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Using DEMATEL Method to Modeling Project Complexity Dimensions

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ABSTRACT

Nowadays, project complexity is considered as one of the reasons for projects failures and many studies have been conducted in order to identify the elements of complexity in projects. However, discovery of the relationships between project complexity dimensions has been less worked. So, the main purpose of this research is to explore the relationships among the most important complexity dimensions. In order to perform this, by reviewing literature the complexity dimensions in projects are identified. Next, The DEMATEL method is used in order to determine the required relationships. The results can be used for better understanding of project complexity concepts and also achieving the most important dimensions. Additionally, these results can be applied in order to facilitate the decision making process.
KEYWORDS: Project complexity, DEMATEL method.

1. INTRODUCTION

Nowadays, most organizations regard project management as a critical capability for growth and prosperity, a key enabler of business change, a vital contributor to future success and as a vehicle for delivering strategic objectives [1]. But it should be considered that projects commonly fail to meet their objectives [2]. One of the reasons for project failures which have been mentioned in recent decades is the increasing complexity of projects or an underestimation of complexity, chaos and uncertainty that exist in our projects [3, 4, 5]. Therefore, studying project complexity concepts can help project managers to deal with this issue.

Our purpose in this research is to identify the relationships between key dimensions of project complexity in order to shows how they impact on each other. To accomplish this, first a review of literature is performed in order to identify the dimensions which have been expressed by researchers. Next, by using DEMATEL method the relationships between the selected dimensions is explored.

2. LITERATURE REVIEW

2.1 Complexity

Complexity theory has been widely reviewed in many disciplines such as physics, astronomy, finance, biology, geology, chemistry and metrology [2, 4]. In addition in recent decade, several researches have been studied in order to reveal the relationship between complexity theory and management theories and indicate the importance of complexity in project management [5, 6, 7, 8, 9]. But what is complexity really is? Many researchers pointed out that the concept of complexity can be understood in different ways and it is used to mean different things in different fields [8, 10, 11]. Some examples for complexity definition are presented in table 1.

Table 1. Definitions of complexity

Researchers	Year	Definition of complexity
Whitty and Maylor	2009	the amount of information need to describe a complex system
Morel and Ramanujam	1999	number of elements in a task, the degree to which the task is programmable, the number of exceptions in the process, etc.
Edmonds	1999	that property of a language expression which makes it difficult to formulate its overall behaviour even when given almost complete information about its atomic components and their inter-relations
Maguire and McKelvey	1999	A complex system is a system (whole) comprised of numerous interacting entities (parts), each of which is behaving in its local context according to some rules, laws and forces. In responding to their own particular local context, these individual parts, can, despite acting in parallel without explicit inter-part coordination or communication, cause the system as a whole to display emergent patterns – orderly phenomena and properties– at the global or collective level

A complex system is a system which consists of a large number of elements. Each element interacts with other elements and also with its environment [10, 12]. Complexity scientists are used “agent” for each of these elements [13]. An agent influence on its systems and also is affected by it. Due to the existence of a large number of interacting agents, complex systems have emergent properties. It means that they exhibit behaviors that may not be inferred from studies of its agents [14].

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Scientists use the phrase “edge of chaos” when they want to show complexity. Complexity arises when complex systems placed at the edge of chaos [15].

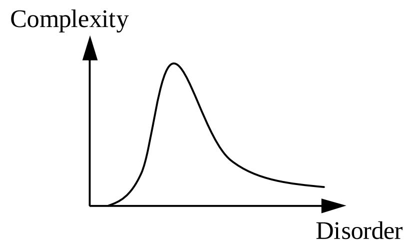

Figure 1. Graph of Disorder against Complexity [16]

Figure 1 illustrates the Graph of Disorder against Complexity. The edge of chaos implies the coexistence of disparate dimensions in the same organization [17]. In other words, it is located in a mid-point between order and disorder [12, 16].

2.2 Complexity in project

Projects have been discussed as a type of complex systems in the past 15 years. According to Whitty and Maylor (2009) in addition to technical issues, projects are faced with the wider organizational factors which are beyond the control of managers; they are complex and needs managements [2].

Baccarini (1996) was one of the first researchers that discussed the concept of project complexity. To do this, he utilized the phrase “Consisting of many varied interrelated parts” and proposed two concepts for project complexity: differentiation - the number of varied elements- and interdependence or connectivity- the degree of interrelatedness between these elements [18]. Since that time, project complexity was studied by different researchers. Vidal et al. (2011) based on the work of researchers such as Baccarini (1996), Edmonds, (1999), Marle (2002), Austin et al. (2002) and Vidal et al. (2008), proposed their definition of project complexity as a property of each project that makes it hard to perceive and forecast, in order to keep control its behaviour, even when complete information about the project system is available [8].

Note that, Projects are considered as a complex adaptive system. In the study of complex systems we are faced with complex adaptive systems. It means that complex systems do not simply respond to events and they are adaptive and spontaneously self organizing [4, 12].

2.3 Project complexity dimensions

Dimensions of project complexity have been investigated by several researchers. Xia and Lee (2004) with the aim of grasping the complexity of information system development projects, considered 4 dimensions which include structural organizational complexity, structural IT complexity, dynamic organizational complexity and dynamic IT complexity [6].

Maylor et al. (2008) studied managerial complexity with respect to five dimensions. These are mission, organisation, delivery, stakeholders and team. Each of these dimensions comprises multiple aspects which shape the MODeST dimensions [19].

In order to measuring project complexity, Vidal et al. (2011) used organizational and technological complexity to classify the project complexity factors. they proposed a framework which has also another aspect. Size, variety, interdependencies and context-dependence are the four concepts which have been used in order to categorize the factors [8].

Bosch-Rekveldt et al. (2011) proposed the TOE framework in order to Grasping project complexity in large engineering projects. They utilized technical, organizational and environmental complexity to form this framework. TOE framework also has fourteen subcategories. These are T: goals, scope, tasks, experience, and risk; O: size, resources, project team, trust, and risk; E: stakeholders, location, market conditions and risk [5].

Xian and Xue-qing (2011) proposed Construction System Complexity Concept Model (CSCCM) which is a three-dimensional model. These are definition dimension, character dimension and perspective dimension. The perspective dimension is made of six project complexity concepts which can be considered as six dimensions for project complexity. These are Project environment complexity, project technology complexity, project stakeholder complexity, project task complexity, project information complexity and project objective complexity [20].

3. RESEARCH METHODOLOGY

In order to modeling project complexity dimensions, first a comprehensive literature study was performed. The different types of dimension were investigated and ultimately the final dimensions were selected. In next step, the DEMATEL analysis was applied in order to determine the relationships between the final dimensions.

3.1 selecting final dimensions

In order to identifying project complexity dimensions, a comprehensive study on previous researches was conducted. Finally, 7 dimensions were selected which include environment complexity, organizational complexity, objective complexity, stakeholder complexity, task complexity, technology complexity and information systems complexity. Note that these dimensions were selected in consultation with experts who work in the field of project management. Figure 2, shows these dimensions.

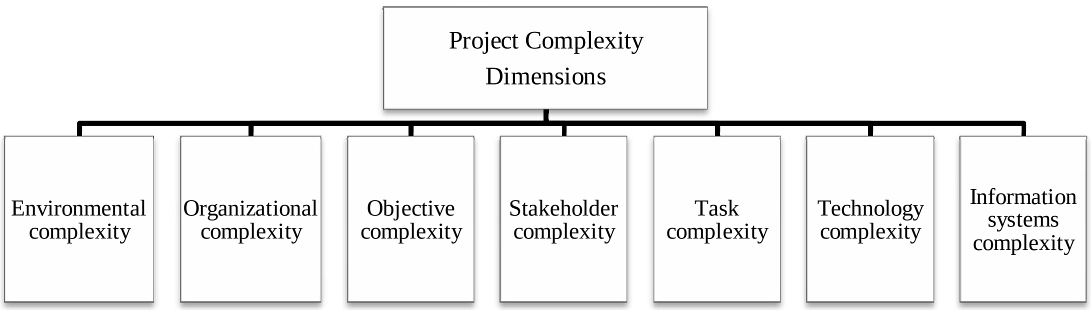

Figure 2. Project complexity Dimensions

3.2 DEMATEL

The DEMATEL method proposed by Battelle Memorial Institute and it is a useful method for creating and analyzing a structural model involving causal relationships between factors [21]. This method has been successfully utilized in many fields, such as development strategies, management systems, e-learning evaluations, and knowledge management [22]. Several steps are involved in DEMATEL which a summary of them is given as follows:

Step 1: Form the average matrix

Assume that there are *h* experts and *n* factors. We proposed the comparison scales, 0, 1, 2, 3 and 4, representing 'no influence', 'little influence', 'medium influence', 'strong influence', and 'very strong influence', respectively. The influence matrix of the h^{th} respondent between total factor n is given as:

$$Z^h = \left[z_{ij}^h\right]_{n\times n} \qquad (1)$$

The total average influenced value from all respondents when considering the score from criteria a_i to a_j is given as:

$$Z_{ij} = \frac{\sum_{h=1}^{H} z_{ij}^h}{H} \qquad (2)$$

Step 2: calculating the normalized initial direct-relation matrix

The normalized initial direct-relation matrix is achieved by normalizing the average matrix Z through the following equation:

$$N = \lambda . Z \qquad (3)$$

$$\lambda = Max\left[\max_{1\le i\le n}\sum_{j=1}^{n} z_{ij}\,,\,\max_{1\le j\le n}\sum_{i=1}^{n} z_{ij}\right] \qquad (4)$$

Step 3: calculating the total relation matrix

The total relation matrix T can be acquired by using the following equation:

$$T = N.(I-N)^{-1} \qquad (5)$$

If t_{ij} be the (i, j) element of matrix T; the sum of the *i*th row and the sum of the *j*th column, d_i and r_j, respectively, are obtained as follows:

$$D_i = \sum_{i=1}^{n} t_{ij} \qquad (i = 1,2,\dots,n) \qquad (6)$$

$$R_j = \sum_{j=1}^{n} t_{ij} \qquad (j = 1,2,\dots,n) \qquad (7)$$

Step 4: Set a threshold value and obtain the impact-relations map
In order to explain the structural relation between the factors, it is necessary to set a threshold value *p* to filter out the unsuitable effects in matrix T. At this step, decision makers or experts will choose the threshold value.

4. RESULTS AND DISCUSSION

The purpose of this study is to find the relationships between project complexity Dimensions. In order to do this, after identifying 7 dimensions, the DEMATEL method was utilized.

A group of 9 experts were applied to implement this method. The initial average matrix for seven project complexity dimensions was prepared as shown in table 2.

Table 2. The initial average matrix

	Environment	Organisation	Objectives	Stakeholders	Tasks	Technology	IS	Sum
Environment	-	3.556	3.222	3	2.778	2.667	2.889	18.112
Organisation	0.889	-	3.111	3.222	3.111	2.556	2.778	15.667
Objectives	0.111	1.667	-	2.778	2.111	1.778	1.778	10.223
Stakeholders	0.222	3.111	3	-	2.889	1.111	3.222	13.555
Tasks	0.222	2.889	2.444	2.111	-	2.889	2	12.555
Technology	0.111	1.444	1.333	1	2.667	-	0.889	7.444
IS	0.333	2	2.444	3.222	2	0.889	-	10.888
Sum	1.888	14.667	15.554	15.333	15.556	11.89	13.556	

In table 2, the sum of the first column is the maximum value among other values with 18.112. Thus, according to Eq. (3) and the values of the average matrix, a direct influence matrix is calculated and illustrated in Table 3.

Table 3. The direct influence matrix

	Environment	Organisation	Objectives	Stakeholders	Tasks	Technology	IS
Environment	0	0.197	0.178	0.166	0.154	0.148	0.160
Organisation	0.049	0	0.172	0.178	0.172	0.141	0.154
Objectives	0.006	0.092	0	0.154	0.117	0.098	0.098
Stakeholders	0.012	0.172	0.166	0	0.160	0.061	0.178
Tasks	0.012	0.160	0.135	0.117	0	0.160	0.111
Technology	0.006	0.080	0.074	0.055	0.148	0	0.049
IS	0.018	0.111	0.135	0.178	0.111	0.049	0

According to Eq. (5) the total relation matrix was achieved and shown in table 4. Values in total relation matrix demonstrate the effect of dimensions on each other, in other words t_{ij} in total relation matrix depict the effect of i^{th} element from rows on j^{th} element from columns. For example, according to table 4, environment impact on organisation with an impact level of 0.508.

Table 4. The total relation matrix

	Environment	Organisation	Objectives	Stakeholders	Tasks	Technology	IS
Environment	0.051	0.508	0.520	0.509	0.504	0.413	0.464
Organisation	0.086	0.286	0.456	0.460	0.460	0.360	0.407
Objectives	0.035	0.278	0.209	0.341	0.316	0.248	0.275
Stakeholders	0.051	0.401	0.420	0.279	0.414	0.269	0.398
Tasks	0.047	0.366	0.366	0.351	0.253	0.332	0.318
Technology	0.028	0.218	0.223	0.206	0.288	0.124	0.184
IS	0.049	0.312	0.350	0.383	0.330	0.221	0.206

Based on Eq. (6) and (7) the value of D_i and R_j can be calculated by using total relation matrix. Likewise, The values $D_i + R_j$ and $D_i - R_j$ can be calculated as shown in table 5.
While the importance of a factor is expressed by the $D_i + R_j$ value, the size of the direct impact of one criterion on other criteria is shown by the $D_i - R_j$ value. In addition, if $D_i - R_j$ value is negative and large, it demonstrates that this criterion is highly influenced by other criteria [23].

Table 5. The causal influence levels

	D_i	R_i	$D_i + R_i$	$D_i - R_i$
Environment	2.969	0.347	3.316	2.622
Organisation	2.515	2.369	4.884	0.146
Objectives	1.702	2.544	4.246	-0.842
Stakeholders	2.232	2.529	4.761	-0.297
Tasks	2.033	2.565	4.598	-0.532
Technology	1.271	1.967	3.238	-0.696
IS	1.851	2.252	4.103	-0.401

Figure 3 demonstrates the casual influence diagram for project complexity dimensions in the following:

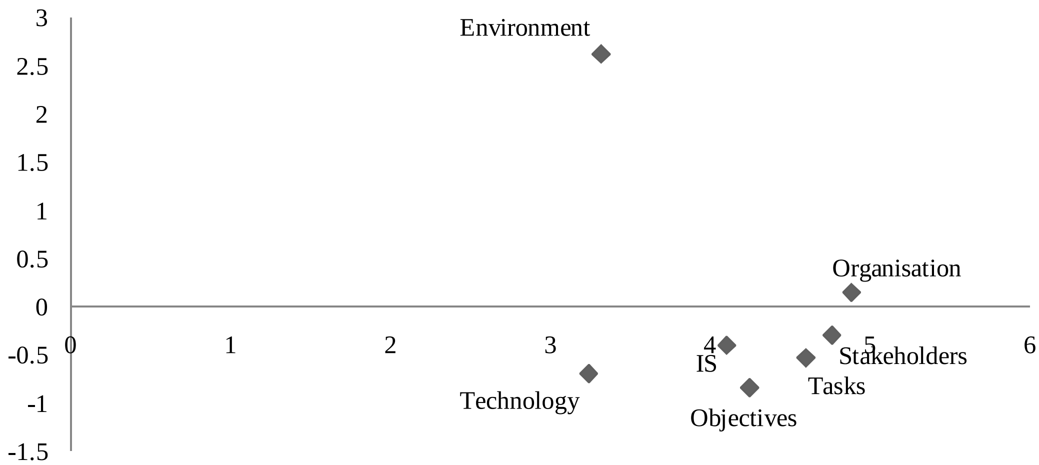

Figure 3. The casual influence diagram

In this step, a group of experts were asked to define a threshold value for dimensions. The threshold value was assigned 0.35, and it means that only values which are bigger than these thresholds were taken into account. For example organisation impact on environment, organisation, objectives, stakeholders, tasks, technology and information systems with an impact level of 0.086, 0.286, 0.456, 0.460, 0.460, 0.260 and 0.407 respectively. Based on threshold value 0.35, objectives, stakeholders, tasks, technology and information systems are influenced by organizational complexity. Figure 4 shows the impact-relations map for project complexity dimensions.

The results for dimensions depict that, environment complexity $(D_i - R_j) = 2.622$ and organizational complexity $(D_i - R_j) = 0.146$ were the positively-affected dimensions. Objectives$(D_i - R_j) = -0.842$, Stakeholders$(D_i - R_j) = -0.297$, tasks $(D_i - R_j) = -0.532$, technology$(D_i - R_j) = -0.696$, and information systems $(D_i - R_j) = -0.401$ were the negatively-affected dimensions.

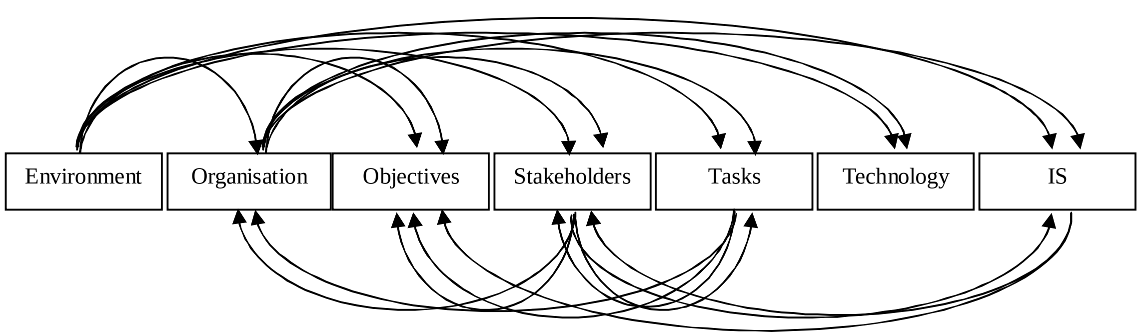

Figure 4. Impact-relations map for project complexity dimensions

Every project is implemented in a series of environments such as economic, social, cultural and political environments. We should keep in mind that these environments have a large impact on other dimensions and are affected by the minimum and this is the main feature of them undoubtedly. The DEMATEL results also indicate this issue so that environment has the highest value of$(D_i - R_j)$. Moreover, based on the impact relations map environment influence on all dimension of project complexity and aren't affected by any of them.

Organizational complexity of the project stems from the business and governance aspects of projects such as financial management, scheduling, resources allocation and decision management. Organizational complexity has the highest value of $D_i + R_j$ which express that this dimension is the most important dimension among all. The next important dimension is stakeholders which cover designers, contractors, subcontractors, material suppliers, banks, government departments that involved in project. Each of these stakeholders has conflicting perspectives which impose complexity to project.

Every project is composed of huge number of tasks from multiple disciplines which have their own features. They are correlated with each other and change over time which causes complexity in projects. Tasks dimension is the next important dimension according to the DEMATEL results.

Projects are made to satisfy different types of objectives. These objectives come from various levels of stakeholders which may have conflicting objectives to each other. In addition, each stakeholder provides large amount of information for project system which this huge information can induce difficulties for project teams. Based on the value of $D_i + R_j$ objectives and information systems are located in fourth and fifth place. Finally, technology is placed which refers to various industries and professional technologies that include in a project. Note that the interaction between professional technologies shapes this aspect of complexity in projects.

5. Conclusion

One of the critical reasons leading to failure projects is lack of enough knowledge to modern project management concepts such as complex systems and complexity in projects. In this research, The DEMATEL method was utilized in order to identify the relationships between project complexity dimensions. In order to do this, a set of relevant dimensions were identified by a literature review. Next, by using DEMATEL the relationships between the final dimensions was found.

The results revealed that environmental complexity is the most effective dimension of projects. This dimension comprises all types of environment such as natural environment, economic environment, social and cultural environment, policy and regulatory environment, and political environment.

Modeling of the project complexity dimensions allows managers to investigate the effect of dimensions on each other and also to see the way that these effects occurred. Therefore, they can identify the sensitive areas and vital aspects of projects. These critical aspects have the greatest influence on other aspects and are influenced by the other dimensions least; a positive change in them can lead to positive change in other dimensions.

Results of these modeling can be used with other decision making method such as analytical network process (ANP) in order to measuring the complexity of projects.

In addition, while each project has its own characteristics, similar researches can be conducted in order to identify the relationships between critical dimensions in different projects and also to explore these differences.

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