DEVELOPMENT OF PROJECT EXECUTION COMPLEXITY INDEX

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ABSTRACT

Growing complexity is one of the main reasons behind failure of many projects. Project management academicians have conceived a few complexity characterization models but a comprehensive complexity measurement model encompassing factors of important project constraints i.e. scope, time and cost is still missing. In this research, a model has been developed to compute PECI (Project Execution Complexity Index) for various categories of projects considering varying levels of complexity, i.e. PECI(R) for R&D/Technology projects, PECI(I) for Infrastructure development projects and PECI(O) for Other projects. A complexity scale starting from 0 = least complex to 10=highly complex has also been proposed in order to rank and compare the projects. This ranking will help the decision makers to decide which projects to include in their portfolio and which projects to give priority while assigning resources more efficiently. Moreover, project managers will be able to manage their projects better, by first comparing them in order of complexity, followed by tweaking the factors which contribute towards enhancing their complexities.

KEYWORDS: *Project Complexity, Managing Complexity, Complex Projects*

INTRODUCTION

In the recent researches, schedule delays and cost overruns have been reported to be the major reasons behind the failure of most of the projects[1]. However, the projects are continuously failing even when the usual success criteria to measure project performance are known[2]. One of the main contributing factors behind these failures is the increased level of complexity during execution phase, being more than anticipated in early stages of planning. Moreover, escalating levels of complexity is making the projects difficult to manage[3-7]. Therefore, it is imperative for the project managers to go beyond it and develop comprehensive measurement models by understanding and measuring the sources and levels of complexity to guarantee the success of projects[1,6]. In the existing literature[3-4,7-9,14-16,] various factors which contribute towards enhancing the complexities in projects have been identified. However, most of the researchers measured complexity considering schedule related factors only, e.g. number of activities and interaction between them etc.[10,11]. On the other hand, a couple of measures have also been proposed taking into account the other soft aspects of project complexity as well, i.e. environmental, technological, informational, cultural, goal, organizational and task complexity[12,13,17]. None of the above mentioned studies developed the complexity measures by combining schedule related complexity factors along with other soft aspects, such as environmental, organizational complexity etc. Moreover, experienced project managers frequently have to make a trade-off among constraints of project, i.e. scope, time and cost throughout the project lifecycle[18]. Hence, the main objective of this research is to develop PECI which would allow the project managers to assign priority to these constraints in order to manage the trade-off. Weightage system has also been developed on the basis of assigned priorities to determine weights which would be assigned to factors/sub-factors while computing PECI. A PECI model has also been developed for three categories of projects, namely, R&D/Technology projects, Infrastructure development project and Other projects, in order to investigate the variations in their levels of complexities by computing three individual indices, i.e. PECI(R), PECI(I) and PECI(O) respectively for each category. For comparison purpose, a complexity scale has been proposed as well in order to rank the

projects; starting from 0=least complex to 10=most complex. This ranking would help the top management to distribute their resources among these projects more rationally during the early phases of project lifecycle. This tool will help to compare the complexities of various projects, change the severity of complexity by changing the characteristics of complexity factors and make important decisions of undertaking the projects or otherwise. This paper is organized as follows: section 2 reviews various factors and measurement models of project complexity and their limitations. Section 3

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discusses the research methodology including proposed model, data collection, data analysis and discussion of results to test the hypotheses. Section 4 has conclusions followed by future work in Section 5.

LITERATURE REVIEW

Project Complexity

Before coming up with an appropriate measure, it is important to first define project complexity followed by indicating factors which enhance the complexity in projects. In the literature of project management so far, there is no consensus on a single comprehensive definition of project complexity[19,20]. However, various scholars have conducted many research studies to identify and categorize project complexity measurement factors. Initially, Baccarini[3] conceptualized project complexity as interconnection of variety of elements. Afterwards, Williams[7] added uncertainty as another aspect of complexity. Structural and dynamic complexity were proposed in combination by Ribbers and Schoo[21] and Xia and Lee[20]. Williams[22] suggested pace as the next type of project complexity. The pairing of structural complexity, uncertainty and pace was then evaluated by Dvir, et. al.[23]. Project complexity was also seen from the social and political perspectives by Remington and Pollack[24] and indirectly by Maylor, et. al.[9]. A few scholars proposed frameworks to categorize project complexity factors. For example, Geraldi, et. al.[19] proposed a framework and grouped the factors of complexity into various categories, i.e., structural complexity, uncertainty, pace, dynamics and socio-political complexity. Bosch-Rekveldt, et. al.[4] suggested a framework for large engineering projects and identified forty-nine elements from the literature and classified them into three categories of TEO (Technical, Organizational and Environmental) complexity.

Discussion of Existing Project Complexity Measures, their Limitations, Categorization of Projects and Construction of Hypotheses

A consensus is still not evident in the literature on the dimensions or factors which should be taken into consideration while quantifying the project complexity. Authors still have to agree on what all really constitutes project complexity. Most of the project complexity measures in the literature are related to network complexity. According to Nassar, et. al.[10], complex schedule is the root cause of various difficulties which the project team members encounter. Network complexity is defined as the difficulty in analysis and synthesis of network schedules of the projects. Several complexity measures have been proposed for the project networks since 1966[10,11,25]. The network complexity measures proposed by Kaimann, Davies, Pascoe, Johnson and Patterson have considered number of activities and nodes to measure the network schedule complexity. However, the authors afterwards added more factors to achieve an efficient measure of the network complexity. Badiru[11] added information of resources and Boushaala[25] took into account number of critical activities, number of critical paths and the ratio of critical activities along with the variables related to resources. Afterwards, a number of authors took many other factors into consideration while measuring the project complexity. Vidal, et. al.[26] developed a CI (Complexity Index) taking into account four drivers of project complexity, i.e. project size, variety, interdependence and context-dependence. Xia and Chan[17] considered the construction related factors of project complexity and developed a CI for mega construction projects in China. Q. He, et. al.[12] proposed a complexity measurement model for mega construction projects in China, comprising of six categories of project complexity, i.e. technological, organizational, goal, environmental, cultural and information complexities. Lu, et. al.[13] measured project complexity taking into account the two factors, task and organizational complexity. This measure reflected the dynamic and emergent behavior of complex projects but did not take into account the environmental and other factors of project complexity. Nevertheless, none of the researchers formally attempts to include other complexity factors from the perspective of project execution (cost, time and scope) in their researches. Moreover, in most of researches on complexity measurement, the emphasis has remained on quantification of limited factors of project complexity in a specific industry. This research is an attempt to measure complexity, encompassing three important project performance constraints i.e., Time complexity, Scope complexity and Cost complexity for various categories of projects.

The categorization of projects has been done on the basis of varying levels of complexities. The industrial and R&D projects remain far more complex than the mechanistic building blocks of construction processes, but the solutions are generally viewed through the perspective of construction managers and civil engineering researchers and academicians. This by-and-large kept the focus of complexity management to the limited factors of construction issues[12,17]. According to Covin and Pinto[27], "R&D and construction projects lie at the opposite ends of a spectrum of characteristics". Shenhar[28] divided the projects on the basis of technological uncertainty which is significant contributor of complexity in projects[4,15]. Technological uncertainty is more in R&D projects as compared to construction and infrastructure projects[28]. Generally, from the perspective of complexity, researchers have only considered R&D and construction projects as investigation targets, whereas, there are other project categories also which need researcher's attention. In real world, any endeavor with a set of activities, joined together for a common deliverable, a start and an end date, a budget and a sponsor is identified as a project. Thus, it is important that projects which do not come under the definition of R&D or construction must also be studied and named. For the purpose of this research all such projects have been considered under the name of Other projects.

In view of the above discussion, in this research, PECI has been developed for three categories/groups of projects namely; R&D/Technology projects (e.g. development of avionics systems for large aircraft, a new powerful computer processor, air defense systems, a commercial airline, an intelligent electronic warfare system, a space vehicle, a super computer or a new computer operating system etc.), Infrastructural development projects (e.g. construction of: high altitude tunnels, super highways, underwater tunnels, railway tracks, high rise buildings, airports etc.) and Other projects (e.g. arranging a mega event, development of a computer game, running a social campaign, development of a media campaign etc.). Since, there is a very distinct variation in level of complexity, hence following hypotheses are set:

H1: R&D/Technology projects are more complex than Infrastructure development projects.

H2: Infrastructure development projects are more complex than Other projects.

The three categories of projects have been named as R projects, I projects and O projects respectively for the sake of reference in this study.

RESEARCH METHODOLOGY

The methodology to compute PECI has been divided into five steps:

(i) Identifying the complexity factors and sub-factors through literature review and developing theoretical framework of project complexity

(ii) Proposing PECI Model

(iii) Development of Questionnaire and description of methodology to compute PECI

(iv) Data Collection and Data Analysis

(v) Hypothesis testing followed by discussion of results

Development of Project Complexity Framework

Development of Project Complexity Framework

Project Constraint is defined as, "a limiting factor that affects the execution of a project, program, portfolio or a process". This paper intends to use the three constraints of project management to encompass all factors of project complexity. PECI is a second-order construct which is measured by three first-order constructs i.e. Time complexity, Scope complexity and Cost complexity which are further measured by items. Some of these items were selected from the existing TOE framework[4]. Ten items are summed up to measure Time complexity. Three items are extracted from TOE framework and study of Vidal and Marle[6]. They are number of activities, total number of non-critical activities and duration of the project.

The items which were identified from the literature of network complexity, i.e. total number of paths10, critical paths and critical activities[25], and the additional four items were also included in order to strengthen and enrich the measurement of Time complexity, i.e. %age of activities greater than 30% of the total duration of project, total number of paths not starting from beginning to end, %age of floats bigger than the total duration of project and probability of accuracy of durations of planned activities.

Forty two items were summed up to measure Scope complexity. Thirty three items have been taken from TOE framework and two items from the study of Pich, et. al.[14], i.e. uncertainties in scope, uncertainty in execution methodologies, strict quality requirements, dependencies on other stakeholders, number of stakeholders, number of site locations, political influence, stability of project environment, weather conditions, experience with parties involved, HSSE awareness, conflicting norms and standards, project team size, trust in project team including JV partner, contract types, number of different languages, trust in contractors, number of different nationalities, organizational risks, variety of stakeholders' perspectives, technical risks, experience in the country, variety of tasks, internal strategic pressure, size of site areas, company internal support, remoteness of location, overlapping office hours, environmental risks, level of competition, required local content, experience with the technology involved, newness of technology (world-wide) or technology novelty, selection of execution methodology (selectionism or learning)[14].

Besides the above mentioned items, seven more items are added in order to capture the breadth of Scope complexity, i.e. high risks involved related to HSSE, % age of activities executed by external stakeholders, increase in scope without change in schedule, frequency of changes in scope, strategic risks for organization in case of not meeting the project completion deadline and missing information and reduction in project duration without change in scope.

It has been mentioned at various places in literature that size of capital expenditures increases the project complexity[4,29,30]. In addition to two items extracted from TOE framework i.e. total budget and availability of financial resources[4], following six items are also included in order to apprehend the measurement of Cost complexity, namely, import of major resources, estimation of financial budgets, development of supply chain, availability of required funds at the start of the project, requirement of foreign exchange and its timely availability. Hence, the project complexity theoretical framework consists of sixty factors in total.

Proposed PECI Model

In this study, PECI is a second-order formative construct which is measured by aggregating first-order formative constructs i.e., Time complexity, Scope complexity and Cost complexity which are further measured by formative items (finalized complexity factors identified in previous section) as indicated in Figure 1. Moreover, it has been hypothesized that R projects are more complex than I projects and I projects are more complex than O projects. Three individual indices i.e. PECI(R), PECI(I) and PECI(O), have also been computed separately for the three categories of projects.

Reliability and Validity

The typical statistical procedures used to assess the validity i.e. factor analysis (EFA, CFA) and reliability i.e., internal consistency (cronbach’s alpha)[31,32] are not meaningful to be used for formative models. Guidelines have been proposed for successful index construction[33,34] including content and indicator specification and multicollinearity among indicators. Content and indicator specifications have been assured by including all the identified items (or indicators) of Time complexity, Scope complexity and Cost complexity in order to capture the breadth of PECI; explicitly mentioned earlier. Failing to include at least one item (or indicator) would eventually alter the composition of PECI. Multicollinearity between indicators is an unwanted property in formative models. It makes it hard to identify the separate influence of indicators on the latent construct. There is a risk of having redundant information contained in these indicators as a result of multicollinearity and hence, should be excluded from the resulting index[33]. There are multiple views in literature for dealing with multicollinearity. However, most of the authors suggest indicator exclusion based on VIF (Variation Inflation Factor) which assesses the degree of multicollinearity[35-37]. The commonly accepted value of VIF is 10 or equivalent to its tolerance[39]. On the other hand, indicator elimination purely on statistical grounds may alter the meaning of the underlying construct altogether. However, the discussion is still going on and there is no single consensus among the researchers regarding formative models.

In PECI model, multicollinearity is checked among constructs of Time complexity, Scope complexity and

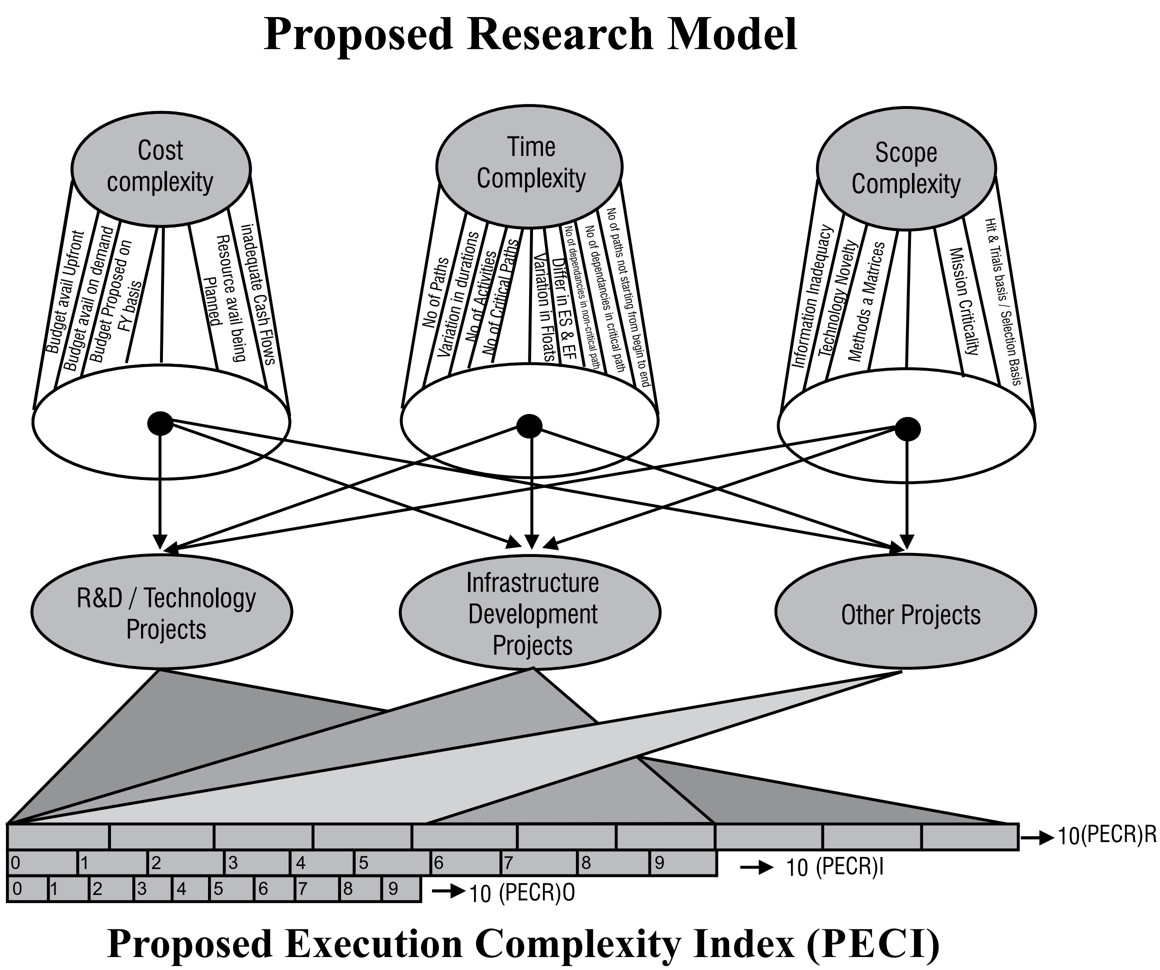

Figure 1. Proposed Research Model

Cost complexity. The maximum value of VIF turned out to be 1.677 which is far below the commonly accepted cut-off threshold of 10[34,35]. It has been proven that there is no multicollinearity between the constructs (Time complexity, Scope complexity and Cost complexity) of PECI so all the three have been retained for inclusion as an aggregated sum into an index, i.e., PECI. Multicollinearity between indicators of all three constructs was also investigated. The iterative process is carried out by taking all the indicators as dependent, one by one, and the maximum value of VIF turned out to be 2.923 for all the ten Time complexity indicators, 2.578 for forty two Scope complexity indicators and 1.489 for eight Cost complexity indicators. Consequently, all the indicators have been included and none proved to be the candidate for exclusion from the resulting index, i.e. PECI.

Development of Questionnaire and Description of Methodology to Compute PECI

A questionnaire was developed to quantify the three constructs Time complexity, Scope complexity and Cost complexity through items. The first section starts with the list of items/questions along with their response scale comprises of ranges of options to be selected from 1-5 (1, least complexity to 5, highest complexity). The second section guides to assign the priority and appropriate weightage to the constructs. Tables 1-2 have been developed to assign priority and appropriate weightage to the constructs depending upon the choice of the sponsor/owner. A sponsor/owner may assign priority in the order of 1 2 3 for Time Complexity first, Scope Complexity second and Cost Complexity third or any either preference, say, 2 for Time Complexity, 1 for Cost Complexity and 3 for Scope Complexity, as may deem necessary by the owner of the project. Table 1 shows all the options available to assign priority to three constructs accordingly. In the next step, the weightages will be assigned to the three constructs on the basis of assigned priorities. Table 2 shows the available weightages which may be assigned to three constructs in case the user selected the priority, i.e. 1-Time, 2-Scope and 3-Cost. From the total weightage of 20, the user may assign 17 to Time, 2 to Scope and 1 to Cost Complexity, or 12 to Time, 5 to Scope and 3 to Cost Complexity accordingly.

In the third section, PECI is calculated by taking the inputs from user scores (first section) multiplied by the weightages (second section) and then integrating them into a mathematical expression.

Calculation of inputs from the first section:

T= Average Time Constraint = ∑ (Time constraint items)/Total number of Time items

S= Average Scope Constraint = ∑ (Scope constraint items)/Total number of Scope items

C= Average Cost Constraint = ∑ (Cost constraint items)/Total number of Cost items

Calculation of inputs from the second section:

Weightage of Time = W_T

Table 1. Priority options of Time, Scope and Cost constraints of project

Time Complexity	Scope Complexity	Cost Complexity
1	2	3
1	3	2
2	1	3
2	3	1
3	1	2
3	2	1

Weightage of Scope = W_S

Weightage of Cost = W_C

$$PECI = [\{(T^* W_T) + (S^* W_S) +(C^* W_C)\}/100\ ]^*10$$

The expression is being multiplied by 10 because we need to gauge the PECI values on a ten point scale ranging from 0 equals to “least complex” to 10 equals to “highly complex”[38]. This scale has been devised for the comparison of degree of complexity between the two or more projects. The derivation of this index assumes that this is a linear and additive model and no multicollinearity among the complexity factors validates this assumption.

Data Collection and Data Analysis

A questionnaire survey was conducted to collect data from already completed projects. Quota sampling was used with separate stratum defined for all three types of completed projects. Sample size for each quota was calculated by taking 5% of population for the three categories of projects. Population size of R projects, I projects and O projects was 100, 119 and 174 respectively (total 393). 5% of 100 equals to 5 R projects, 5% of 119 equals to 6 I projects and 5% of 174 equals to 9 O projects.

Among the participants, 75% were project managers, 10.1% project directors, 6.7% assistant directors, 4.7% senior managers and 0.7% directors, project officers, executive directors, general managers and project architects. 56.4% worked in public sector organizations and 43.0% in private sector organizations. 52% of the respondents had 11-15 years of professional experience, 37% had 6-10 years and only 17% of the respondents had 16-20 years of professional experience.

A total of 393 questionnaires along with the consent forms were sent to different project managers through email. 183 responded (47% response rate) and showed the willingness to participate in the research by returning the signed consent forms. All the project managers were approached. 165 project managers out of 183 gave the audience (42% response rate) and allowed to physically visit them for the questionnaires. Out of 165 questionnaires 16 incomplete responses (having 50% or more missing data) were discarded. In total, 149 questionnaires

Table 2. Weightage selection table for priority 1-time 2-scope 3-cost

The weightage selection table for priority 123, i.e., 1-time complexity, 2-scope complexity and 3-cost complexity								
Weightages								
1-Time	17	16	15	14	13	12	11	10
2-Scope	2	3	4	5	6	7	8	9
3-Cost	1	1	1	1	1	1	1	1
Weightages								
1-Time	15	14	13	12	11	10	9	
2-Scope	3	4	5	6	7	8	9	
3-Cost	2	2	2	2	2	2	2	
Weightages								
1-Time	13	12	11	10	9			
2-Scope	4	5	6	7	8			
3-Cost	3	3	3	3	3			
Weightages								
1-Time	11	10	9					
2-Scope	5	6	7					
3-Cost	4	4	4					
Weightages								
1-Time	8							
2-Scope	7							
3-Cost	5							

were selected with the acceptance rate of 90.3%. This sample includes already completed or finished projects. 44 R projects, 75 I projects and 30 O projects were taken into account for the construction of PECI, which meets the required sample size.

Development Methodology for Calculation of Indices; PECI(R), PECI(I) and PECI(O)

As hypothesized, it was expected that the collected data would represent variations in complexity between R, I and O projects in the order from high to low. Based on technological uncertainty and other complexity enhancing factors, R projects are likely to have much larger range of complexity and thus a complete scale of 0 to 10 has been assigned to them. On the other hand, I projects traditionally have lesser variation in technology and thus have lesser uncertainty[28]. Therefore, the ranges for indexing these projects have been allotted two third space in the range of 0-10, i.e. from 0-6.66.

However, for the sake of simplicity and comparison

Table 3. Tests of normality for Infrastructure Projects

	Kolmogorov-Smirnova			**Shapiro-Wilk**		
	Statistic	**Df**	**Significant.**	**Statistic**	**Df**	**Significant**
PECI for Infrastructure Projects	0.099	75	0.063	0.978	75	0.226
PECI for R&D Projects	0.150	44	0.014	0.929	44	0.010
PECI for Other Projects	0.173	30	0.023	0.945	30	0.049

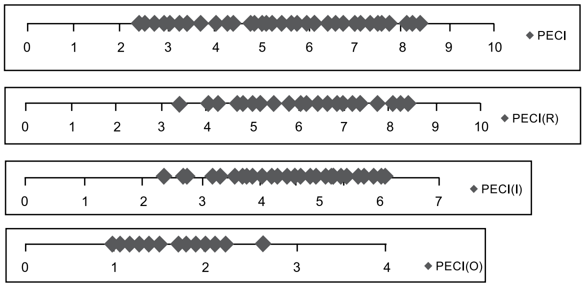

Figure 2. The comparison scales for PECI, PECI(R), PECI(I) AND PECI(O)

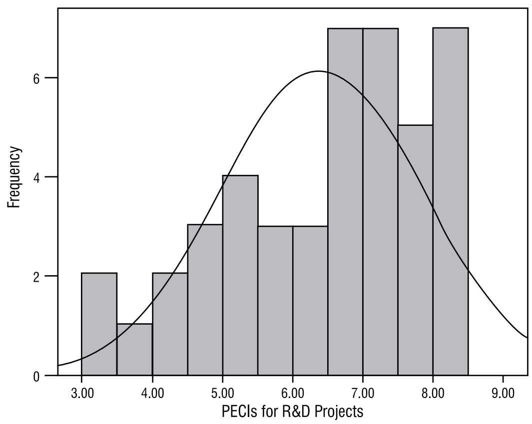

Figure 3. (a) Histogram of PECIs for R&D/Technology Projects

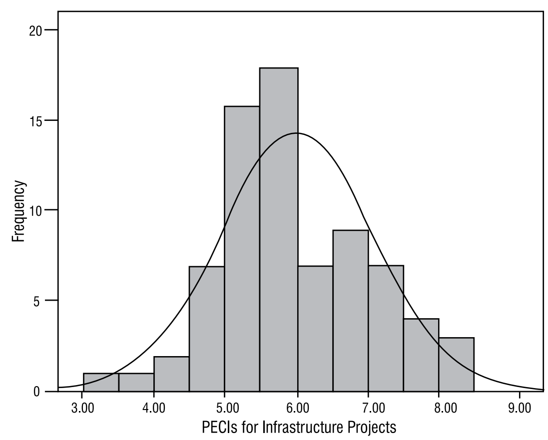

Figure 3. (b) Histogram of PECIs for Infrastructure Development Projects

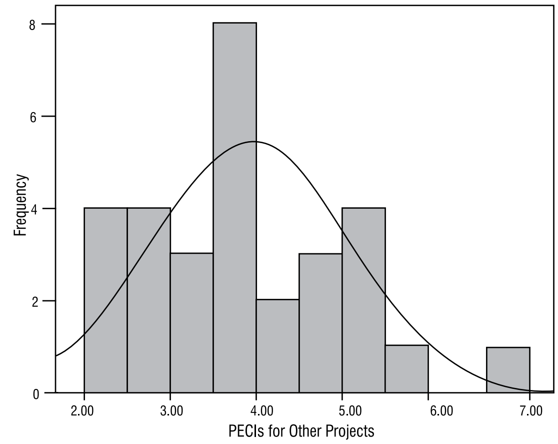

Figure 3. (c) Histogram of PECIs for Other Projects

Figure 3. Comparison of PECIs for three categories of projects

The proposed complexity scale will let the project owners and contractors to identify the difficulty or ease of execution of the project by identifying and then controlling the escalation of complexity. Moreover, the project managers may spot the factors which are escalating the complexities in their projects and hence, may modify them or choose alternative methodology with lesser complexity during the early stages of project planning. Furthermore, contractors of the projects will use these indices to tackle the problems in completing the projects on time and within budget and demand compensation for the added complexity in execution. Owners of the projects can use these indices to evaluate the uncertainties of completion on time and in budget well before the completion of the project and hence, opt for new goals.

PECI is the first multidisciplinary index which exhaustively measures the complexities of all types of projects grouped into various categories. This index is novel and more comprehensive in its scope than the other past attempts of similar nature. This index has the advantage of being composed of almost all the complexity enhancing factors which have been identified before by some of the academicians in the field of project management. Though the methodology used to develop this index may be refined in future, its approach is innovative because it allows the user to assign weightages (from the wide range of selection options) of their own choice, to three constraints of projects (time, scope and cost). This index purposes, it has been enhanced to 7 rather than 6.66.

In case of O projects, which include social sector projects, such as, planning and executing a campaign, arranging a festival, etc., the scope complexity is relatively lesser even if technological uncertainty is high as compared to I projects. Therefore, out of full range of 0-10, only one third from 0-3.33 has been allocated to O projects. But for the purpose of simplicity and comparison, it has been further modified to 0-4.

Hypothesis Testing and Discussion of Results

The values of PECI, PECI(R), PECI(I) and PECI(O) have been computed for 149 projects. As illustrated in Figure 2. PECI values of all the projects are marked on a scale from 0-10, PECI(R) from 0-10 (same scale), PECI(I) from 0-7 and PECI(O) from 0-4.

Histograms have been plotted in order to analyze the general trend of projects for the three indices as illustrated in Figure 3(a-c).

- "R" projects are negatively skewed because higher PECI values are more in number and hence making a tail towards left side of the histogram. Mean i.e. 6.4180 is less than the Median i.e., 6.7450 and value of skewness is negative i.e. -0.653.

- "O" projects are positively skewed because lower PECI values are more in number and hence making a tail towards right side of the histogram. Mean i.e. 3.9310 is greater than the Median i.e. 3.7650 and value of skewness is positive i.e. 0.584.

- "I" projects have normal distribution because Mean i.e. 5.9227 is almost equal to the Median i.e. 5.7300 indicating the normal distribution. For dataset smaller than 2000 elements, Shapiro-Wilk test is performed to check the normality of data as indicated in Table 3. Any value greater than 0.05 indicates normal distribution. For I projects, its value is 0.239 which is greater than 0.05. This is also obvious that data for R and O projects is not normal i.e. Shapiro-Wilk values are 0.011 and 0.049 which are less than 0.05.

The minimum PECI value for R projects is 3.38 and maximum is 8.31, minimum value for I projects is 2.11 and maximum is 5.89 and minimum value for O projects is 0.94 and maximum value is 2.63. Considering these values and their depiction on the comparing scales as shown in Figure 2, it may be concluded that generally R projects are more complex than I projects and I projects are more complex than O projects. The same has also been supported by the histograms in Figure 3(a-c). Hence, the results support both the hypotheses, i.e. H1 and H2 and verified the comparative categorization of projects as postulated earlier in this study.

CONCLUSIONS

The real complexities actually accrue when the planning of the project is completed and the execution of the project begins. The project execution entails resolving many uncertainties in processes, methodology, resource allocation, configuration management, integration, quantification and user acceptance process of a project. However, before a solution to managing complexity can be defined, it was very important to develop a measuring scale for it. Previous researchers have come up with a big list of factors which are contributing towards the complexity of projects, but no significant research work has followed to quantify these factors and develop a sum total effect of all important factors on complexity of projects. All of these factors are multi-dimensional and associate uncertainties with them. Some projects are more complex than others, but mostly, stakeholders just look at the projects from the perspective of time and cost. Projects overshoot time and cost regularly. There is a need to find which projects may overshoot and how much they may. A well-defined Complexity Index may provide answers to many of these questions. The dilemma of finding complexity is closely associated with measuring complexity and defining a universally acceptable index for it for different categories of projects. A gap also exists in defining complexity for all phases of projects rather than planning alone, as was the trend previously, where researchers were mostly contemplating complexity in the planning phases. Therefore, quantitative research in the field of project complexity was obligatory in order to measure the severity of each factor on complexity. It is extremely important that widely acceptable measurement methodologies and scales can be agreed upon so that performance expectations can be rationalized and tolerances can be adjusted depending upon the extent and nature of complexity of projects.

is not specific to any particular area and may be generalized and implemented to any project undertaken in any country. However, the users of these indices should be aware of the potential benefits of its application in order to achieve the best results.

FUTURE RESEARCH

Researchers have considered various factors affecting the complexity of projects. A few more factors (items) have been incorporated in this study considering the division of projects into various categories and constraints. These factors have been added based on previous literature and the authors' experiences. However, the diversity of project types and constraints experienced by various project managers may add more factors which may affect the PECI to some extent. However, due to the number of factors already considered, this may not significantly change the index quantitatively.

The following points may be considered for future research:

(i) The PECI calculated in this research is generic to countries and industries but due to the prevailing regulations, standards and practices, various countries may have dissimilar factors affecting the complexity of projects. Therefore, the countries can further be categorized in developed and developing countries for calculation of PECI. Different questionnaires can also be developed to establish PECIs for these categories of the countries which would relate closely to the veracities of projects in those countries. Researchers may further this research by categorizing the PECIs for different groups of countries.

(ii) This research combines the factors of time, scope and cost to calculate the indices. It will be very useful if this research is used to develop individual complexity indices for the factors of time, scope and cost.

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REFERNCES

1. *Sinha, S., Kumar, B., and Thomson, A., 2006. "Measuring Project Complexity: A Project Manager's Tool". Architecture Engineering and Design Management 2:187-202.*

2. *Qureshi, S.M., and Kang, C., 2015. "Analysing the Organizational Factors of Project Complexity Using Structural Equation Modeling". International Journal of Project Management 33:65-176.*

3. *Baccarini, D., 1996. "The Concept of Project Complexity - A Review". International Journal of Project Management 14:201-204.*

4. *Bosch-Rekveldt, M., Jongkind, Y., Mooi, H., Bakker, H., and Verbraeck, A., 2011. "Grasping Project Complexity in Large Engineering Projects: The TOE (Technical, Organizational and Environmental) Framework". International Journal of Project Management 29:728–739.*

5. *Nguyen, A.T., Nguyen, L.D., Le-Hoai, L. and Dang, C.N., 2015. "Quantifying the Complexity of Transportation Projects using the Fuzzy Analytic Hierarchy Process". International Journal of Project Management 33:1364-1376.*

6. *Vidal, L.A., and Marle, F., 2008. "Understanding Project Complexity: Implications on Project Management". Kybernetes, 37:1094-1110.*

7. *Williams, T.M., 1999. "The Need for New Paradigms for Complex Projects". International Journal of Project Management 17:269-273.*

8. *Jaafari, A., 2003. "Project Management in the Age of Complexity and Change". Project Management Journal 34:47-57.*

9. *Maylor, H., Vidgen, R., and Carver, S., 2008. "Managerial Complexity in Project Based Operations: a Grounded Model and its Implications for Practice".*

Project Management Journal 39:15-26.

10. *Nassar, K.M., and Hegab, M.Y., 2006. "Developing a Complexity Measure for Schedules", Journal of Construction Engineering and Management 132:554–561.*

11. *Badiru, A.B., 1988. "Towards the Standardization of Performance Measures for Project Scheduling Heuristics". IEEE Transactions on Engineering Management 35:82-89.*

12. *He, Q., Luo, L., Hu, Y., and Chan, A.P., 2015. "Measuring the Complexity of Mega Construction Projects in China - A Fuzzy Analytic Network Process Analysis". International Journal of Project Management 33:549-563.*

13. *Lu, Y., Luo, L., Wang, H., Le, Y., and Shi, Q., 2015. "Measurement Model of Project Complexity for Large-Scale Projects from Task and Organization Perspective". International Journal of Project Management 33:610–22.*

14. *Pich, M., Loch, C.H., and De Meyer, A., 2002. "On Uncertainty, Ambiguity, and Complexity in Project Management". Management Science 48:1008-1023.*

15. *Tatikonda, M.V., and Rosenthal, S.R., 2000. "Technology Novelty, Project Complexity, and Product Development Project Execution Success: A Deeper Look at Task Uncertainty in Product Innovation". IEEE Transactions on Engineering Management 47:74-87.*

16. *Whitty, S.J., and Maylor, H., 2009. "And then Came Complex Project Management (Revised)". International Journal of Project Management 27:304–310.*

17. *Xia, B., and Chan, A.P., 2012."Measuring Complexity for Building Projects: A Delphi Study". Engineering, Construction and Architectural Management 19:7-24.*

18. *Project Management Institute, 2013."A Guide to the Project Management Body of Knowledge Guide", 5th Edition, Newtown Square.*

19. *Geraldi, J., Maylor, H., and Williams, T., 2011. "Now, Let's Make it Really Complex (Complicated): A Systematic Review of the Complexities of Projects". International Journal of Operations & Production Management 31:966-990.*

20. *Xia, W., and Lee, G., 2004. "Grasping the Complexity of IS Development Projects". Communications of the ACM 47:68-74.*

21. *Ribbers, P.M.A., and Schoo, K.C., 2002. "Program Management and Complexity of ERP Implementations". Engineering Management Journal 14:45-52.*

22. *Williams, T.M., 2005. "Assessing and Moving on from the Dominant Project Management Discourse in the Light of Project Overruns". IEEE Transactions on Engineering Management 52:497-508.*

23. *Dvir, D., and Shenhar, A., 1998. "In Search of Project Classification: A Non-Universal Approach to Project Success Factors". Research Policy 27:915-935.*

24. *Remington, K., and Pollack, J., 2007. "Tools for Complex Project", Gower Publishing Company, Aldershott, UK.*

25. *Boushaala, A.A., 2010. "Project Complexity Indices based on Topology Features". World Academy of Science, Engineering and Technology 69:49-54.*

26. *Vidal, L.A., Marle, F., and Bocquet, J.C., 2011. "Using a Delphi Process and the Analytic Hierarchy Process (AHP) to Evaluate the Complexity of Projects". Expert Systems with Applications 38:5388–5405.*

27. *Pinto, J.K., and Covin, J.G., 1989. "Critical Factors in Project Implementation: A Comparison of Construction and R&D Projects". Technovation 9:49-62.*

28. *Shenhar, A.J., 2001. "One Size Does Not Fit All Projects: Exploring Classical Contingency Domains". Management Science 47:394–414.*

29. *Müller, R., and Turner, J.R., 2007. "Matching the Project Manager's Leadership Style to Project*

Type". International Journal of Project Management, 25:21-32.

30. *Williams, T.M., 2002. "Modelling Complex Projects", John Wiley & Sons, Chichester.*

31. *DeVellis, R.F., 2012. "Scale Development: Theory and Applications", Sage Publications, Volume 26.*

32. *Netemeyer, R.G., Bearden, W.O., and Sharma, S., 2003. "Scaling Procedures: Issues and Applications", Sage Publications, London.*

33. *Diamantopoulos, A., and Winklhofer, H.M., 2001. "Index Construction with Formative Indicators: An Alternative to Scale Development". Journal of Marketing Research 38:259-277.*

34. *Diamantopoulos, A., Riefler, P., and Roth, K.P., 2008. "Advancing Formative Measurement Models". Journal of Business Research 61:1203–1218.*

35. *Diamantopoulos, A., and Siguaw, J.A., 2006. "Formative Versus Reflective Indicators in Organizational Measure Development: A Comparison and Empirical Illustration". British Journal of Management 17:263-282.*

36. *Helm, S., 2005. "Designing a Formative Measure for Corporate Reputation". Corporate Reputation Review 8:95–109.*

37. *Witt, P., and Rode, V., 2005. "Corporate Brand Building in Start-Ups". Journal of Enterprising Culture 13:273-294.*

38. *Little, T., 2005. "Context-Adaptive Agility: Managing Complexity and Uncertainty", IEEE Software 22:28–35.*

39. *Kennedy, P.A., 2003. "Guide to Econometrics", 5th Edition, MIT Press, Boston.*