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Designing the Resource Allocation System for the Effective Equipment Utilization: Case Study of a Saudi Industry

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Abstract

In this research paper, a resource allocation system for a Saudi industry is designed. There is a limited supply of four types of equipment in the company's main warehouse, which is causing equipment utilization problems. There are 13 ongoing sites where the equipment is transported and used. Instead of using the available equipment, project managers rent these items. As a result, the company incurs an avoidable cost. For the selected Saudi industry, the problem is identified, objectives are established, constraints are also identified, and the data was collected from the company, filtered, and analyzed. Two alternative solutions have been developed for each type of equipment using transportation models, lowest cost method, and mathematical models. In addition to developing a complete resource allocation system, the testing, validation, cost analysis, and recommendations for the company were conducted. After the analysis, the optimum solution for resource allocation problem was found, where all the analysis was done using XLS sheet solution to trace the system for optimum solution. The XLS sheet solution was used to analyze the data and identify the best allocation of resources. The findings were then used to create a plan to implement the new resource allocation system. Finally, the new system was recommended for the company to be put into operation.

Keywords
Resource Allocation, Equipment Utilization, Mathematical Modelling, Transportation Models and Least Cost Method.

1. Introduction
This research is critical for firms dealing with equipment that needs to be allocated to projects or sites effectively. It is intended to benefit the selected Saudi industry and other companies with similar networks. The application of this project is allocating resources and facilities based on supply, demand, distances, and cost. The solution generated in this paper is intended for global use. This solution was designed for one of the leading firms in the industry with actual data and will contribute to effective resource allocation and significant cost reduction. A Projects Regional Manager at the selected Saudi industry is dealing with a facility utilization issue. The company owns different types of equipment: compactors, crane trucks, excavators, and dump trucks with a supply of 15, 15, 5, and 10 respectively in the main warehouse. The equipment are sometimes needed in different locations around the country at the same time. The company relies on renting the requested equipment if all are occupied at different locations. It was also noticed that some of the equipment are held at certain locations for a long period of time without being used, and that other sites have to rent the same equipment to avoid any delay. This issue is adding an avoidable cost to the company. So, there is a need for an effective resource allocation system at the selected Saudi industry.

1.1 Objectives
The following are the objectives of this paper:
1) To design a transportation system for equipment utilization
2) To design a schedule for allocation
3) To provide a tracking system for equipment for effective equipment utilization

2. Literature Review
A literature review was conducted before starting this research to get exposed to other projects and papers with similar or connected backgrounds. These papers revolved around equipment utilization, queuing theory related to utilizing equipment, overall equipment effectiveness, overall input efficiency, total equipment efficiency, scheduling equipment, tracking systems, and different engineering tools used.

In a study, an edited approach has been applied to investigate utilization of equipment and estimating machine rates (Sessions et al., 2021). The approach lied in adjusting the equipment life for the utilization. It has been found that this edited approach resulted in more accurate estimates of machine cost. In another study, the queuing theory was applied in construction management to increase productivity and utilize equipment effectively (Sheikh et al., 2016). The theory was applied to activities of construction. The results suggested that the queuing theory increased the productivity and decreased the total cost. In a different paper, Overall Equipment Utilization was investigated and reviewed (Patel & Deshpande, 2016). The concerned metrics are Performance, Availability, and Quality. The evidence was provided that applying tools, such as 5S, can contribute to a visible increase in the OEE percentage. Other factors have also been investigated, as well as performance measures in a manufacturing process. This approach can also be applied to multiple industries. It has been found out that OEE is considered one of the simplest measures for the calculation of equipment efficiency in a company. Losses can be reduced by multiple ways, for example, monitoring different types of data, such as wear and tear of machines. In a similar study, the comparison between OEE and OIE (Overall Input Efficiency)/TEE (Total Equipment Efficiency) was studied and presented (Sheu, 2006). For the past years, OEE was considered the ultimate measure for production equipment efficiency calculation, however, this study found out that in different scenarios, this is not the case, and it only part of the equation. The idea of OIE was the missing part of the equation. Multiplying both OEE and OIE resulted in TEE, which is described as the true OEE, as the author explained. In another research, scheduling equipment and people was studied on container terminals (Hartmann, 2005). The methodology was generating a general model for the scheduling issues in the logistics of the terminal, as well as a dispatching heuristic discussion. It has been found out that the Algorithm is strongly suitable for use and application in real life. Another study investigated how to optimize trackless equipment scheduling (Wang et al., 2020). Genetic Algorithms were used, and the study was in underground mines. The results suggested that the Algorithm provided a solution for effective scheduling of equipment. In a different study, a resource allocation problem was solved using a tool that gives the DM the ability to include preference data regarding the relative relevance of inputs and outputs in the analysis that was created by combining DEA and MOLP (Korhonen & Syrjänen, 2004). In another paper, the robustness of a resource allocation was measured (Ali et al., 2003). The study outlines a process dubbed FePIA for methodically determining the robustness metric for several distributed and parallel resource allocation schemes. In a different area of study, to optimize the resource allocation strategy for the development work, a multi-objective evolutionary algorithm is built on top of a multi-objective particle swarm optimization (MOPSO) algorithm (Xilin et al., 2019). The case study demonstrates how optimizing resource allocation can significantly help to cut the development task's length and substantially lower its cost. In another study, they developed a scalable engineering approach to transfer real-world sensor data to update 3D device models in graphical digital twins and present a prototype application framework for simultaneously visualizing supervised construction processes (Talmaki & Kamat, 2022). They found that higher operating speeds required larger tolerances. In a study conducted by Amit et al by using the PULP software the transportation problem is solved. A mathematical model is made in order to minimize the cost, time as well as the distance (Jha et al., 2023) . Cesar et al solved the vehicle allocation problem (VAP) by using the integer linear programming (ILP) model based on the idea of representing the demands to be met as nodes on a graph. The authors used branch-and-price (BP) method to derive a Dantzig–Wolfe reformulation. The proposed BP uses a stabilized interior-point column generation approach and a branching procedure that imposes constraints in the master problem, thus not damaging the structure of the sub-problems (Cruz et al., 2022). In another research, linear programing was used to optimize the cost of transportation of goods of a flavors and fragrance company. The problem is solved by using the EXCEL Solver (Vamsikrishna et al., 2021).

The novelty of the presented paper is that it differs from other ones since it consists of several areas of study within the same problem and solutions. The proposed approach lied in generating complex transportation models since the supply is less than the demand, and generating multiple alternative solutions to the company that are all feasible. To reach this goal and other objectives, multiple tools from different industries and areas of research are used. The proposed final system is a combination of complex analysis, set of tools, models, alternatives, and software.

3. Methods

In this research paper, several methods were used to generate the resource allocation system. This session shows the different methodologies and tools used as a solution to the problem to meet the objectives.

3.1 Design Methodology

The first step was to identify the problem clearly and to determine the design constraints. The problem had to be clear before proceeding. Then, literature review was conducted to gather information that can help in this research from MDPI, Taylor & Francis, and other sources. The papers reviewed revolved around equipment allocation, scheduling, transportation, and connected concepts and tools. After that, the objectives were identified and set clearly in a way that ensures that they are doable and measurable. These objectives were abiding by the needs of the company and project goals. Moving on, one of the most critical stages was data collection. If the data was misleading or incorrect, the solution would be infeasible or invalid. Main data was provided by the company, however, the data was raw and it was needed to continue collecting data, such as distances between cites, in order to proceed with the upcoming stages. After the data collection was done, data analysis was performed. During the data analysis, any data that is not clear or misleading was cleaned and filtered, and multiple tables were designed to have a clear picture in mind displaying the relationships between cites, supply, demand, and timeline. After the data has been analyzed, the solutions are generated. While working on the solutions, engineering tools, such as the transportation model and lowest cost method, were used to generate solutions to the real-life problem. Multiple scenarios and approaches were implied, which all use the tools but also abide by the real-life constraints, scenarios, and contracts. When choosing the best solution, multiple criteria were kept in mind. The most critical one for the company was cost. The company can choose a different alternative for each type of equipment to reach a feasible optimal solution depending on their goals and decisions. The optimal solution was suggested. A complete transportation system with the tracking device of equipment was provided to the company. This was achieved using an Excel file that has interface to the user.
Figure 1 shows the design methodology used in this research paper:

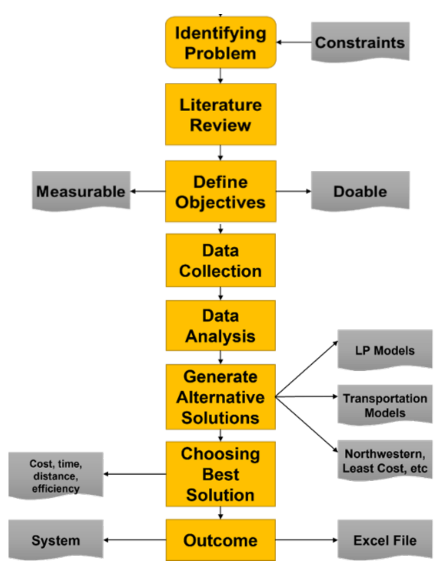


Figure 1. The followed design methodology to reach the final system.

3.2 Generating Alternative Solutions

Two main alternating solutions are designed in this research, which were further divided into six. The proposed solutions allocated the currently available equipment in warehouse, generated ways to cover the missing equipment if demand is larger than supply, and provided tracking options for the equipment. To achieve the objectives of the paper, the device tracking options for the equipment were studied. After understanding the company's requirements, these are the two devices conforming to the needs of the company, and that will be included in the alternative solutions: PTR501 GPS – Present Global and Bolt2 4G LTE-M / NB-IoT OBD-powered Tracker - Digital Matter.

3.3 Alternative Solution 1

In the first solution, the allocations were made for the available equipment and rented the missing equipment in their respective sites. This solution was extended to 4 solutions, which are described as follows:

1) In the first approach, tracking was done for only the equipment owned by the company, and the rented equipment will not be tracked. The device used for tracking will be the PTR.
2) In the second approach, rented equipment was not tracked also, however, the Bolt tracking device was used.
3) In the third approach, tracking was performed for both the owned and rented equipment with the PTR device as the company might also want to calculate their efficiency.
4) In the fourth approach, Bolt device was used to track all owned and rented equipment.

The first two approaches might be more convenient and less costly to the company since the tracking devices might be in the warehouse initially, so it might be difficult to distribute them to sites with rented equipment. However, due to efficiency and cost calculations for each site, the company might want to track all equipment with no exceptions, therefore, the last two approaches were provided as solutions.

3.4 Alternative Solution 2

In the second solution, the difference lied in the way of covering the missing equipment when the demand was higher than the supply. All missing equipment were bought in this solution, and two approaches were considered:

1) In the first approach, the PTR device was used to track all equipment, which were the ones available in warehouse and newly bought ones.
2) In the second approach, all equipment were also tracked with the Bolt device.

3.5 Tools Used to Generate Solutions

The main tool used as a starting point to generate solutions was the transportation model. Transportation problems usually involve the shipment from several sources to multiple destinations. If they supply and demand are equal, it is called a balanced transportation problem, otherwise, it is considered an unbalanced transportation problem, in which a dummy row/column is added. This is not a trial-and-error method, in which a solution is the result. A special table with cells is designed, and the data is added to the table. The designed table is shown in Table 1. Transportation models can be solved using multiple ways, such as The Northwestern Corner Method, The Lowest Cost Method, The Vogel's Approximation Method, and The Stepping Stone Method. The solution was built on the basis of the principles of the

Table 1. The designed unbalanced transportation table (cost in SR).

From	Site 1: B-1	D-1	H-1	…	SA-1	SU-1	U-1	Site 13: W-1	Dummy	Supply
Warehouse	3200	2400	2700	2400	1200	1500	4300	4500		15 (Var)
U-1	∞	∞	2700	∞	∞	3500	∞	∞		
J-1	∞	∞	3200	∞	∞	∞	∞	∞		
B-1	∞	∞	∞	∞	∞	∞	∞	∞		
Dummy										
Demand	1	2	1	…	1	1	1	1	Demand: 23 (Var)	

Lowest Cost Method, in which the allocation of the equipment is done according to the ascending order of cost or distance. This means that the first allocation is set to the site with the least cost of transportation. This procedure is repeated until the demand is met. In the proposed solution of this study, the idea of sorting sites based on the ascending cost of transportation was utilized. The sources of transportation were identified based on the feasibility of transportation according to the project end dates and the corresponding start dates of the next project. For each of the equipment, a similar model was generated according to the available supply of equipment and relative demand in all sites.

4. Data Collection and Analysis

The following section discusses how data was collected, the ways of its cleaning and filtering as well as the data analysis.

4.1 Data Collection

The data was mainly provided by the selected Saudi industry. This data included the supply of each of the equipment in the warehouse, the demand in each site, project start and end dates, as well as an estimation of the rent, buy, and transportation costs. Table 2 shows the available equipment, their supply in the warehouse, and the costs of renting and buying each. The project starts and end dates were also provided in Table 3. Distances between work sites in Table 4 were extracted using Google Maps as shown in Figure 2.

Table 1. Raw equipment data from company with supply and costs.

Equipment	Warehouse Supply	Rental Cost per Day (SR)	Buying Cost (SR)
Compactor (10 ton)	15	800	100,000
Crane Truck (16 tons)	15	1,800	400,000
Excavator	5	2,000	750,000
Dump Trucks	10	1,000	450,000

Table 2. Project start and end dates.

Civil start work	Civil End work	Months
01.01.2023	01.12.2023	11
01.05.2023	01.01.2024	8
01.03.2023	01.07.2024	16
01.07.2023	01.10.2023	3
01.04.2023	01.02.2024	9
01.06.2023	01.05.2024	11
01.06.2022	01.06.2024	24
01.08.2022	01.04.2024	15
01.10.2023	01.05.2024	7
01.06.2022	01.06.2024	12
01.02.2023	01.08.2024	18
01.02.2023	01.08.2024	18
01.11.2022	01.05.2024	18
01.10.2022	01.04.2024	18
01.10.2022	01.04.2024	18
01.06.2022	01.07.2022	1
01.08.2022	01.04.2024	8
01.05.2022	01.07.2023	14
01.01.2022	01.01.2023	12
01.01.2022	01.03.2023	14

Table 3. Distances between sites.

From	To	Distance
Warehouse	B-1	913
Warehouse	D-1	501
Warehouse	H-1	728
U-1	H-1	721
J-1	H-1	937
Warehouse	J-1	543
Warehouse	J-2	553
Warehouse	J-3	553
U-1	J-3	1656
J-1	J-3	23
B-1	J-3	1341
Warehouse	N-1	1315
Warehouse	R-1	110
Warehouse	R-2	117
Warehouse	SA-1	128
Warehouse	SU-1	260
U-1	SU-1	1017
Warehouse	U-1	1225
Warehouse	W-1	1374

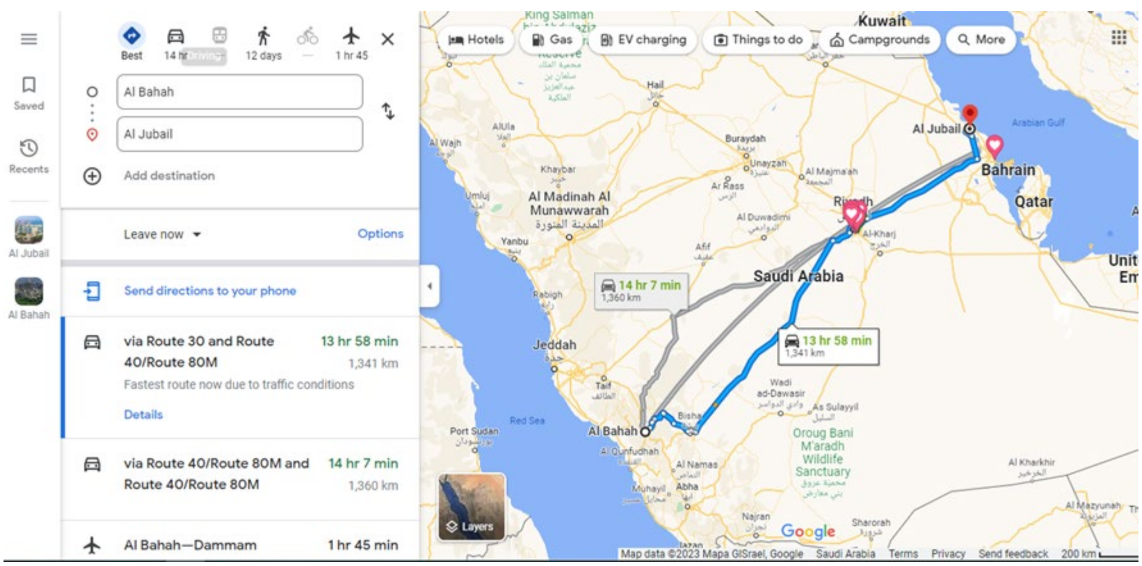


Figure 2. Distances between sites extracted using Google Maps.

4.2 Data Cleaning and Filtration

Before proceeding with the analysis the data was filtered to reduce complexity and increase feasibility of solutions. Table 5 shows the ongoing sites after completed projects were excluded and the sorting was done according to the nearest end date. The no. of months was necessary for the rent cost calculation in the alternative solutions.

Table 4. Ongoing sites after cleaning and sorting by end date.

Site	Starting from	Ending at	No. of months
U-1	1-Apr-23	1-May-2023	1
J-1	1-Apr-23	1-Jun-2023	2
B-1	1-Apr-23	1-Jul-2023	3
R-1	1-Jul-23	1-Oct-2023	3
J-2	1-Apr-23	1-Nov-2023	7
W-1	1-Apr-23	1-Dec-2023	8
SU-1	1-May-23	1-Jan-2024	8
R-2	1-Apr-23	1-Feb-2024	10
H-1	1-Jun-23	1-May-2024	11
J-3	1-Oct-23	1-May-2024	7
D-1	1-Apr-23	1-Jun-2024	14
SA-1	1-Apr-23	1-Jul-2024	15
N-1	1-Apr-23	1-Aug-2024	16

4.3 Data Analysis

After the data was filtered out and ready for the next step, the data analyses was performed to ensure that the designed tables and solutions were feasible. Since all supplied equipment were in the warehouse, the transportation from warehouse to all sites is feasible. However, the projects that ended before the start of other projects were identified so that all possible sources of transportation are considered. Regarding the transportation costs, a costing reference table was developed based on the company's given data and our collected data. Table 6 shows the transportation costs reference. After that, the previous findings were linked to the costing reference, and the final cost to transport equipment between two sites is shown in Table 7. Finally, the demand for equipment was extracted from the number of remaining months, which is shown in Table 8.

Table 5. The developed transportation cost reference.

Distance	Cost in SR
0-100	800
100-200	1200
200-300	1500
300-400	1800
400-500	2300
500-600	2400
600-700	2500
700-800	2700
800-900	3000
900-1000	3200
1000-1100	3500
1100-1200	3600
1200-1300	4300

1300-1400	4500
1400-1500	4700
1500-1600	5000
1600-1700	5200
1700-1800	5500
1800-1900	6000
1900-2000	6500

Table 6. Cost to transport equipment between feasible sites.

From	To	Distance	Cost in SR
Warehouse	B-1	913	3200
Warehouse	D-1	501	2400
Warehouse	H-1	728	2700
U-1	H-1	721	2700
J-1	H-1	937	3200
Warehouse	J-1	543	2400
Warehouse	J-2	553	2400
Warehouse	J-3	553	2400
U-1	J-3	1656	5200
J-1	J-3	23	800
B-1	J-3	1341	4500
Warehouse	N-1	1315	4500
Warehouse	R-1	110	1200
Warehouse	R-2	117	1200
Warehouse	SA-1	128	1200
Warehouse	SU-1	260	1500
U-1	SU-1	1017	3500
Warehouse	U-1	1225	4300
Warehouse	W-1	1374	4500

Table 7. Demand for each type of equipment in all sites.

Symbol	No. of months	Demand
U-1	1	1
J-1	2	1
B-1	3	1
R-1	3	1
J-2	7	1
W-1	8	1
SU-1	8	1
R-2	10	1

H-1	11	1
J-3	7	1
D-1	14	2
SA-1	15	1
N-1	16	10
	Total	23

5. Results and Discussion

The work done in previous sections was combined to develop mathematical models that were used to generate the alternatives and design the resource allocation system. The system was presented as an XLS file, in which the VBA and macro is used to design the interface and link it to the output sheet. This allowed it to be dynamic, meaning that the system will work according to the user's inputs and not only based on the case study data. The initial stage was to develop solutions for allocating available equipment to all sites based on their transportation costs. After that, the tracking system costs were added to the generated solutions. The system ensured that the objectives are met, and further improvement can be made to this system in future.

5.1 Numerical Results

A generalized objective function is developed that can be used to find the solution with the lowest cost according to each scenario's constraints, which will be input by user. This model was used to program the resource allocation system as the starting point:

$$Minimize\ Z = \sum\{(n_{ijk}c_{ijk}) + Min\ [\ m_{ijk}b_{ijk}\ , m_{ijk}r_{ijk}]\}$$

where:
$Z = total\ solution\ cost$
$i = equipment\ type\ (compactor, crane\ truck, \dots)$
$j = source$
$k = destination$
$n = number\ of\ transported\ (allocated)\ equipment$
$c = cost\ of\ transportation$
$m = number\ of\ missing\ equipment\ to\ cover\ demand$
$b = cost\ of\ buying\ equipment$
$r = cost\ of\ renting\ equipment$

The numerical results obtained using this approach are visible in Table 9.

Table 8. Numerical Results

Equipment	Total Cost of Transporting Available and Buying Missing Equipment (SR)	Total Cost of Transporting Available and Renting Missing Equipment (SR)
Compactor	743,700	2,731,700
Crane Truck	2,843,700	6,091,700
Excavator	12,758,300	13,448,300
Dump Truck	5,421,400	5,113,700

5.2 Graphical Results

An interactive interface, shown in Figure 3, was designed and built using Microsoft Excel VBA and macro, in which the user form files were provided to the company. This interface allowed the system to be more user friendly and dynamic, meaning that it is easy to follow instructions to reach the final output, and the system was flexible, so the user can enter the city names, project durations, costs and other variables, such as available resources. The user is asked to enter the city names and transportation costs for all equipment. The program sorts the cities based on the least transportation cost as shown in Figure 4. After that, he is prompted to enter the demand and resources with the help of boxes, such as Figure 5. Then, he enters the project durations. Finally, he enters the rental and buying costs for the calculations. After clicking on the 'Show Result' button, the sheet containing the solution costs is displayed to the user after his inputs are translated onto it. As an output, the program allocates the available resources initially as shown in Figure 6. It calculates if there is a surplus in any of the equipment. The total allocation cost for each equipment is also calculated. In addition, it shows the number of missing equipment for each type as well as the allocation cost per city. The grand total allocation cost is also displayed. Finally, the rental and buying costs per city are displayed, and the grand total costs of alternative solutions are displayed in Figure 7.

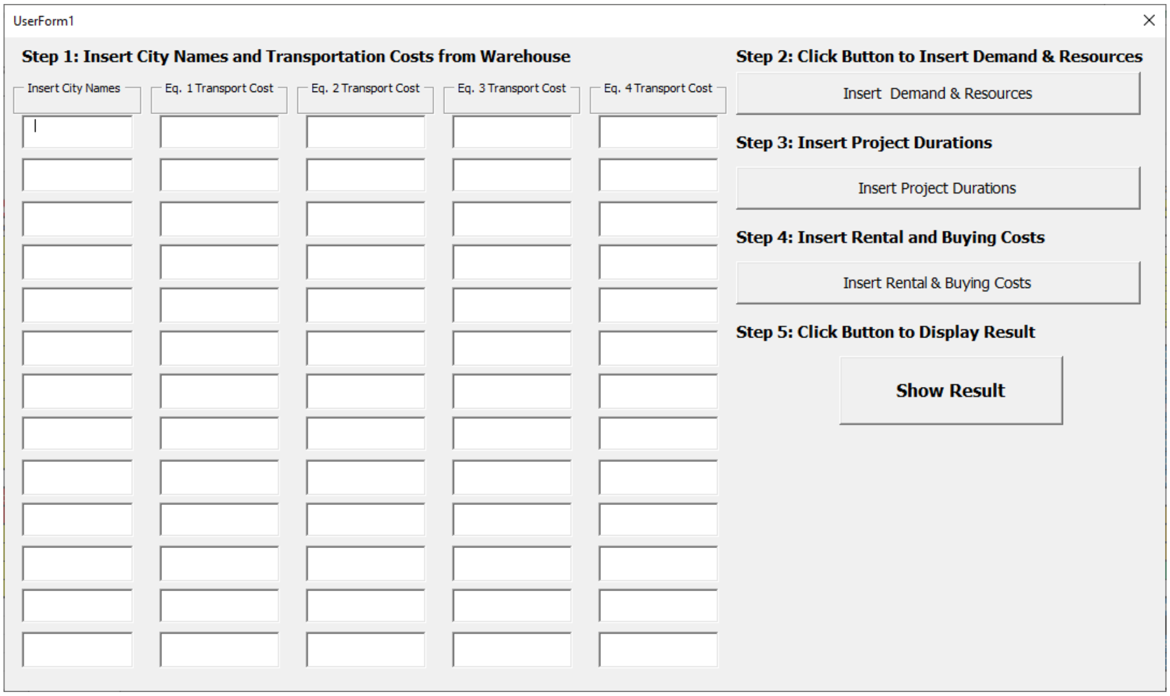


Figure 3. A view of the resource allocation system interface.

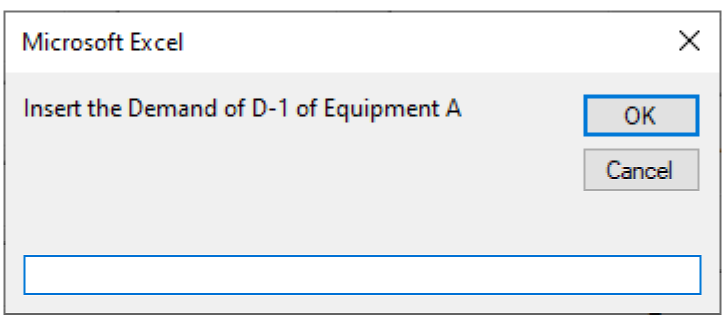
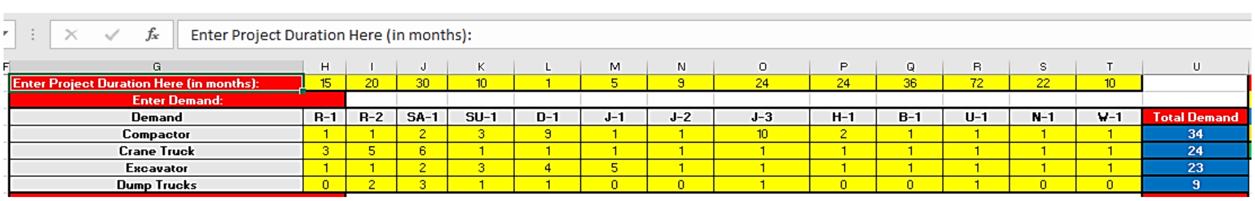


Figure 4. A sample of the prompt message for the user.



Enter Project Duration Here (in months):

G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
Enter Project Duration Here (in months):	15	20	30	10	1	5	9	24	24	36	72	22	10	
Enter Demand:														
Demand	R-1	R-2	SA-1	SU-1	D-1	J-1	J-2	J-3	H-1	B-1	U-1	N-1	W-1	Total Demand
Compactor	1	1	2	3	9	1	1	10	2	1	1	1	1	34
Crane Truck	3	5	6	1	1	1	1	1	1	1	1	1	1	24
Excavator	1	1	2	3	4	5	1	1	1	1	1	1	1	23
Dump Trucks	0	2	3	1	1	0	0	1	0	0	1	0	0	9

Figure 5. Output after sorting cities showing demand in each city respectively.

Enter Available Resources:														Remaining	
Compactor	15	14	13	11	8	0	0	0	0	0	0	0	0	0	
Crane Truck	15	12	7	1	0	0	0	0	0	0	0	0	0	0	
Excavator	5	4	3	1	0	0	0	0	0	0	0	0	0	0	
Dump Trucks	10	10	8	5	4	3	3	3	2	2	2	1	1	1	Allocation cost per equipment
Cost of Compactor	1200	1200	2400	4500	19200	0	0	0	0	0	0	0	0		28,500
Cost of Crane Truck	3600	6000	7200	1500	0	0	0	0	0	0	0	0	0		18,300
Cost of Excavator	1200	1200	2400	1500	0	0	0	0	0	0	0	0	0		6,300
Cost of Dump Trucks	0	2400	3600	1500	2400	0	0	2400	0	0	4300	0	0		16,600
Missing Compactors	0	0	0	0	1	1	1	10	2	1	1	1	1		
Missing Crane Trucks	0	0	0	0	1	1	1	1	1	1	1	1	1		
Missing Excavators	0	0	0	2	4	5	1	1	1	1	1	1	1		
Missing Dump Trucks	0	0	0	0	0	0	0	0	0	0	0	0	0		
															Totals
Allocation cost per city	6000	10800	15600	9000	21600	0	0	2400	0	0	4300	0	0		69,700

Figure 6. The allocation schedule, cost, and missing equipment.

														Totals
Allocation cost per city	6000	10800	15600	9000	21600	0	0	2400	0	0	4300	0	0	69,700
To Generate Alternative Solutions:														
Rental Cost	0	0	0	240000	1272000	1890000	552000	1062000	810000	1656000	3312000	4554000	690000	16,038,000
Buying Cost	0	0	0	1500000	3500000	4250000	1250000	2150000	1350000	1250000	1250000	1250000	1250000	19,000,000

Solution 1 (Allocate + Rent without tracking)	16,107,700	Solution 1A (PTR for allocated only)	16,133,616
		Solution 1B (Bolt for allocated only)	16,133,935
		Solution 1C (PTR for allocated and rented)	16,134,205
		Solution 1D (Bolt for allocated and rented)	16,134,531
Solution 2 (Allocate + Buy without tracking)	19,069,700	Solution 2A (PTR for allocated and bought)	19,096,205
		Solution 2B (Bolt for allocated and bought)	19,096,531

Figure 7. The final display of rent, buy, and alternative solutions costs in SR.

5.3 Proposed Improvements

In the future, the system can allow relocation of allocated equipment, in which the destination can be set as a new source. More prompts can be displayed to the user so that the system can generate more solutions. The system can be integrated with project management software to track the equipment transportation schedules. Further measures can be added to the system if the criterion for the best solution is changed, like efficiency. The interface is simple and user friendly, however, if the system is approved, it can be built as an actual application that can be used routinely.
Conclusively the ultimate findings are that in the existing scenario following weaknesses were identified such as:

1. Inefficient resource allocation
2. Inappropriate reliance on rental equipment

Based upon these findings, following solution strategies are designed and proposed such as:

1. Designing the user-friendly interface for resource allocation
2. Effective use and scheduling of available or newly purchased equipment

5.4 Validation

A set of test cases was created to cover various scenarios and use cases. Test cases including both normal and exceptional scenarios to ensure the system behaves correctly in different situations. Each test case had expected results or outputs. The process for this phase begins by testing individual components of the system. This approach aids in the identification of any bugs or issues within specific modules. Integration testing was performed to verify the interactions between different components of the resource allocation system. Especially when applying the macro tools on the master excel sheets used and the Visual Basic Applications. This ensures that the system functions as a whole and that the components work together correctly. Integration testing focuses on testing the compatibility and interaction between the track devices and the fleet management system. It ensures that the devices seamlessly integrate with the system, exchange data correctly, and respond appropriately to commands or requests from the system. Performance of the resource allocation system was evaluated under normal and peak load scenarios. This involves testing the system response time and output accuracy. As for the tracking devices, performance testing evaluates how well the track devices perform under different conditions and workloads. It includes stress testing, where the devices are subjected to high traffic, extreme temperatures, or poor connectivity to ensure they can handle such scenarios without compromising functionality or data integrity. All these tests are already performed with clear and shared results by the manufacturers. The resource allocation system's ability to handle errors and exceptional scenarios were tested repeatedly. The assessment of the security aspects of the resource allocation system was concluded to be highly secure. Since it operates on XLS sheets & Visual Basic Applications. Security testing helps identify vulnerabilities in the track devices, such as weak authentication mechanisms or data encryption flaws. It ensures that the devices are resistant to unauthorized access, data breaches, and tampering.

The resource allocation system was validated by using real-world data obtained from the client to ensure its accuracy and reliability. By using representative data sets that reflect the actual usage patterns and allocation requirements of the system, and eventually comparing the system outputs with expected results and manually verify the correctness of the allocations. After a series of fine tuning the system to reach the desired result, it was evident that the real data input led to an output that matched the theoretical expectation. This means that the system's output is validated. Track devices generate a significant amount of data that is crucial for fleet management operations. Data validation involves verifying the accuracy, completeness, and integrity of the data collected by the devices. It ensures that the data is reliable and can be effectively utilized for decision-making and analysis.

6. Conclusion

In this research, a resource allocation system has been designed that allows the user to enter inputs and generates alternative solutions based on these inputs. This system was built based on the selected Saudi industry's real data. After data filtration and analysis, an interface was developed and a complete system was designed accordingly. The transportation system and allocation schedule were included in the resource allocation system, in which the program displayed the allocation of equipment in respective sites. Two tracking systems were provided and included in the alternative solutions to meet the objectives fully.

The designed transportation models and the interface can be effectively be used to perform the following functions:

- Allowing the flexibility in inputs for the demand and resources
- Allocate the desired equipment for a specific location
- Determination of the transportation cost of individual equipment
- Determination of the overall cost of the solution
- Tracking and the availability of a certain equipment

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Biographies

Rafeek Mushtaha is a senior industrial engineering student at Al Yamamah University in Riyadh, where he has maintained an outstanding academic record with a perfect CGPA of 4.0/4. Currently serving as an advisor at Guidepoint and concurrently holding the position of project manager at Advance Technology Company for Information Technology, his journey began as an operations excellence supervisor. He has demonstrated exemplary leadership as the president of the university media club. Additionally, he dedicated his time to community service by volunteering as a tutor. As a graduate of both the McKinsey Forward Program and Mustashar Accelerator, Rafeek has further enriched his strategic and entrepreneurial acumen. Rafeek's commitment to continuous improvement is evident in his certifications, which include Lean Six Sigma, OSHA, and ISO 9001:2015. In the realm of knowledge dissemination, Rafeek runs an automotive educational channel, where he shares insights, tips, and mechanical industry trends. He is a member of the SPE and SCE. Rafeek Mushtaha stands as a multifaceted individual poised to make significant contributions to the field of industrial engineering and beyond. His journey is a testament to his dedication to excellence, continuous learning, and the betterment of the community.

Abdulaziz AbuRahmah is an Industrial Engineering graduate with a First-Class Honor's with a 3.95 out of 4.0 CGPA from Al Yamamah University. As President of the Industrial Engineering Club at Al Yamamah University, the club won first place as the best club at Al Yamamah University. He worked at Obeikan Investment Group as an industrial engineer and at Authentic Marketing and Business Solutions as a project manager. Abdulaziz graduated from the McKinsey Forward program after completing six months and acquired critical thinking, adaptation, leadership, and digital skills. Abdulaziz has several volunteering works, the most notable of which is volunteering as a tutor at the Tutoring Center at Al Yamamah University to help students. Certified Lean Six Sigma Green Belt and ISO 9001:2015 holder. He has also gained OSHA certificates of General Safety and Food Safety. He is a member of SCE, IEOM, and SPE. Abdulaziz has sufficient skills and experience in the field of industrial engineering that he acquired during his period of study, in addition to leadership skills, analysis, management, and time management that made him distinguished in his work.

Moath Alluhidan is an experienced professional with a Diploma in Arts & Sciences from Camosun College in Canada and an Industrial Engineering graduate with honors from Al-Yamamah University in Saudi Arabia. With around eight years of experience, he has specialized in project management and shared services, particularly in contracts, credit control, business development, risk management, and vendor management. In the past two years, Moath has excelled as a project manager, focusing on project implementation and change management. His expertise lies in successfully navigating complex projects, mitigating risks, and delivering outcomes within budget and timeline constraints. He possesses excellent communication and interpersonal skills, enabling him to build productive relationships with stakeholders at all levels. He has a strong track record of leading high-performing teams and creating a positive work environment. With a passion for research and a solid academic and professional background, he is poised to contribute his expertise to the academic community. His combination of theoretical knowledge and practical experience makes him an ideal candidate for publishing research papers and advancing the field of project management.

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