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Winter 2020

# Optimization model for Project Manager Assignments

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### Citation Details

Verma, Neeti; Ganoskar, Poonam; Gusain, Pallavi; Vemulapally, Thanvi; Kalyan, Sai; Krishnamoorthy, Bala; and Krishna Gali, Sai Kalyan, "Optimization model for Project Manager Assignments" (2020). *Engineering and Technology Management Student Projects*. 2296.

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Portland State  
UNIVERSITY

# *Optimization model for Project Manager Assignments*

Course Title: Operations Research

Course Number: ETM 540

Instructor: Dr. Timothy R. Anderson

Term: Winter

Year: 2020

Author(s): Neeti Verma, Poonam Ganoskar, Pallavi Gusain, Thanvi Vemulapally, Sai Kalyan Krishna Gali<sup>1</sup>

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ETM OFFICE USE ONLY

Report No.:

Type: Student Project

Note:

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# Abstract

The main objective of every project in an organization is to maximize its profit. This maximization of profit can be achieved through proper allocation of project managers to projects in an organization. But assigning a project to a project manager is still considered a difficult issue and is not yet fully addressed in the literature. However, in high-tech industries various project assignment methodologies are used to assign project managers to multiple projects and reassignment during new-product development projects. The aim of the optimization model created in this project is to develop a framework for project assignments to project managers including some assignment criteria and processes. The framework contains many strategic elements like project prioritization, project requirements and competencies of project managers and limitations of organization. The project assignment should be in alignment with the strategic goal of the organization. The objective of this paper is to create a model which will help in the process of project assignment to project manager for better performance of projects and maximizing the gain of the organization.

# Introduction

We wanted to use the opportunity provided by the class to look into a problem that we witness frequently in the workplace. The work in any organization is performed in teams. Teams are generally composed of individuals with different skill sets. The work for a team includes work that requires different skill sets and expertise in various domains. The members also have different years of experience. One of the trickiest tasks in project management is resource allocation. Teams have to balance a wide variety of ongoing and upcoming projects across resources while meeting the timelines for the projects.

We used the decision support model for project manager assignment as the basis of our model.<sup>[2]</sup> Patanakul, et.al. present a theoretical framework for project assignments, including some significant assignment criteria and processes. They found that to be effective in project assignments, management should consider strategic alignment of the organizational goals in project prioritization, project requirements and competencies of project managers in project manager-to-project matching, and some organizational/ personal limitations while determining project assignment. They also presented linear programming equations along with the data in the paper to model project manager assignments.

We recreated the model in R for the class project and made a few changes and enhancements to the model as part of our work. The model was run on a smaller and a larger data set to validate it scales as per the inputs provided in the expected format.

# Project Goals

The goal of the class project for us was to create a model that can give insights into resource allocation. We decided to work with the data and assumptions as presented in the decision support model paper to create a baseline for the model in R. We wanted to make the

model scalable for different number of projects and project managers for assignment. Our model can accept any data set in the defined format and be able to generate project to project manager assignment recommendation to be reviewed by management.

We ran the model with the data from the decision support model paper to assign 6 projects to 6 project managers with workload as per paper. A smaller dataset was created for assigning 3 projects to 3 project managers as well as a larger dataset was created for assigning 8 projects to 8 project managers. The dataset was generated without any strategic goal to prove or disprove any hypothesis. The goal with the different size data set was to test the scalability of the model. This model can now be extended to validate some scenarios for project management assignments.

We wanted to include time off planning in the project manager assignment for any leaves greater than 3 weeks. Since switch-over time increases significantly with increase in the number of projects handled by the project manager<sub>[1]</sub>, we decided to include it in the availability of the project manager to scale well with larger data sets.

## Literature Review

In order to get some background on project management and assignments for our main paper we studied some reference papers to understand project manager characteristics and selection criteria.

Hauschildt, et.al. (2000), believe that their selection criteria mix is universal but some firms can also identify their own particular mix. They advocate for matching project managers to project properties with which they are most likely to be successful. They show the results to maintain the pool of Project managers, which can either be a pool of candidates who are all project stars or it can be the mix of all types as per the firm's projects needs. But when a pool of talent can never be matched perfectly to the project requirements, then one way to do it is – assignment of people with complementary skills to individual projects.

Pennypacker and Dye (2002), in their paper “Project Portfolio Management and Managing Multiple Projects: Two Sides of the Same Coin”[6] describe the difference between the project portfolio management and multiple project management. The authors try to answer the question, why do firms fail to realise that the projects carried out in a firm are not independent but form a portfolio i.e. a group of projects with interdependencies, consuming time and resources. They suggest the need for senior managers to create a balance between providing a cultural ambience in the enterprise that encourages people to bring forth innovative product and process ideas and an environment that ensures that rigorous strategic assessment will be done on the emerging ideas to determine their likely strategic fit in the enterprise’s future.

Brown and Eisenhardt (1995), in “Product development: Past research, present findings, and future directions”,[7] synthesized a model of factors affecting the success of product development. Team members, project leaders, senior management, customers, and suppliers were considered as agents that directly or indirectly affect outcomes. The goal of the paper was to establish the hierarchy of impact from the agents on product development. Successful product development involves relatively autonomous problem solving by cross - functional teams with high communication highlights the role of project leaders and senior management. The authors describe the power and vision of Project leaders in improving the process performance. A solid

point which sums the characteristic of powerful project leaders is that they are particularly effective politicians in lobbying for resources, protecting the group from outside interference, and managing the impressions of outsiders.

Dr. Patanakul, et. al. (2007), presented an optimization model that can be applied in an organization for resource allocation to align project assignments with the strategic goals of the organization along with matching the competencies of project managers to project requirements.<sup>[2]</sup> They presented a methodology to extend the strategic importance of projects to organization to project managers assignment. We used this paper as the basis of our model and the baseline was created using the data as presented in the paper.

Woraruthai, et.al (2009), revised the decision making model to balance workload over project lifecycle by adding time dimension.<sup>[3]</sup> They extended Dr. Patanakul, et. al. model to assist management in balancing and forecasting the workload of each project manager in a given time period. The time-management literature considers the allocation of time to scheduling. There is also research showing that it is beneficial to divide a task into subtasks before performing task estimates. They validated the model utilizing live data from Intel.

## Our Methodology

We decided to minimize the equations and reduce the variable set to debug. The equations from the original paper were reduced to consume equations with equalities. This reduced equation set was then modelled to create the first iteration of the model.

The model was reviewed with Dr. Anderson and his feedback was incorporated to generate the second revision of the model. We separated the data from the model and also used more functionality from R to also reduce our lines of code to generate a compact and enhance readability of code.

The next iteration of the model was to make it flexible to work with any data set. The model was then modified to read data from files. The base files needed to input data were defined in a matrix and global variables were used to reference different dataset. The team then worked on creating different data sets to simulate different sized organizations for using the model. The results from the model are summarized in the following sections.

## Optimization Model

An optimization model is nothing but key characteristics of a business problem that we want to solve. The model consists of three elements

1. Objective function
2. Decision variables
3. Constraints

Optimization model is a type of a mathematical model which optimizes the objective function while satisfying all the constraints. To build an optimization model for the project manager assignments problem, let us start by defining the three main elements of the model. This model was built based on the paper “A Decision Support Model for Project Manager Assignments”.

### Decision variables

$X_{\{i,j\}}$  is a binary decision variable used to decide whether or not project  $j$  is assigned to project manager  $i$ .

$Y_{\{i\}}$  is a binary decision variable used to represent whether more than one project is managed by project manager  $i$ .

$Z_{\{i\}}$  is a binary decision variable indicating whether or not project manager  $i$  is managing more than one project simultaneously.

### Objective function

Objective function is built by considering all the project priorities and levels of matching between project managers and projects.

$$Max \sum_{i=1}^n \sum_{j=1}^m \sum_{k=1}^o (\alpha_{ijk} G_k V_{jk} W_{ij} X_{ij})$$

$\alpha_{\{i,j,k\}}$  is the coefficient of effectiveness of  $PM_{\{i\}}$  (Project Manager  $i$ ) in managing project  $j$ 's contribution to goal  $k$ . Value is between  $0$  and  $1$ .

$G_k$  is the matrix representing the relative contribution of organizational goals  $k$  to the organizational mission.

$V_{\{j,k\}}$  is the matrix representing the relative contribution of project  $j$  to organizational goal  $k$ .

$W_{\{i,j\}}$  is the project manager  $i$ -to- project  $j$  matching score based on project requirements and competencies of project managers.

### Constraints

Constraints are formed based on the organizational/personal limitations.



$$\sum_{j=1}^6 D_{ij} X_{ij} + S_i \leq A_i \quad \forall i$$

$$A_i = E_i - L_i$$

$$S_i = 1.5Y_i + 4.5Z_i \quad \forall i$$

$$N_i = \sum_{j=1}^n X_{ij} + n_i \quad \forall i$$

$$\gamma_i \leq 1 - 0.25N_i \quad \forall i$$

$$Y_i = N_i + \gamma_i - 1$$

$$4Z_i - Y_i \geq 0$$

$$Z_i - Y_i \leq 0$$

$$\sum_{i \in \{A, B, \dots, F\}} X_{ij} = 1 \quad \forall j$$

**Project assignment constraints**

$$\sum_{i \in \{A, B, \dots, F\}} X_{ij} = 1 \quad \forall i$$

**Project manager assignment constraints**

$X_{ij}, \gamma_i, Z_i = 0, 1$  binary variables

$SD_{\{i,j\}}$  = time demand of project  $j$ 's for project manager  $i$ .

$SA_{\{i\}}$  = the resource availability of project manager  $i$  over planning period.

$SS_{\{i\}}$  = switch-over time for project manager  $i$

$SE_{\{i\}}$  = the effective capacity of project manager  $i$

$SL_{\{i\}}$  = the existing workload of project manager  $i$

$n_i$  = Total number of existing projects under the responsibility of project manager  $i$ , not subject to potential reassignment

$SN_{\{i\}}$  = Total number of projects under the responsibility of project manager  $i$  (existing projects and new assignment)

# Latex Equations

```

$$
\begin{split}
\begin{aligned}
& \text{\text{Maximize }} & \sum_{i \in \{A,B, \dots, F\}} \sum_{j=1}^m \sum_{k=0}^{\alpha_{i,j,k}} G_{i,j,k} V_{i,j,k} W_{i,j} X_{i,j} \quad \&\& \text{ Objective Function} \\
& \text{\text{subject to }} & \sum_{j=1}^m D_{i,j} X_{i,j} + S_{i,j} \leq E_{i,j} - L_{i,j} \quad \& \quad \forall i \\
& & \gamma_{i,j} + 0.25 \sum_{j=1}^m X_{i,j} + 0.25 n_{i,j} \leq 1 \quad \& \quad \forall i \\
& & 4 Z_{i,j} \geq \sum_{j=1}^m X_{i,j} + n_{i,j} + \gamma_{i,j} - 1 \quad \& \quad \forall i \\
& & Z_{i,j} \leq \sum_{j=1}^m X_{i,j} + n_{i,j} + \gamma_{i,j} - 1 \quad \& \quad \forall i \\
& & \sum_{j=1}^m X_{i,j} = 1 \quad \& \quad i=1, \dots, n, \quad \& \quad j=1, \dots, m \\
& & \sum_{j=1}^m X_{i,j} = 1 \quad \& \quad i=1, \dots, m, \quad \& \quad j=1, \dots, n \\
& & S_{i,j} X_{i,j} = 1 \quad \& \quad \forall i, j
\end{aligned}
\end{split}
$$

```

# Model in R

```

---
title: "PMAssignment8"
author: "TeamFinal_Project"
date: "3/1/2020"
output: pdf_document
---

```{r setup, warning=FALSE, include=FALSE}
knitr::opts_chunk$set(echo = TRUE)
knitr::opts_chunk$set(tidy = F)
knitr::opts_chunk$set(cache = TRUE)
knitr::opts_chunk$set(width = 30)
library (magrittr, quietly = TRUE) #Used for pipes/dplyr
library (dplyr, quietly = TRUE)
library (ROI, quietly = TRUE)
library (ROI.plugin.glpk, quietly = TRUE)
library (ROI.plugin.lpsolve, quietly = TRUE)
library (ompr, quietly = TRUE)
library (ompr.roi, quietly = TRUE)
library (pander, quietly = TRUE)
library (gridExtra)
library (formatR)
library (tufte, quietly = TRUE)
library (tint)
library (knitr)
library (rsvg, quietly=TRUE)
library (htmltools, quietly=TRUE)
```

```

```

`` {r team_data}
n <- 8
# no of projects
m <- 8
# no of goals
g <- 8

file_names <- matrix(c("effectiveness_coefficient", "goal_percent", "project_goal_percent",
                      "competency_matrix", "demand", "switchover", "capacity", "workload",
                      "existing_projects", "timeoffs"), ncol=1)

file_path <- "inputs/OtherData/"

#Alpha i,j,k
filepath_alpha <- paste(file_path,file_names[1], sep = "")
Alpha <- array(unlist(read.csv(filepath_alpha, FALSE, ",")), dim = c(n,m,g))

#Gk
filepath_goalper <- paste(file_path,file_names[2], sep = "")
Goaltomissionpercent <- array(unlist(read.csv(filepath_goalper, FALSE, ",")), dim = c(g))

#Vjk
filepath_projectgoalper <- paste(file_path,file_names[3], sep = "")
Projecttogoalpercent <- matrix(unlist(read.csv(filepath_projectgoalper, FALSE, ",")), byrow=T,ncol=g)

#Wij
filepath_projectPM <- paste(file_path,file_names[4], sep = "")
Projectmanagertoproject <- matrix(unlist(read.csv(filepath_projectPM, FALSE, ",")), byrow=T, ncol=m)

#Dij
filepath_demand <- paste(file_path,file_names[5], sep = "")
Demand <- matrix(unlist(read.csv(filepath_demand, FALSE, ",")), byrow=T, ncol=m)

#Si
filepath_switchover <- paste(file_path,file_names[6], sep = "")
Switchover <- array(unlist(read.csv(filepath_switchover, FALSE, ",")), dim = c(g))

#Ei
filepath_capacity <- paste(file_path,file_names[7], sep = "")
Capacity <- array(unlist(read.csv(filepath_capacity, FALSE, ",")), dim = c(n))

#Li
filepath_workload <- paste(file_path,file_names[8], sep = "")
Workload <- array(unlist(read.csv(filepath_workload, FALSE, ",")), dim = c(n))

```

```

#Existing number of projects for managers = n_i
filepath_existingproject <- paste(file_path,file_names[9], sep = "")
Existing_Projects <- array(unlist(read.csv(filepath_existingproject, FALSE, ",")), dim = c(n))

#Ti
filepath_timeoff <- paste(file_path,file_names[10], sep = "")
timeoff <- array(unlist(read.csv(filepath_timeoff, FALSE, ",")), dim = c(n))

...

```{r print_myPackages}

ip <- as.data.frame(installed.packages()[,c(1,3:4)])
rownames(ip) <- NULL
ip <- ip[is.na(ip$Priority),1:2,drop=FALSE]
write.csv(ip, file = "my_packages.csv")

...

```{r final_model, message=FALSE}
Base_Model <- MIPModel() %>%

#Binary Variable Xij
add_variable(X[i,j], i=1:n, j = 1:m, type = "binary") %>%

#Binary Variable Zij
add_variable(Z[i], i=1:n, type = "binary") %>%

#Binary Variable Lambda ij
add_variable(lambda[i], i=1:n, type = "binary") %>%

set_objective(sum_expr (Alpha [i,j,k] * Goaltomissionpercent [k] * Projecttogoalpercent [j,k] *
Projectmanagertoproject [i,j] * X [i,j], i=1:n, j=1:m, k=1:g), "max") %>%

#Resource Availability Constraint
add_constraint (sum_expr(Demand[i,j]*X[i,j], j=1:m)+ Switchover[i] <= Capacity[i] - Workload[i] ,
i=1:n) %>%

add_constraint (lambda[i] + 0.25 * sum_expr(X[i,j], j=1:m) +0.25 * Existing_Projects[i] <= 1 , i=1:n)
%>%

add_constraint (4*Z[i] >= sum_expr(X[i,j], j=1:m) + Existing_Projects[i] + lambda[i] -1 , i=1:n) %>%

add_constraint (Z[i] <= sum_expr(X[i,j], j=1:m) + Existing_Projects[i] + lambda[i] -1 , i=1:n) %>%

```

```

#Project Assignment Constraints

add_constraint (sum_expr(X[i,j], i=1:n) == 1, j=1:m) %>%

#Project Manager Assignment Constraints

add_constraint (sum_expr(X[i,j], j=1:m) == 1, i=1:n)

...

```{r result_new_data}
result <- solve_model(Base_Model, with_ROI(solver = "glpk"))
result
ResultTable <- get_solution(result, X[i,j])
ResultTable <- matrix(c(ResultTable[, c(4)]), ncol=n)

colnames(ResultTable)<-list("Project1", "Project2", "Project3", "Project4", "Project5", "Project6",
"Project7", "Project8")
rownames(ResultTable)<-list("PM1", "PM2", "PM3", "PM4", "PM5", "PM6", "PM7", "PM8")

pander(ResultTable, caption = "Raw results for X ij Variable")

...

```

### Results Base model

```
Status: optimal
Objective value: 8786.419
```

	Project1	Project2	Project3	Project4	Project5	Project6
**PM1**	0	0	1	0	0	0
**PM2**	0	1	0	0	0	0
**PM3**	1	0	0	0	0	0
**PM4**	0	0	0	1	0	0
**PM5**	0	0	0	0	0	1
**PM6**	0	0	0	0	1	0

The above model is a base model which we have implemented to match with the paper. As an enhancement to the model we have considered time-off of the project managers in the form of sabbatical/maternity leaves. Below is the model with time off taken into consideration.

## Timeoff

```
`` {r addingTimeOff}
#Ti
timeoff <- array(c(192, 0, 0, 192, 0, 0))
modified_Model <- add_constraint(Base_Model, sum_expr(Demand[i,j]*X[i,j], j=1:m)+
                               Switchover[i] <= Capacity[i] - Workload[i]- timeoff[i], i=1:n)

result_timeoff <- solve_model(modified_Model, with_ROI(solver = "lpsolve"))

ResultTable_timeoff <- get_solution(result_timeoff, X[i,j])
ResultTable_timeoff <- matrix(c(ResultTable_timeoff[, c(4)]), ncol=6)

colnames(ResultTable_timeoff)<-list("Project1", "Project2", "Project3", "Project4", "Project5",
"Project6")
rownames(ResultTable_timeoff)<-list("PM1","PM2","PM3","PM4","PM5","PM6")
pander(ResultTable_timeoff, caption = "Raw results for X ij Variable with timeoff" )

pander(head( get_solution(result_timeoff, Z[i])),
       caption = "Raw results for Z i Variable with timeoff")

pander(head( get_solution(result_timeoff, lambda[i])),
       caption = "Raw results for lambda i Variable with timeoff")

``
```

## Results Modified Model

```
Status: optimal
Objective value: 8036.84
```

&nbsp;	Project1	Project2	Project3	Project4	Project5	Project6
**PM1**	0	0	0	1	0	0
**PM2**	0	1	0	0	0	0
**PM3**	1	0	0	0	0	0
**PM4**	0	0	0	0	0	1
**PM5**	0	0	1	0	0	0
**PM6**	0	0	0	0	1	0

Table: Raw results for X ij Variable

When considered time off of the project managers, Project assignments to the project managers are changed when compared to the base model.

Also tried out the above model for reduced projects/project managers (3x3) and also for increased projects/project managers (8x8) . Data is taken from the paper.

### Results for reduced data set

```
Status: optimal
Objective value: 172.0435
-----
&nbsp;      Project1  Project2  Project3
-----
**PM1**    0         1         0
**PM2**    1         0         0
**PM3**    0         0         1
-----
```

Table: X[i,j] for reduced data set

The results for the 3x3x3 data show each Project Manager getting assigned to a particular unique project based on their skillset and available bandwidth. The objective function is also 172.0435 which essentially indicates that this assignment is the best possible fit for the success for the entire organization for this 3x3x3 setup.

### Results for increased data set

```
Status: optimal
Objective value: 1198.337
-----
&nbsp;      Project1  Project2  Project3  Project4  Project5  Project6
-----
**PM1**    0         0         0         0         0         0
**PM2**    0         0         1         0         0         0
**PM3**    0         0         0         1         0         0
**PM4**    0         0         0         0         1         0
**PM5**    0         0         0         0         0         1
**PM6**    1         0         0         0         0         0
**PM7**    0         1         0         0         0         0
**PM8**    0         0         0         0         0         0
-----
```

Table: Raw results for X ij Variable (continued below)

&nbsp;	Project7	Project8
**PM1**	1	0
**PM2**	0	0
**PM3**	0	0
**PM4**	0	0
**PM5**	0	0
**PM6**	0	0
**PM7**	0	0
**PM8**	0	1

The results for the 8x8x8 data show each Project Manager getting assigned to a particular unique project based on their skillset and available bandwidth. The objective function is also 1198.337 which essentially indicates that this assignment is the best possible fit for the success for the entire organization for this 8x8x8 setup.

## Result Analysis

The result generated from our optimization model matches the result given in the paper that we used as a reference to create this model. We run the model using different solvers like “glpk” and “lpsolve”. We got the exact same results from both the solvers as the number of variables and the constraints used in the model are very small. We modified the base model by adding time-off constraint for sabbatical and maternity leaves and the model was able to generate an optimal solution in both cases. However, adding a time-off constraint reduced our optimal value from the value we got from the base model as adding a new constraint to our base model reduced the feasible region thereby reducing the optimal value. The model when run for a smaller dataset where there are 3 project managers assigned to 3 projects with three organizational goals and a larger dataset of 8 project managers assigned to 8 projects in alignment to 8 organizational goals, the optimal value significantly reduced in both cases from the base model as the number of resources reduced for the smaller dataset and increased for the larger dataset.



# Challenges Faced

Due to limited online debug information for R, we spent a lot of time debugging the issues we encountered. There were many challenges that we came across while working on this project which are listed as follows:

1. The main problem that was faced by all the people in the group was running the model with “glpk” solver on Rstudio cloud. However, we were able to get the results with “lpsolve” solver on Rstudio cloud. The desktop version was able to run the model with desired results using “glpk” solver. The reason for the “glpk” solver not working on the cloud for this model is still unknown even after debugging.
2. The other challenge that we faced was generating the results using the model for a bigger dataset. The base model was created with 6 project managers assigned to 6 projects in alignment to 4 goals of the organization. We were trying to run the model with 8 project managers assigned to 8 projects in alignment to 8 goals of the organization. We tried running the model with different solvers but we were getting the error in the multiplier with missing values in the error statement. However, we were able to run the model successfully for a smaller dataset of 3 managers, 3 projects and 3 goals.  
We were able to debug it to NULL value in the data set and were able to resolve it to generate recommendations for 8 project manager assignments.
3. The other challenge we faced was printing the model results using the “get\_solution(<model>, <variable>)” function for a smaller dataset of 3 managers, 3 projects and 3 goals. But we were able to print the results correctly using this function for the base model dataset.

After using different debug strategies and referring to the error statement on various websites we were able to resolve our errors. The bigger dataset multiplier error was resolved when we realized there was a null value in one of the csv that we are loading directly into the model. The printing issue for the smaller dataset was also resolved after trying different types of arguments to get\_solution() function. Now the model works without any error and can be used for any type of dataset.

# Future Work

The goal of human resource management in the modern workplace is not just to match the skill-set of the human resource to the project but also to provide the resource with opportunities for his/her long-term career goals. Career progression is one of the key motivating factors for millenials to accept or continue employment with a company. Management wants to retain top talent by providing growth opportunities (both skills and career progression) to resources. It would be a good enhancement to the model to help assign projects to managers not just based on their current skill but also include the desired skill/experience sought by the resource.

# Conclusion

As a result, from this model, we were able to create an integer-programming model in R which can perform project manager assignment to various projects taking into consideration different assignment criteria. The results generated from our base model matched the results generated in the paper we referenced for creating this model.

The model created in the project proposes the project assignment to the project manager using different constraints like project requirements, manager competencies to work on the projects, project prioritization and the organizational/personal limitations. Along with this we added one more time-off constraint which considers the sabbatical, maternity or paternity leaves taken by any manager which performs the project assignment process.

As an extension to this model, we tried running this model for the smaller and larger dataset, and we were able to generate desired results using this model. So, this framework and the optimization model can be used for project manager assignment to projects in any smaller or bigger organization and this assignment will be in alignment with the organization's goal to maximize profit.

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