,33	108,00	26,57%	10	0,0301	0,0059	0,0002
11	148,00	148,00	172,00	16,22%	11	0,0134	0,0082	0,0004
12	113,33	113,33	133,33	17,65%	12	0,0194	0,0011	0,0002
13	113,33	113,33	120,00	5,89%	13	0,0111	0,0028	0,0002
14	108,00	108,00	108,00	0,00%	14	0,0186	0,0097	0,0001
15	68,00	68,00	69,33	1,96%	15	0,0153	0,0044	0,0002
16	175,33	175,33	195,33	11,41%	16	0,0125	0,0079	0,0002
17	165,33	165,33	178,67	8,07%	17	0,0175	0,0077	0,0006
18	103,33	103,33	142,00	37,42%	18	0,014	0,0065	0,0002
19	106,00	106,00	130,00	22,64%	19	0,0137	0,0071	0,0002
20	93,33	93,33	110,67	18,58%	20	0,01	0,0016	0,0002
				13,11%	Average	0,01793	0,005353	0,000271
				37,42%	Worst	0,0522	0,00978	0,000653

Based on the comparison results, it can be observed that both the GPS and Hungarian algorithms yield optimal solutions, while the heuristic method fails to achieve the optimal solution. Despite the heuristic method's notable speed, the Hungarian algorithm also exhibits considerable efficiency. Based on these findings, it is determined that the problem will be solved using the Hungarian algorithm.Upon completing the six-month shelf allocation for the products in Model 1, Model 2 will come into play to optimize the daily picking/placement operations of the products. After creating a list of products to be picked/placed daily, the first-in-first-out (FIFO) system is applied to select the product from the occupied locations for picking. The product that was initially placed in a location will be chosen first for picking based on the FIFO principle. For the product to be placed, one of the reserved empty locations is selected by the model in such a way that the distance is minimized, ensuring efficient placement of the product.

TABLE VIII.

PICK AND PLACE OPERATIONSS OF PRODUCTS

Picked	Full Cells Reserved For Item				
X62	44	33	43		
X120	174	25	127	173	
X65	249	304			
X185	303	155	293	339	257
X110	384	256	292	200	246

Picked	Selected Shelf Location For Picking
X62	44
X120	127
X65	249
X185	257
X110	384

Placed	Empty Cells Reseved For Items				
X45	84	88	130	75	
X61	164	72	36		
X146	23	69	124	159	217
X71	300	254	382	336	428
X188	379	471			

Placed	Randomly Selected Cells Location For Placing
X45	75
X61	72
X146	159
X71	254
X188	379

After determining the shelves for the products to be collected/placed, a distance matrix is constructed for the products. It is essential for the matrix to be square in order to solve the assignment problem. In case the matrix is not square, dummies must be incorporated to ensure its squareness.

TABLE IX.

DISTANCE MARIX SAMPLE OF MODEL 2

	44	127	249	257	384
75	63	98	127	133	183
72	48	76	99	103	142
159	56	88	115	120	165
254	18	28	36	38	52
379	65	101	132	138	189

V. RESULTS

The performance of Totomak Company, which randomly places products on the shelves in the warehouse, has been compared with the results of optimization in this project for a period of 22 working days. It has been observed that as a result of the implemented improvement, an average improvement of 22.7% has been achieved.

TABLE X.

COMPARISON TABLE COMPARING THE OPTIMIZATION WITH TOTOMAK PERFORMANCE

	TOTOMAK'S TOUR (m)	OUR TOUR (m)	DIFFERENCE	EFFICIENCY
DAY 1	6397	5123	1274	19,92%
DAY 2	6167	4981	1186	19,23%
DAY 3	4990	2992	1998	40,04%
DAY 4	6615	4009	2606	39,40%
DAY 5	6171	3682	2489	40,33%
DAY 6	6893	5067	1826	26,49%
DAY 7	6065	4112	1953	32,20%
DAY 8	6778	6011	767	11,32%
DAY 9	4347	3781	566	13,02%
DAY 10	4322	3792	530	12,26%
DAY 11	6575	5137	1438	21,87%
DAY 12	7516	5568	1948	25,92%
DAY 13	6053	4843	1210	19,99%
DAY 14	4719	4140	579	12,27%
DAY 15	7960	5897	2063	25,92%
DAY 16	7982	7002	980	12,28%
DAY 17	3956	3440	516	13,04%
DAY 18	8454	6657	1797	21,26%
DAY 19	4877	4205	672	13,78%
DAY 20	4950	3779	1171	23,66%
DAY 21	6160	5177	983	15,96%
DAY 22	7144	5332	1812	25,36%
MINIMUM	3956	2992	516	11,32%
MAXIMUM	8454	7002	2606	40,33%
AVERAGE	6141	4760	1380	22,07%

VI. Decision Support System

The generated Decision Support System allows for the viewing of project reports and presentations. After the user inputs the product name and demand, the allocated locations for the product can be shown. Additionally, the user has the ability to select the products to be placed on the shelves and picked from the shelves for any given day. Subsequently, the system matches the products to be picked from the shelves with the products to be placed on the shelves and presents the corresponding distances to the user.

Figure 5. Decision Support System User Interface

VII. Conclusion

In conclusion, a decision support system has been developed to optimize shelf organization and forklift movements for Totomak Company, which had a chaotic warehouse management and relocated to a new facility. A two-stage solution approach was devised after conducting analyses. The first stage involved allocating items to locations based on a six-month demand list. The second stage aimed to minimize the distance covered by daily forklift movements by optimizing them upon item arrivals and shipments. Mathematical models were solved using Excel and Python applications as the solution approach. Subsequently, the obtained results were compared with Totomak Company's performance, revealing an observed improvement of 22.7%.

VIII. References

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