A Design of Enterprise Systems View on A Retailer Cashiers Shifts Scheduling

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Abstract
This study is about workers shifts scheduling problem at a famous retailer branch in Jeddah. The goal of this study is to schedule cashiers shifts with respect to cashier cost and company policies, as well as increasing the productivity of cashiers. In order to achieve the goal, the team used the Enterprise Design Methodology. The team started collecting the data by using a questionnaire. After the data has been collected, the team analyzed it using multiple techniques such as the fishbone diagram. The next step was to develop a linear programming model. The model used to integrate the problem and to suggest the optimal decision that would complement the goal. As a result of devolving the model, the team was able to increase the saving by 10% through setting the new policy.

Keywords
Systems Engineering, Enterprise Engineering and Operations Research

1. Introduction
The objective of this project is to integrate the enterprise engineering methodology in a real application. We searched for a real-world application in which we can apply the enterprise engineering project methodology. Our topic is about workers shifts scheduling problem at famous retailer branch. Where our goal in this project is to propose a new works shifts scheduling system. We aim to minimize the overall labor cost by optimizing the number of shifts and the number of cashiers in each shift of the day.

This project will demonstrate the seven phases of the enterprise design engineering project methodology, literature review, and discussion. We have used an operations research tool which is linear programming to model the problem and to suggest our solution. We discussed in detail all the seven phases for the enterprise design methodology which are, the project initiation, project planning, analysis, generate and evaluate alternatives, design, construction, and implementation. The team held several meetings to discuss how to implement this methodology on our problem. We used data gathering techniques in this project such as questionnaire to better understand the scheduling system and to gain as much information as possible about it.

2. Literature Review
The problem of personnel scheduling could be defined as a process of producing optimized timetables of organization employees. In the last decades, this kind of problems has attracted the researchers to study it due to significant effect as direct labor on any firm. As a result, any firm will try to reduce this cost as much as possible (Talarico and Duque 2015). Integer programming is one of the powerful tools to accomplish this goal by satisfying variation of the customer either in a week or within the day. One of the examples is Stop & Shop retailer in Boston, Massachusetts after they have forecasted number of needed cashiers, they proceed to allocate them by using an integer programming software. As a result, they implemented this system for several months. Kathy Collins, front-end manager said that this system has been a success (Melachrinoudis and Olafsson 1992).

3. Methodology

In order to solve this problem, the team used enterprise design methodology which includes seven phases that project initiation, project planning, analysis, generate and evaluate alternative, design, construction, and implementation.

3.1 Project Initiation

The team was formed as a part of system analysis and design course's project at King Abdulaziz University and it is composed of four students. All team members will continue working together until the project is completed.

3.1.1 Project Stimulate

In order to find a problem for our project to work on, the team has searched for a company, restaurant or shop that has an issue facing them and would like to find a solution for it. So, the team continued searching for several weeks until they found that a retailer branch has a problem concerning shift scheduling of cashiers. This retailer is one of the largest hypermarkets chains in the world which has several branches in Saudi Arabia.

3.1.2 Project Charter

Employees shift scheduling is an important concern for every business manager. Managers can feel the pressure mounting when there is a lack of an effective scheduling process. Similarly, any number of extra or lack of cashiers could drain the organization recourses such money and time. So, in order to obtain more clarity about the situation, the team conducted a meeting with the branch manager. After a long discussion and as a result of this meeting, the team decided to optimize, and schedule cashiers shift with respect to labors cost and company policies. This decision represents the goal of the project. Also, as we move forward throughout the project, we will try to find what is the real problem is and what the root causes of it by using multiple analysis techniques.

3.1.3 Business Case

The main deliverable that is expected from the team at the end of this project is to provide a set of recommendations for the branch manager about the problem and how he could deal with it. These recommendations could be actions that the manager might take such as the introduction of new policies or even a change in cashiers shifts system. Moreover, the branch could have multiple benefits. One of them might be a reduction in the total cost of cashiers since each one costs the branch 5000 SR monthly and 60000 SR annually. Finally, it is known that each project must have a budgeting plan, time schedule, specific objectives and scope that would help complement the main goal (Giachetti 2010). In other words, the team should use the idea of project management to help to manage the project phases during its lifetime. All these requirements will be explained in detail throughout the following phase which is Project Planning.

3.2 Project planning

The second phase in the enterprise design methodology is to set the project planning, the project planning will provide a definition for the project goal and objectives. The project plan will serve as an agreement between the project manager, project team, customers, and any other personnel who affected by the project.

3.2.1 Project Goal and Objectives

Scheduling cashiers shifts with respect to cashier cost and company policies, as well as increasing productivity of cashiers.

Supporting our project goal, the objectives of this project are:

- To increase the satisfaction of customers with a minimum number of cashiers.
- To reduce the cashiers' cost.
- To optimize the number of cashiers in each shift.

3.3 Analysis

In this phase, the team is going to understand what is the problem at the branch through gathering data. The next step is to analyze this amount of data to have and derive requirements of the proposed solution that will treat this problem. As known, analysis cannot start unless the problem is completely planned as it is done in the previous stage of methodology that is project plan (budget and schedule) is the main input to this problem. This phase includes two reports will be conducted and shown consequently: problem analysis and requirements analysis.

3.3.1 Problem Analysis

First, we are going to gather data about the branch. After that, the problem will be documented and then the team will analyze the causes and effects of this problem.

3.3.2 Data Gathering

The team decided to use mainly data gathering to obtain data: questionnaire this technique have been designed well to help the team to understand the real problem. The cause of choosing this technique is the speed especially that the duration of this project is limited as well as it has moderate accuracy.

3.3.3 Questionnaire

A questionnaire has been distributed among retailers' cashiers in Jeddah, in order to investigate them about which working system is preferred to them. The aim of this step is to engage who will be directly affected by any solution to this problem. Indirectly, the profit of the branch that we studuing will be increased, if cashiers are satisfied with their work. The questionnaire results are shown in Figure (1) as it includes one question (which working system would you prefer?) with three possible answers or policies are as follows:

- **A.** Five consecutive working days and two days off (the proposed one).
- **B.** Ten consecutive working days and four days off.
- **C.** Three consecutive working weeks and six days off (or any similar system).

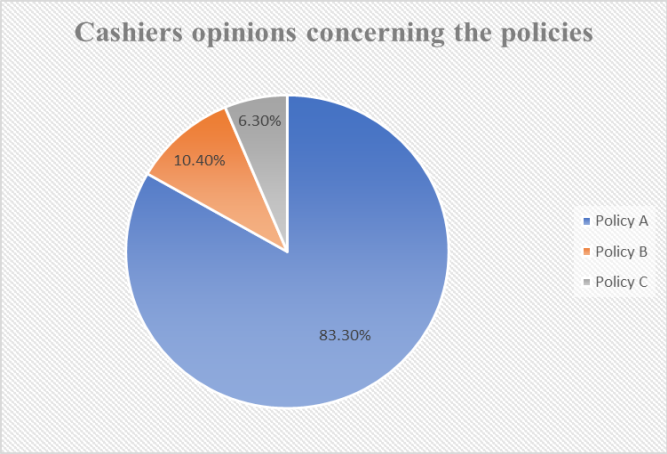

Figure 1: Cashiers opinions concerning the policies

3.3.4 Problem Statement

This subsection of problem analysis addresses that have been identified in the branch that we studying it. The problems list is as follow:

1. An excess number of cashiers than needed.
2. Scheduling is not based on the demand either within the days or between days.
3. Low Productivity of cashiers because of vacation system.

3.3.5 Analysis of Causes and Effects

Fishbone diagram is uesed to investigate what is the cause behind the Current situation of cashiers of an extra number of them as well as their vacation system. Fishbone diagram is shown in Figure (2):

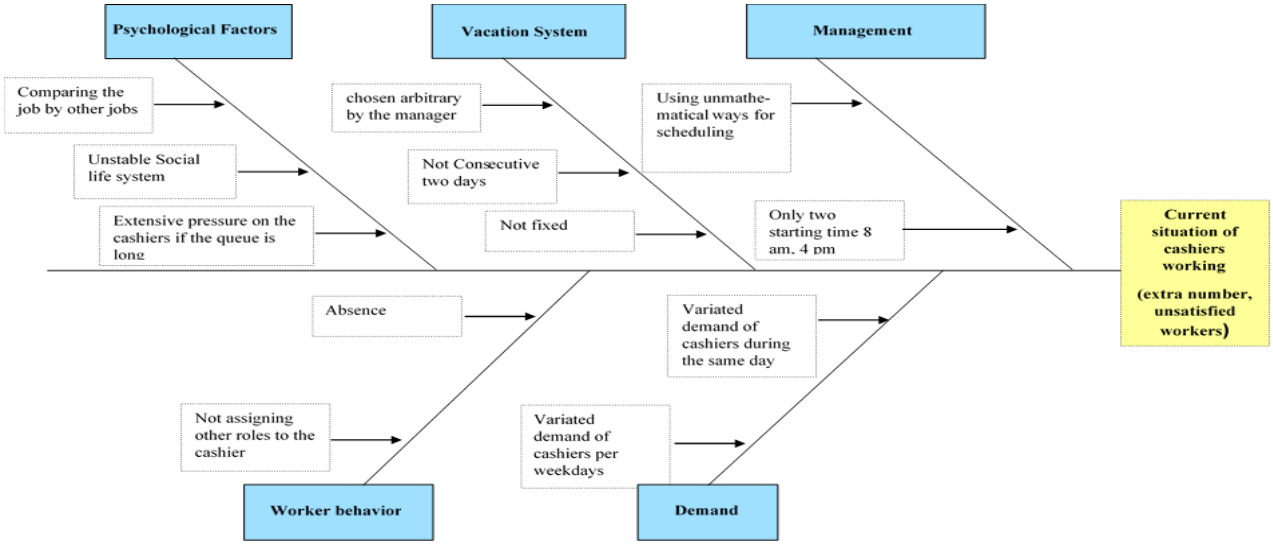

Figure 2: Fishbone Diagram of cause and effect

3.3.6 Linking Problem Analysis and Requirements

As it is shown in the previous two sections, each of problem analysis and requirement analysis has been shown separately. In this section, we will connect each problem with its' causes. Specifically, we will trace how problems to goals. problem will be traced to goals in Figure (3).

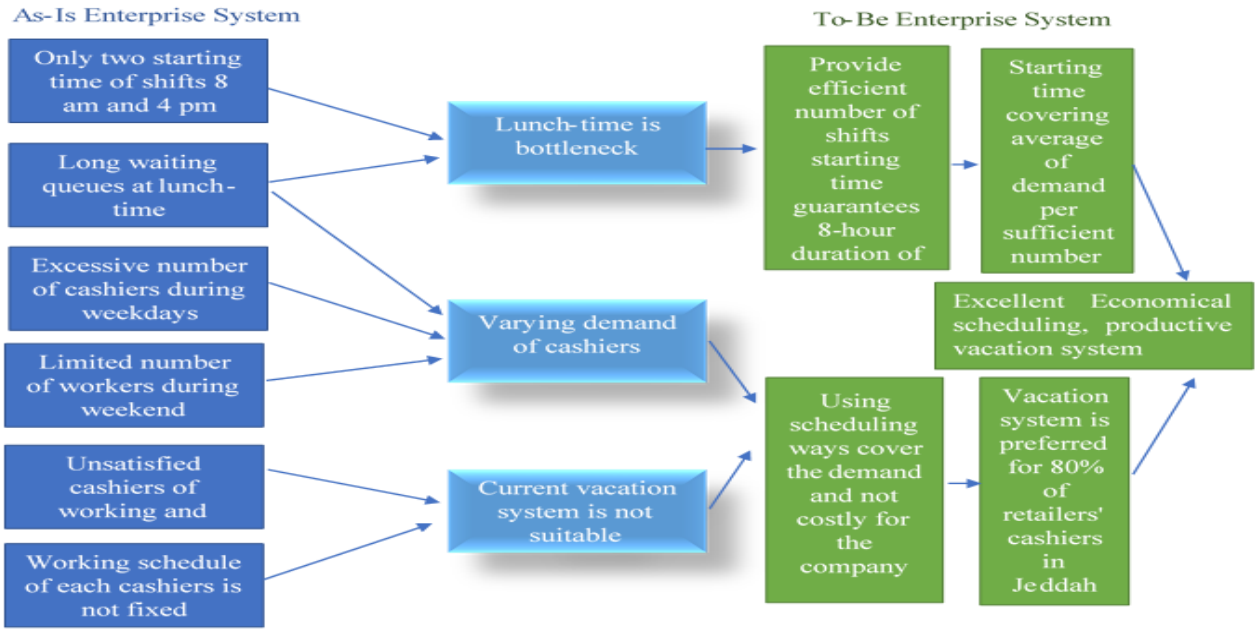

Figure 3: Tracing problems to goals

3.4 Generate and Evaluate Alternatives

In this phase, we want to find the appropriate candidate solution for our problem. Thus, we proposed two possible models that we can use in the later phases.

1. A linear programming model, where we just need the current requirement of a number of cashiers as well as brief work schedule of the work shifts. In this model, the aim is to determine the optimal number of cashiers that can handle the work demand in each shift.
2. A simulation model that would require a detailed work scheduling with all the breaks including prayer breaks, we need to determine the distribution of customer arrivals. It requires trial and error execution of the model to find the optimal number of cashiers (servers) at each shift. Thus, making it more time demanding approach in our case.

We have determined that the time of creating the model and time to collect the data required for each model are the criteria to evaluate the appropriateness of the two alternatives. We are going to use the analytic hierarchy process (AHP) to evaluate each alternative with respect to each criterion. This technique is useful when we want to select an alternative where our selection decision is influenced by a number of criteria the final result for the AHP is a weight for each alternative. We will select the alternative with the highest weight. Table (1) shows the AHP final weights of the two alternatives (Anderson 2008).

Table 1: AHP final weights of the two alternatives -1-.

Alternative	**Final Weight**
Linear programming model	0.8913
Simulation model	0.1081

Therefore, we will select the linear programming approach to model our problem. Also, because the simulation model would require much more data gathering activity which require more time than what is available to us. At the same time, our goal can be modeled using a linear programming approach as well if we widen the scope of our goal. For example, if we wanted to find a suitable number of customers in the cashier queue that will minimize the waiting time along with our first goal. Then in this situation, we need to include more detailed data about the queuing system which require to use a simulation model rather than a linear programming model.

Now after we settled with linear programming to model our problem. We have proposed two scheduling plans (alternatives) for cashiers' shift.

1. Each four-hours will join new cashers.
2. Each two-hours will join new cashers.

The first scheduling plan suggests that a working day (8 A.M. – 12 A.M.) Will be divided into four periods. Each period will be four-Hours long (8 A.M. – 12 P.M., 12 P.M. – 4 P.M., 4 PM – 8 P.M. and 8 P.M. – 12 A.M.). Each cashier will join the system either at the start of the first period, the second period or the third period. And will work for eight hours.

Likewise, for the second scheduling plan but we will divide the working day into eight periods. Each period will be two-hours long.

(8 A.M. – 10 A.M., 10 A.M. – 12 P.M., 12 PM – 2 P.M., 2 P.M. – 4 P.M., 4 P.M. – 6 P.M., 6 P.M. – 8 P.M., 8 P.M - 10 P.M. and 10 P.M. – 12 A.M.)

Each cashier will join the system either at the start of the first period, second period, third period, fourth period or the fifth period. And will work for eight hours.

Where we want to evaluate these two plans with respect to two criteria. The first one is which alternative will cover the cashiers demand best and the other criterion is which alternative will have more accurate time to shift. Meaning when a new cashier will handle the placement of the leaving cashier, we want this process to happen without waste of time when the switch occurs. So, we will use the AHP technique again to evaluate. Table (2) shows the final AHP weights for each alternative. Finally, we will use the four-hour period scheduling alternative.

3.5 Design

In our case, the goal of our modeling effort is generally to optimize scheduling of cashiers shifts at retailer branch. And more specifically to find the optimal number of cashiers that work eight consecutive hours in five consecutive days while taking two days off each week. In the branch as we decided to go with the scheduling alternative of four periods and each period is four hours long starting from 8 A.M. to 12 A.M.

Table 2: AHP final weights of the two alternatives -2-.

Alternative	**Final Weight**
Four-hours period	0.8416
Two-hours period	0.1584

Therefore, our objective function has to apply the summation of all cashiers who start their duty at the begging of each of the four periods of the day in all weekdays must be minimum.

Since there are four periods then the constraints that we should implement in our (LP) model is that at the begging of each four-hour period the number of cashiers that start their duty must not exceed the required number of cashiers identified by the management. Table (3) show the required number of cashiers at each period provided by the branch management (Hillier and Lieberman 2010).

Table 3: The required number of cashiers at each period

Days	8 AM – 12 AM	12 AM – 4 PM	4 PM – 8 PM	8 PM – 12 AM
Sunday	5	6	9	11
Monday	5	6	9	11
Tuesday	5	6	9	11
Wednesday	5	6	9	11
Thursday	5	6	11	13
Friday	7	8	11	13
Saturday	7	8	11	11

These cashiers will be responsible for the activities of controlling cash register, informing customers their total price of purchase, receiving payments either in cash or credit card, giving change back to customers with their receipts. So, all these activities are factors that were used to determine the service time of a customer. Eventually, were used to determine all the requirements of the number of cashiers in each four-hour period shown in Table (4).

3.6 Construction

In this phase, we will build a model that can represent the enterprise for the branch in addition to writing the work policies that can comprehend the enterprise also, the software program that will be used. So, that been said to build a model we need to understand the mathematical logic of the problem by defining the problem statement and analyze the enterprise we have come to conclusion that the problem given can be integrated to linear programming model to understand the correlation between the constraints that we have given and the schedule data as mentioned in the Design phase. By using linear programming method for the data given in the design phase Table (4), we need to define the main objective that can give us the optimization of the cashiers shift and make a new policy that can make an optimization to the system. To do the building of the model we need some steps that can be described as the following:

3.6.1 Declaring Variables

In this step, we need to declare variables so that we can use it to find the optimal solution by using the POM-QM (Production and operation management Quantitative method) software basically the QM can solve and deal with linear programming, assignment problems, work management, and quality control, etc. the program can deal with many statistical problems. So, that means we will be declaring the variables in algebraic designations to determine their optimal values by using optimization method (Jensen 2004) So, that the team defined the decision variables in the way of Xij where i represents the order of the shift while j represents the day where the cashier starts his work.

3.6.2 Objective Function
By using the declared variables, we can calculate the important parameter which is the number of cashiers in this problem in a mathematical linear way to evaluate and optimize it. As a result, money will be saved by using the needed numbers of cashiers.

3.6.3 Constraints
In this step, we will define the boundaries of the model we are constructing in a mathematical way to find the feasible region which means the mathematical optimization in solution space where all the possible points of the variables satisfies the constraints. The problem will subject to the minimum number of cashiers in every four hours of the day in a weak.

3.6.4 The Optimal Solution
After the formulation of the problem completed, the team moved to the next step which is running the model that we constructed to find the optimal solution. All this have been solved by using POM-QM for Windows as mentioned in the declaring variables step. The optimal solution was found that we need 27 cashiers in the branch that satisfies the constraints. That been said we can say that we can minimize the number of cashiers from 30 to 27 cashier.

3.6.5 Sensitivity Analysis
To study the model in depth we have used the sensitivity analysis (SA) it's a tool to measure different values and uncertainty overall depended on value under certain condition (Helton 1993). So, in our case, we have been used this type of analysis to see the range of a number of cashers that depending on a number of cashiers and shifts changes and to how much we can change these parameters. In the table below we describes the days where Sunday, Monday, Tuesday, Wednesday, Thursday, Friday and Saturday in Sun, Mon, Tues, Wed, Thu, Fri and Sat respectively in the other hand the time of the shift can be described as 1 from 8:00 am to 12:00 pm, 2 from 12:00 pm to 4:00 pm, 3 from 4:00 pm to 8:00 pm and 4 from 8:00 pm to 12:00. In addition to considering if their extra number of cashiers and the optimal number of cashiers also, the range of the number of cashiers.

3.6.6 Verification and Validation
To make sure that the model we construct can implement it the real system we need to do the V&V (Verification and Validation) analysis that means we make sure that the model is executed smoothly with no error in the logic of the model and valid means the model represent the system that we study (Balci 1970). By using a static technique, we can verify and validate the model the technique that we going to use is data flow chart it's a commonly used technique to see the flow of the data and process in terms of symbols (Giachetti 2010). The data flow chart clearly shows that to find optimal solution to the problem we need to go through the process of linear programming method and solve it by using the POM-QM software that must satisfy the constraints of the problem that gives us indication of how the model is verified and valid to the data that given from the real system.

3.6.7 Enterprise Policy
The main goal of our problem is to optimize the schedule cashiers shift with respect to labors cost and company policies. So, our team found the best possible scheduling for branch, during the minimum number of cashiers that illustrated by using linear programming and solve it by POM-QM software, the team found that the branch needs to hire only 27 cashiers to operate the branch. By comparison, the old policy is to hire 30 Cashiers. Also, the old policy doesn't give the cashier two-days off in a week, but it gives it a vacation after an unspecific number of days that might be two weeks or more. Surely, the new policy will enhance the productivity of the cashiers by giving him/her weekly vacation. According to the result, we found we can make the new policy that not only we need to 27 cashiers in the branch but we can transfer the extra employees to another department that needed for staff members and fitting them to the new jobs and according to the survey that we distrusted we found that many are willing to take two days off in a week rather than ten continuous working days then take the four-days off. So, we can make the new policy of the

company that scheduling of the workdays and the holidays will be five continuous working days then take two days off.

Table 4: Sensitivity analysis

Day/shift	The extra number of cashiers	The optimal number of cashiers	Lowest number of cashiers	Highest Number of cashiers
Sun.1	1	6	5	6
Sun.2	1	7	6	7
Sun.3	3	12	9	12
Sun.4	0	11	11	11
Mon.1	0	5	5	5
Mon.2	0	6	6	6
Mon.3	4	13	9	13
Mon.4	1	12	11	12
Tues.1	1	6	5	6
Tues.2	1	7	6	7
Tues.3	3	12	9	12
Tues.4	0	11	11	11
Wed.1	2	7	5	7
Wed.2	1	7	6	7
Wed.3	2	11	9	11
Wed.4	0	11	11	11
Thu.1	2	7	5	7
Thu.2	1	7	6	7
Thu.3	3	14	11	14
Thu.4	1	14	13	14
Fri.1	0	7	7	7
Fri.2	0	8	8	8
Fri.3	5	16	11	16
Fri.4	2	15	13	15
Sat.1	0	7	7	7
Sat.2	0	8	8	8
Sat.3	1	12	11	12
Sat.4	0	11	11	11

3.7 Implementation

In this phase to implementing the model into the real system we need to make sure that the organization policy is fully clear to the employees and stakeholders of branch the new policies of the project was the numbers of cashiers needed was found 27. The other policy is to make it clear that the work days will be five days then take two days-off but to make sure that there will be no direct cut-over this means making a shift of the old system to the new system at once to prevent that from happening to the real system we need to implement the changes after employees take their holidays or at the start of the new year. Implementing these policies to the system will make the system more productive.

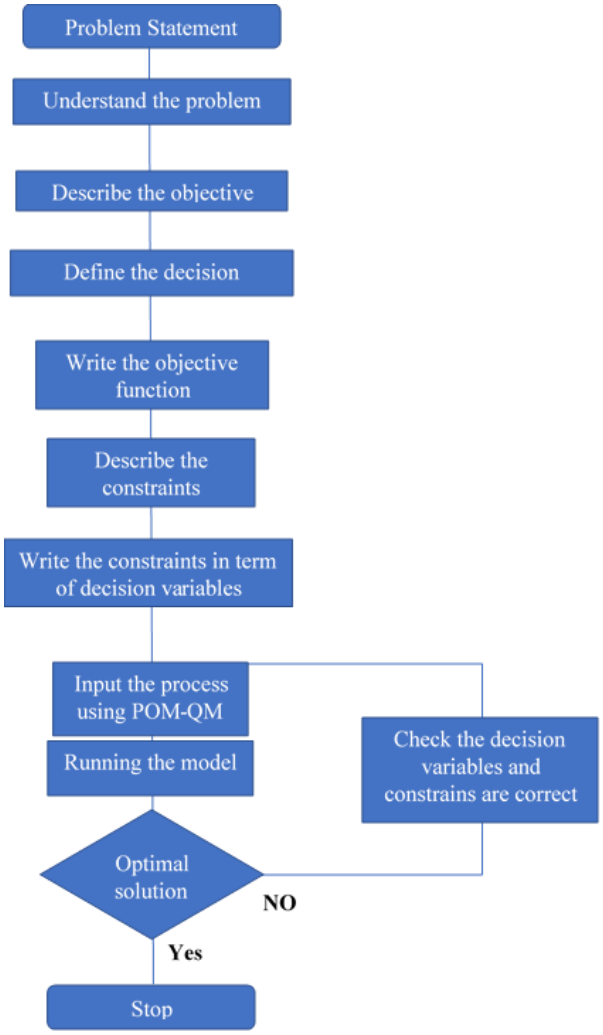

Figure 4: Flow chart of constructing linear programming model

4. Discussion

After constructing and run the model in the software, the team found the most feasible possible scheduling for the branch, depending on the minimum number of cashiers needed. By using the idea of operation research (in this case integer linear programming), the team found that the branch needs to hire 27 cashiers to operate. By comparison, the old policy is to hire 30 cashiers. Also, the old policy does not give the cashier two-days off in a week, but it gives it a vacation after an unspecific number of days that might be two weeks or more. Surely, the new policy will enhance the productivity of the cashiers by giving him/her weekly vacation. On the cost point of view, the average monthly salary of each cashier is 5,000 SR. As a result, 15,000 SR will be saved monthly by using the new policy. This means that

the branch can save 180,000 SR in a year. Notice the annual saving is only at one branch but imagine when the optimization solution (linear programming) applied in all the branches. This means that millions of riyals will be saved annually. A comparison between the old policy and the new policy is shown below on Table (5).

Table 5: Comparison of the two policies

	The Old Policy	**The New Policy**
Needed number	30 cashiers	27 cashiers
The difference	The new policy is less by 3 cashiers	
The ratio of saving	The new policy approximately can save 10% of the total cost	
The amount of saving	15,000 SR monthly and 180,000 SR annually	

Moreover, this reduction in cashiers' number, indicates that more cashiers are needed only in a few hours (small duration) because the branch gets crowded only in small periods, not for long ones. In addition, this also tells us that identifying the required cashiers every four hours of a working day is more efficient and effective for eight hours.
Furthermore, as we know, it is important to communicate with and persuade those persons who will be affected by implementing the new policy (the optimization solution) because the project represents a change from the current situation to the new one (Williams 2017). Additionally, there might be a resistance to this change by cashiers or in other words, they might give the manager the "kiss of yes". So, in order to ensure that most of the cashiers were engaged in the decision, the team distributed a questionnaire to them to see their viewpoints about several policies (see analysis phase), one of them is the proposed policy. After analyzing the results, we found that most of the cashiers (82%) prefer the proposed policy and hope that the branch would apply it. This analysis tells us that the resistance to change toward the proposed policy is low and it was a good idea to engage the affected ones in the decision-making process.

5. Conclusion and Recommendations

In this project, the team gathered the required number of cashiers for every four hours as well as made the inter starting time between every two consecutive shits four hours. For further studies, it is recommended to analyze and identify the required numbers for smaller periods such as three and a half hour or even smaller. Furthermore, it might help to plot the required number against each period to know which one has the highest number of cashiers in order to know how to organize and develop the model to get more accurate results.

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