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# Assigning Projects to Project Managers in a Multiple-Project Management Environment: A Pilot Study of a Decision Support Model

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**Abstract-** Project assignment is considered one of the critical project decisions since it influences the performance of projects, and eventually the performance of the organization. Despite its importance, the literature reveals two major gaps on project assignment criteria and methodology. To close these gaps, this study proposes an additional set of project assignment criteria and a systematic methodology for project assignments, so called, a decision support model for project assignments (DSM). By using the concepts of case study research combined with a literature review, the important potential criteria for project assignments are identified. These criteria are used in conjunction with the concepts of the analytic hierarchy process (AHP) and the integer programming (IP) to develop a DSM for one company. The DSM is executed and validated with the company's information. As a part of this research project, this paper illustrates the results of the pilot study developed for the feasibility study of the DSM development.

## I. INTRODUCTION

Research on project assignments, a process of assigning a project to a project manager, has exhibited a peculiar dichotomy in the approaches to (i) the influences of project assignments and (ii) methodologies for project assignments. A tendency among those studying the influences is that a

project assignment is a critical project decision [1]. The rationale is that such a decision affects the project performance, which then affects the organizational performance.

When being assigned a project with requirements that match his competencies well, the project manager is likely to perform better than if there was no match. The higher performance, then, contributes to the project success, that is the project performance (see the left portion of Figure 1) [2-5]. The better project performance will contribute to the higher organizational performance (see the upper portion of Figure 1) [6].

Project assignments, however, have a direct influence on the organizational performance as well (see the right portion of Figure 1). This is possible to discern in the case of strategically important projects. Such projects are conceived to directly support some of the organizational goals whose accomplishment is the measure of the organizational performance. The degree of the accomplishment may significantly depend on the competencies of the assigned project manager. In short, literature on project assignment influences argues that project assignment influences both project and organizational performance.

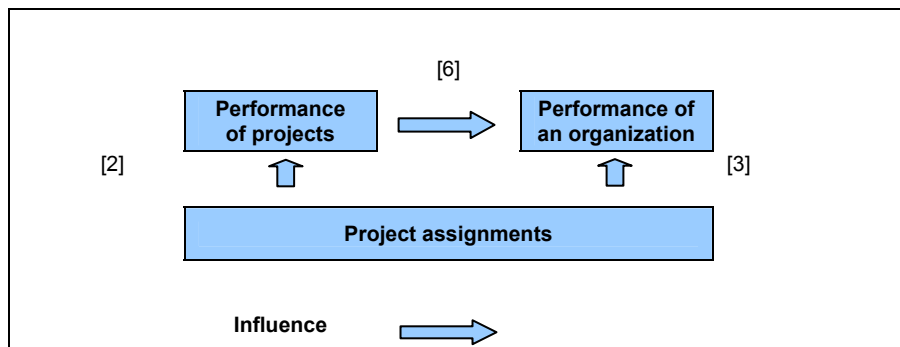


Figure 1: The influence framework of project assignment

Methodologies for project assignment, on the other hand, exhibit a different perspective.

They are mainly based on criteria that address the influences of the project assignments on the performance of projects [7-9]. The influence of project assignments on the performance of the organization in the methodologies is largely absent, creating the above mentioned dichotomy.

The purpose of this study is to develop a new systematic methodology for project assignments. Specifically, two distinct research goals are pursued: 1) to investigate the existing project assignment processes in order to identify

project assignment criteria, and, based on such criteria, 2) to construct a methodology for project assignments in the form of a decision support model (DSM). When accomplished, these goals would go far toward reconciling the approaches to the influences of project assignments and methodologies for project assignments.

## III. THEORETICAL BACKGROUND

We begin by reviewing the literature on project assignments divided into two streams: project assignments as

*assignment criteria and assignment methodologies.* By the project assignment literature, we mean mostly empirical studies in which a project assignment is a unit of analysis.

Although there are overlaps in focus across the streams, research within each stream concentrates on a particular aspect of the project assignment. The assignment criteria research focuses on various criteria that can be used to assign a project to a project manager, whereas the assignment methodology work concerns the framework and process of applying the criteria to the assignment. After providing a critical review of each stream, we indicate gaps in the literature and also what these gaps imply in this study.

#### *A. Project Assignment Criteria and Methodologies*

Assignment criteria: The literature on assignment criteria stresses that a successful project assignment is one in which a project manager possesses competencies compatible with project requirements – type of project, its size, complexity, durations, etc. [2, 3, 10, 11]. The focus in this stream is on discovering which competencies are correlated with project requirements, and thus those competencies represent the most appropriate criteria to assign a project [12-16].

The earliest work in this stream emphasized the importance of competencies such as technical knowledge, administrative skills, and leadership ability including communication, problem solving, conflict resolution, integration, and analysis [12, 16]. Similarly, a later study of Pettersen included competencies of problem solving, administration, supervision and project team management, interpersonal relations, and some other personal qualities for selecting project managers [13]. The work of Thamhain centered on leadership, technical, and administrative competencies as ideal attributes for project managers [14, 17]. On the other hand, Frame recognizes business-judgment competencies as essential to successful project management [15].

Assignment methodologies: A second stream of literature is what we have termed the methodologies for project assignments. This stream evolved from the first stream, the assignment criteria. In this case, a successful project assignment is seen as a balancing act between project managers' competencies and project requirements. Perhaps one of the strongest methodologies is one of Adams, *et al.* [7], proposing a contingency approach for project assignments. This approach utilizes the concepts of the Scoring Model based on attributes for matching a project to a project manager. Hauschildt, *et al.* [8] categorize types of projects and types of project managers, arguing that project managers should be assigned to the types of projects that they are most likely to manage successfully. Mian and Dai [9] rely on the Analytic Hierarchy Process (AHP), focusing on technical, administrative, and interpersonal competencies.

#### *B. Critical Review and Implications*

Although the extant literature contributes significantly to the better understanding of the criteria and methodologies for project assignments, two observations stand out as follows:

Observation 1: *The assignment criteria and methodologies are incomplete.* In particular, while assigning projects per project-specific requirements and competencies is necessary because of their influence on project performance [7, 8, 18], it is also necessary to include criteria related to the performance of the organization (see the right portion of Figure 1). As already mentioned, performance of the projects affects the performance of the organization, specifically the accomplishment of the organizational goals and strategies (further referred to as organizational factors). Additionally, to assign a project, there are some personal and organizational limitations (further referred to as organizational constraints) such as the resource capacity of project managers (e.g., expressed in terms of person hours per time period) and their career path interests. Therefore, criteria related to the accomplishment of the organizational factors and the organizational constraints should also be considered during a project assignment.

Because they use assignment criteria as a foundation, the current methodologies for project assignments are developed based on the dominant assignment criteria approach, matching project requirements and the project manager's competencies as criteria. Therefore, when assigning projects these methodologies do not account for criteria related to the organizational factors and constraints. In summary, the implication of these arguments about observation 1 is as follows.

**Implication 1:** *In addition to criteria related to project requirements and competencies, the project assignment criteria and methodologies should include those related to the organizational factors and constraints. In that way, all criteria related to project and organizational performance would be accounted for.*

Observation 2: *The project assignment criteria and methodologies in the literature do not account for a situation where one project manager leads multiple, simultaneous projects;* rather they tacitly assume that the project manager manages one project at a time. This is important, because according to some accounts, a large majority of projects are managed by project managers who manage multiple, simultaneous projects [19]. These project managers should possess some competencies not necessary for managing a single project at a time, and not included into the criteria from the extant literature. For example, managing multiple projects creates a need for the interproject process, which coordinates the interdependencies and interactions among simultaneous projects. Another example is multitasking, an important competency for project managers of multiple, simultaneous projects [20]. These competencies should also be included in project assignment criteria. In addition, the organizational constraints regarding the resource capacity of

the project manager who manages multiple simultaneous projects are of major significance. In fact, it is rather challenging to balance the number of person hours per time period that the project manager has available with the number of person hours the management of his multiple projects requires [21]. In particular, when being assigned too many simultaneous projects, a project manager may lose value-added time in switching contexts among projects. This is what Rubenstein calls the switchover time cost [20].

The methodologies proposed in the literature were also developed for the context in which project managers manage a single project at a time. Hence, they are not quite applicable to project assignments in a multiple-project environment. Employing these methodologies for project assignments in situations where a project manager manages multiple, simultaneous projects may lead to a local optimum and an overall suboptimum [22, 23]. In summary, the implication of these arguments about this observation is as follows.

**Implication 2:** *The project assignment criteria and methodologies should account for project assignments in an organization where a project manager handles one project at a time, as well as for an organization employing a project manager managing multiple, simultaneous projects.*

#### IV. RESEARCH DESIGN

To address the critical review observations and to respond to the implications, this study has two already mentioned research objectives: 1) to investigate the existing project assignment processes in order to identify project assignment criteria, and 2) to construct a methodology for

project assignments in the form of a decision support model (DSM). These research objectives are supported by the research questions as follows.

##### Research objective 1

Research question 1: What organizational factors influence the project assignment process?

Research question 2: What competencies must project managers possess?

Research question 3: What project requirements impact project assignments?

Research question 4: What organizational constraints are typically imposed on project assignments?

##### Research objective 2

Research question 5: How should the DSM for project assignment be constructed to assure that the organizational factors, the project requirements, the competencies of project managers, and the organizational constraints are properly considered during project assignments?

These research objectives and questions are focused on companies that pursue new product development projects in a multiple-project environment, where some project managers manage one project at a time, while others lead multiple, simultaneous projects. The set of project assignment criteria and the methodology for project assignments proposed in this study are tailored for those companies.

To accomplish the research objectives, the study includes two main phases: the development of project assignment criteria and the development of the DSM for project assignments, as shown in Figure 2. Note that this paper reports the current status of this study, which is in the pilot study stage.

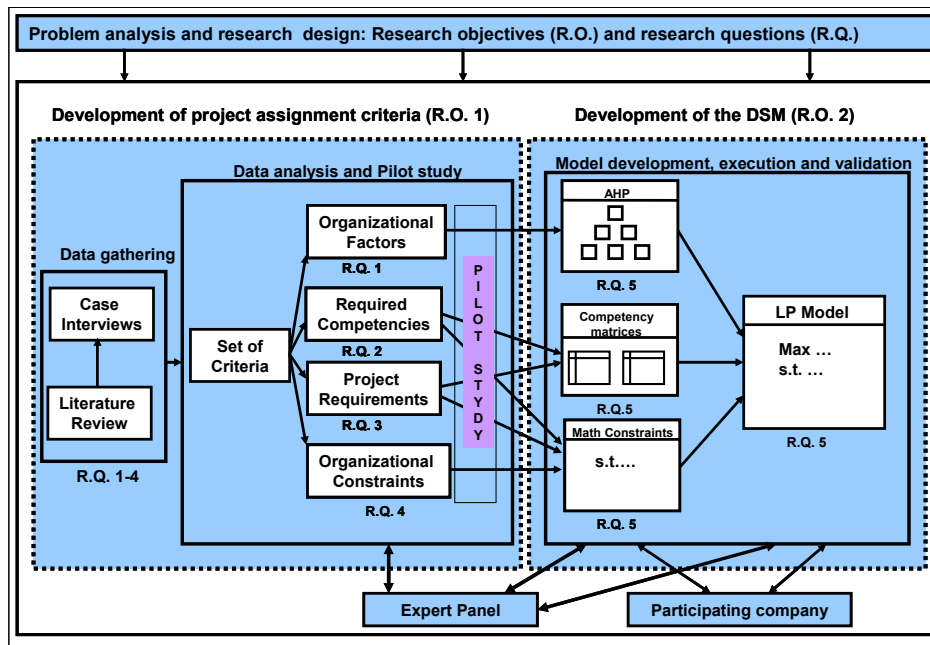


Figure 2: The research process

### A. The Development of Project Assignment Criteria

This phase consists of two research steps: 1) data gathering and 2) data analysis and pilot study.

1. *Data gathering*: The literature review is conducted to explore project assignment criteria. In addition, the project assignment processes of four specific companies are studied

by means of case study method, including interviews with project managers and their superiors and project document reviews. These companies are selected since they are in high-technology industry and execute NPD projects in a multiple-project environment. Table 1 illustrates the description of the companies.

TABLE 1: THE DESCRIPTION OF THE COMPANIES FOR CASE STUDY RESEARCH

	Company A	Company B	Company C	Company D
Department Purpose	Program Management Department Product development management	Program Management Department: Product development management	Project Management Department: Software development management	Eng. Management Department: Support software development
Number of department's projects per year	40-50	16-20	>50	>100
Number of project managers of multiple projects in department	18	4	8	4
Average number of concurrent projects per project manager	3-4	2-4	4-8	10-12
Typical project duration (months)	Small projects: 9-15 Medium projects: 12-24 Large projects: 18-36	Small projects: 3-6 Large projects: 9-12	Small projects: 1-2 Medium projects: 3-4 Large projects: 12-36	3-18
Typical project budget	Small: \$ 1-2 M Medium: \$ 2-5 M Large: > \$ 5 M	Small projects: \$ 0.5-3 M Large projects: \$ 6-9 M	Small: 300-400 hrs Medium: 1000-3000 hrs Large: > 3000 hrs	Small: < 300 hrs Medium: 300-1000 hrs Large: > 1000 hrs
Typical # of participants per project	20-60	Large projects: 25-35 Small projects: 20	8-25 people	20-56 people
Typical projects	New product development	New product development	Software Development	Hardware support to software development

2. *Data analysis and pilot study*: The case analyses [24] and literature comparisons are performed to identify a preliminary set of project assignment criteria. These criteria are categorized into the criteria regarding organizational factors, required competencies, project requirements, and organizational constraints. To test the feasibility of the DSM, some criteria in the set are used to develop a pilot model of the DSM (PDSM), which is quantified by using a hypothetical example. It is this PDSM that is the focus of the remaining portion of this paper. In parallel with the work on the PDSM, the preliminary set of project assignment criteria is presented to a panel of experts for their evaluation. This panel consists of six individuals from academic, consulting, and industry environments who have knowledge and experience in project management. The panel will recommend a final set of project assignment criteria that can be subsequently employed to develop the DSM.

### B. The Development of the DSM

This phase, which has not started yet, is designed to provide the model development, execution, and validation. In particular, the project assignment criteria that will be recommended from the experts will be employed to develop the DSM by applying the concepts of the analytic hierarchy process (AHP) and the integer programming (IP) (see Figure 2). The AHP integrates organizational factors, project manager's competencies, and project requirements into the project assignment process (Figure 2). Note that project manager's competencies and project requirements are in the

form of competency matrices. The IP model incorporates outputs from the AHP including those from the competency matrices into its objective function and performs multiple project assignments with the consideration of the organizational constraints (formulated into mathematical constraints). Afterward, the model will be quantified by using the information from one participating company, which executes its NPD projects in a multi-project environment where a project manager may lead a single project or multiple projects at a time. The steps of model development, execution, and validation are as follows:

1. Construct a decision hierarchy (a part of the AHP) by using the project assignment criteria regarding organizational factors
2. Quantify the hierarchy by using a pairwise comparison method. The results will illustrate the importance of projects to the organization
3. Develop competency matrices (a part of the AHP) based on the project assignment criteria regarding the required competencies and project requirements, and quantify the matrices by using the Anchor scales
4. Establish the correspondence between a project and a project manager by means of multiplication of the competency matrices from step 3
5. Employ the results from step 2 and 4 to develop an objective function of the IP model
6. Formulate mathematical constraints of the IP model from the project assignment criteria regarding organizational

constraints with some additional information from the required competencies and the project requirements

7. Execute and validate the IP model

As mentioned earlier, this study is in the pilot study stage. The set of preliminary project assignment criteria is used to develop the pilot model (PDSM). To do so, these seven steps of model development are applied. In addition, the preliminary assumptions are also made as follows:

1. *Project assignment is a static process*, meaning an assignment considers only projects and the resource capacity of project managers at the time of the assignment.
2. *Project assignment is a process of assigning a new project*. In the case that the existing projects need to be reassigned, they will be treated as new projects.
3. *Projects can be categorized to different types depending on their requirements*. These project types will assist in identifying required competencies and resource capacity of a project manager. One possible project typology that is developed by Wheelwright and Clark [25] is discussed later in Section IV.
4. *The resource capacity of a project manager is measured in the unit of numbers of projects*. Specifically, the

resource capacity of a project manager who leads multiple, simultaneous projects is expressed in terms of the total number of projects, the number of projects of a certain type, and the number of projects in a certain phase that he can lead.

Later in the study, these assumptions will be examined. Future work may include relaxing these assumptions.

### III. RESULTS

The results of this pilot study, which is developed for the feasibility study of the DSM, are reported as the preliminary set of project assignment criteria and a pilot model of the DSM (PDSM) based on a hypothetical example.

#### A. The Preliminary Set of Project Assignment Criteria

By following the steps of data gathering and preliminary data analysis, a preliminary set of project assignment criteria is developed. These criteria are categorized into organizational factors, required competencies, project requirements, and organizational constraints, which are supported by references as shown in Table 2.

TABLE 2: THE PRELIMINARY PROJECT ASSIGNMENT CRITERIA

Category	Criteria		Examples of supported references
Organizational Factors	Organizational objectives/goals	Innovation	[26-29]
		Business expansion	[26, 27]
		High profit margin	[26, 27, 30-33]
Required Competencies	Technical competencies	Technical expertise	[11, 16, 34-36]
		Problem analysis	[12-14, 16, 34, 37]
	Administrative/process competencies	Planning and scheduling	[10, 12, 13, 15, 16, 34, 36, 38]
		Monitoring and control	[12, 13, 16, 34, 36, 38]
		Team building and management	[13, 34, 38]
	Human/Interpersonal competencies	Leadership	[8, 10, 16, 34-37]
		Communication	[10, 12, 13, 16, 34, 37]
	Business/strategic competencies	Strategic thinking	[13, 34, 38]
		Customer coordination	[15, 16, 34, 39, 40]
		Business sense	[15, 38]
	Some additional competencies for managing multiple projects	Experience	[10, 41]
		Interproject planning/scheduling	[10, 19, 42-45]
Interproject resource allocation		[6, 46, 47]	
Multitasking		[10, 20]	
Project Requirements	Project type	Size	[5, 8, 25, 48-50]
		Duration	
		Complexity	
Organizational Constraints	Capacity of project managers	The effective capacity	[6, 21, 51, 52]
		The current workload	
		The availability	

1. *Organizational factors* are a group of criteria based on the strategic elements of the organizations such as the organizational mission, objectives, goals, and strategies. To be competitive, most organizations put more emphasis on technology-related and business-related elements, which are continuous innovation, business expansion, high profit margin, etc. The degree to which projects contribute to the accomplishment of these
2. *Required competencies* are the knowledge, skills, and experience of a project manager that are required to lead a project. These competencies can be categorized into technical, administrative/process, human/interpersonal, and business/strategic competencies. In addition, some other competencies such as interproject

elements is important to project ranking, and to which project managers the projects will be assigned.

planning/scheduling, interproject resource allocation, and multitasking are especially needed for project managers who lead multiple, simultaneous projects.

3. *Project requirements* are criteria based on the project characteristics such as the complexity, size, and duration of projects. These requirements can be used to identify the project type and which competencies a project manager needs to manage a project. For example, the commercial development projects can be categorized based on the degree of complexity regarding product and process changes starting from the little or incremental changes of incremental/derivative projects to radical changes of breakthrough/radical projects. Platform or next generation projects land in between the two. The high end of the spectrum arrive R&D projects, which focus on the creation of knowledge as a basis for the commercial development [25]. The higher the project complexity, the more a project needs a competent project manager to manage it [53].
4. *Organizational constraints* are criteria representing some personal and organizational limitations regarding project assignments. One limitation that deserves special attention is the resource capacity of a project manager referred to as the effective capacity, the current workload, and the availability (expressed in person-hours per time period). The effective capacity is the real level of resources available after taking out vacation, etc. [21] and the availability is equal to the effective capacity minus the current workload. The capacity limitations can be, for example, a project manager cannot lead too many projects with the high degree of complexity (e.g. a breakthrough project). A project manager cannot lead too many projects in a particular phase (e.g. conceptual/development) since the project works are very demanding. These limitations are accounted for a project manager who lead multiple, simultaneous projects.

**B. The Pilot Model of the DSM (PDSM)**

The following is a hypothetical example of an organization that is used to quantify the model.

“An organization has the organizational goals include introducing innovation, expanding business to new markets, and boosting the profit margin. This organization has five NPD projects (P1 to P5) to be assigned to three project managers (PM 1 to PM 3). P1 and P2 are categorized as breakthrough projects; P3 is an platform project while P4 and P5 are derivative projects. Regarding the current resource capacity of project managers, both PM 1 and PM 2 lead one breakthrough project while PM 3 leads one platform project. None of them has any project in the conceptual and development phase. The organization sets some constraints regarding the capacity of a project manager such that none of them can simultaneously lead more than three projects, especially two out of three projects are breakthrough ones, and none of them can lead more than one breakthrough project in the conceptual and development phase.”

To report results for this hypothetical example, we use the framework of steps described earlier in the section “The Development of the DSM.”

1. *Construct a decision hierarchy by using the project assignment criteria regarding organizational factors:* The top level of the hierarchy is the organizational mission, the second level is the organizational objectives/goals, and the third level is the projects to be assigned. Figure 3 illustrates the decision hierarchy.

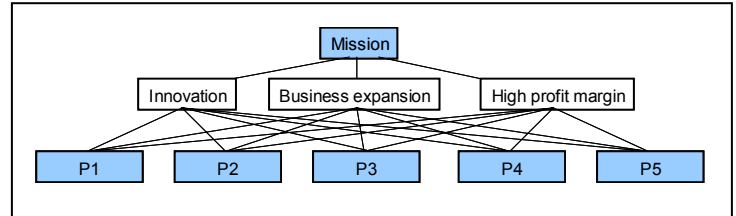


Figure 3: Decision hierarchy

2. *Quantify the hierarchy by using a pairwise comparison method:* The constant-sum method proposed by Kocaoglu [54] is used in this study. From pairwise comparisons, the significance of projects in influencing the organizational mission accomplishment ( $V_j$ ) will be determined. For this hypothetical example,  $V_1 = 0.33$ ,  $V_2 = 0.36$ ,  $V_3 = 0.18$ ,  $V_4 = 0.08$ , and  $V_5 = 0.05$ . This indicates that the breakthrough projects, P1 and P2, are relatively more important to the organization than projects P3, P4, and P5.
3. *Develop competency matrices based on the project assignment criteria regarding the required competencies and project requirements:* Table 3 illustrates a matrix of the required competencies. This matrix shows the levels of competencies of project managers that each project needs. A matrix of the available competencies, which show the levels of competencies that each project manager possesses is illustrated in Table 4. These matrices are quantified by using the 1-5 Anchor scales (1: Low, 5: High).

TABLE 3: A MATRIX OF REQUIRED COMPETENCIES ( $A_{REQ \times PROJ}$ )

	P1	P2	P3	P4	P5
Technical expertise	5	4	3	3	2
Problem analysis	4	5	4	2	2
Planning/scheduling	3	4	3	2	3
Monitoring/control	5	3	2	3	3
Team building/ management	4	5	4	3	2
Leadership skill	4	3	4	3	3
Communication	5	4	4	2	2
Strategic thinking	3	5	3	3	2
Customer coordination	4	5	4	2	2
Business sense	5	4	4	3	3

TABLE 4: A MATRIX OF AVAILABLE COMPETENCIES ( $B_{REQ \times PM}$ )

	PM 1	PM 2	PM 3
Technical expertise	5	4	4
Problem analysis	4	4	3
Planning/scheduling	4	5	4
Monitoring/control	5	5	4
Team building/ management	4	4	3
Leadership skill	4	5	5
Communication	5	4	2
Strategic thinking	5	4	4
Customer coordination	5	5	3
Business sense	4	5	4

4. *Establish the correspondence between a project and a project manager ( $W_{ij}$ ) from a matrix multiplication:* If matrix  $A_{req \times proj}$  is a matrix of required competencies (Table 3) and matrix  $B_{req \times pm}$  is a matrix of available competencies (Table 4). The values  $W_{ij}$  of matrix  $C_{pm \times proj}$  (correspondence matrix) can be calculated from " $C = B \times A$ ". Table 5 illustrates the results of the multiplication, which show that PM1 has the high correspondence with P1, P2, P3, and P4 and PM2 has the high correspondence with P1, P3, P4, and P5.

TABLE 5: A CORRESPONDENCE MATRIX ( $C_{PM \times PROJ}$ )

	P1	P2	P3	P4	P5
PM 1	190	189	156	117	107
PM 2	189	187	157	117	110
PM 3	155	152	128	98	91

5. *Employ the results from step 2 and 4 to develop the objective function of the IP model:* "The maximization of the project assignments to the organizational mission"

This maximization is influenced by the significance of projects on the organizational mission accomplishment ( $V_j$ ), and the correspondence of the project requirements and the project managers' competencies ( $W_{ij}$ ). The model will perform the project assignments ( $X_{ij}$ ) by considering these two factors together with the factors in the mathematical constraints later discussed. The following is the objective function of the model.

$$Max \sum_{i=1}^n \sum_{j=1}^m V_j W_{ij} X_{ij}$$

- $V_j$ : The relative significance of project j to the organizational mission accomplishment
- $W_{ij}$ : The level of correspondence between project manager i and project j
- $X_{ij}$ : Decision variables; 0, 1 binary variables
- i = project manager 1 to n
- j = project 1 to m

6. *Formulate the mathematical constraints of the IP model from the project assignment criteria regarding*

*organizational constraints with some additional information from the required competencies and the project requirements:* The mathematical constraints are developed based on the capacity of project managers. At this time, instead of expressing in the unit of person-hours, the number of projects is used as a proxy. The following data is used in the constraints:

- $M_i$  = Maximum number of projects per project manager i
- $C_i$  = Current number of projects per project manager i
- $MBC_i$  = Maximum number of breakthrough projects in the conceptual and development phases per project manager i
- $CBC_i$  = Current number of breakthrough projects in the conceptual and development phases per project manager i
- $MBP_i$  = Maximum number of breakthrough projects per project manager i
- $CBP_i$  = Current number of breakthrough projects per project manager i
- $BP_j = 0, 1$  binary value
- = 0; if project j is not a breakthrough project
- = 1; if project j is a breakthrough project

**Constraint 1:** Limit the maximum number of projects per project manager, i.

$$\sum_{j=1}^m X_{ij} + C_i \leq M_i \forall i$$

For this hypothetical example,  $M_i=3, C_i=1$ , for all i

**Constraint 2:** Limit the maximum number of breakthrough projects in the conceptual and development phase per project manager, i.

$$\sum_{j=1}^m BP_j \times X_{ij} + CBC_i \leq MBC_i \forall i$$

For this hypothetical example,  $BP_1=BP_2=1, BP_3=BP_4=BP_5=0, CBC_i=0$  and  $MBC_i=1$ ; for all i

**Constraint 3:** Limit the maximum number of breakthrough projects per project manager, i.

$$\sum_{j=1}^m BP_j \times X_{ij} + CBP_i \leq MBP_i \forall i$$

For this hypothetical example,  $BP_1=BP_2=1, BP_3=BP_4=BP_5=0, CBP_1=CBP_2=0, MBP_i=2$ ; for all i

**Constraint 4:** Each project, j, can be assigned to only one project manager.

$$\sum_{i=1}^n X_{ij} = 1 \forall j$$



**Constraint 5:** Binary variables
 $X_{ij} = 0,1$  binary variables

7. *Execute and validate the IP model:* The IP model is formulated, executed, and validated by using Microsoft Excel Solver. For this hypothetical example, the model suggests assigning P1 and P4 to PM 2, P2 and P3 to PM 1, and P5 to PM 3 with the optimum solution of 168.47. This optimum value indicates the contribution of the project assignments to the accomplishment of the organizational mission and the correspondence between project requirements and the project managers' competencies by considering the capacity of project managers as the organizational constraints. The discussion of the results is as follows.

From the hierarchy quantification, the breakthrough project P1 and P2 are found to be important to the organization ( $V_1 = 0.33$  and  $V_2 = 0.36$ ). They also require high level of project manager competencies (Table 3). As of Table 4, both project managers, PM 1 and PM 2, are highly competent. They have high correspondence with P1 and P2 (Table 5). According to this information, either of them can lead P1 and P2 if they have the sufficient capacity. The results of the model show that P2 should be assigned to PM 1 and P1 should be assigned to PM 2. Since PM 1 and PM 2 are competent, they can also lead other new projects. The model additionally assigns P3 to PM 1 and P4 to PM 2. No additional project can be assigned to these project managers since it will fail the capacity constraints. The model, then, assigns P5 to PM 3. The current workload after the assignments of each project manager is shown in Table 6.

TABLE 6: THE CURRENT WORKLOAD OF PROJECT MANAGERS AFTER ASSIGNMENTS

	New assignments	Total No. of projects	Total No. of Breakthrough projects	Total No. of Breakthrough projects in Con. & Dev. phase
PM 1	P2, P3	3	2	1
PM 2	P1, P4	3	2	1
PM 3	P5	2	0	0

## IV. MANAGERIAL IMPLICATIONS

The purpose of this study was to test the preliminary set of project assignment criteria and the pilot model of the DSM (PDSM). The results of the testing revealed several important implications that we summarize in this section.

1) *The PDSM provides a systemic methodology for project assignments.* Essentially, this means that PDSM includes all relevant criteria related to both organizational and project performance. *Firstly*, when assigning projects management needs to evaluate and rank each project by the degree of its strategic importance of to the organization. With its decision hierarchy, the PDSM makes it possible to perform this evaluation. *Secondly*, management needs to ensure that the competencies of a project manager correspond to the project requirements. To do so, the PDSM introduces the competency matrices that management can use to identify the degree of correspondence between the project requirements and the competency level of each project manager. *Thirdly*, the project assignments should conform to some organizational or personal limitations such as whether or not a project manager has sufficient resource capacity to lead a project. These limitations can be formulated into the mathematical constraints of the PDSM. In summary, after producing ranking of projects through the decision hierarchy, developing the competency matrices, and identifying the mathematical (organizational) constraints, the PDSM performs project assignments in such a way that projects of the higher rank (strategic importance) are assigned to the more competent project managers who have the sufficient resource capacity to lead them.

2) *The PDSM is applicable to both situations where one project manager leads a single project or leads multiple, simultaneous projects.* In addressing the latter, PDSM is perhaps unique in the literature. We, therefore, emphasize such attributes of the model. In particular, in the case of managing multiple simultaneous projects the PDSM introduces several mathematical constraints regarding the resource capacity of project managers in order to ensure effective multitasking and context switching among projects. For this purpose, the PDSM recognizes that a project manager should not lead more than a certain number of projects. It also accounts for the fact that the demand for the project manager's time and the complexity of projects vary across phases in the project life cycle and the type of projects. For example, the project manager should not concurrently lead several projects that are very time-demanding (e.g., projects in conceptual/ development phase are very time-demanding) or complex (e.g., breakthrough projects). Later in the study, the aggregation approach will be introduced to combine these mathematical constraints.

In the case when a project manager leads a single project at a time, the mathematical constraints regarding the resource capacity of a project manager have to be modified. If organizations need so, the PDSM can introduce other constraints. One such example is a constraint regarding the type of project that a project manager can lead.

3) *The PDSM offers a contingency approach.* Specifically, this means that the PDSM is most useful when management employs a set of project assignment criteria tailored to their strategy and organizational conditions, while using the criteria proposed in this study as guidelines. Then, the project assignment model can be developed by following

the concepts and steps as shown in this pilot study. However, the development of this model may be demanding. For example, i) management have to identify a time period for project assignments and the capacity of project managers. ii) This capacity may be expressed in the units of person-hours. Also, when a project manager leads multiple, simultaneous projects, the capacity loss related to multitasking or context switching has to be carefully identified. iii) If it is applicable to the organization, the model should be formulated to recognize the impact of the project manager reshuffling. For example, a project manager may be relieved from managing project A (which is underway) in order to take on a new project B, while project A is assigned to another project manager. In that case, the PDSM is formulated such that project A is treated as a new project and assigned with an assumption that "the new project manager can quickly catch up with the project A."

## V. CONCLUSION AND FUTURE RESEARCH

The results of this pilot study centered on the preliminary set of project management criteria and the PDSM. By employing these criteria and the PDSM, the project assignments in multi-project environment were successfully performed, considering both the organizational and project performance. Obviously, such results indicate that building and deploying a full-scale DSM is feasible. Therefore, in the next step that is beyond the scope of this paper, we will focus on researching such DSM, building on the lessons learned in this pilot study.

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