Identifying and measuring project complexity

Bac Daoa*, Sharareh Kermanshachi, Jennifer Shanel, Stuart Andersona, Eric Hareb

aTexas A&M University, 3136 TAMU College Station, TX 77843-3136, USA
bIowa State University, 498 Town Engineering, Ames, IA 50011, USA

Abstract

This study provides a constructive approach to identify and assess project complexity as a separate factor influencing projects. Project complexity was described in terms of managing projects rather than project physical features to ensure the research results can be generalized across different industries. The complexity attributes and indicators deemed to measure those associated attributes were developed. The data collected through a survey was analyzed using statistical methods to test the significance of complexity indicators in differentiating low complexity projects from high complexity projects. The data analysis resulted in 37 complexity indicators associated with 23 attributes statistically significant to project complexity. The research findings help scholars and practitioners in the project management field in developing an appropriate strategy to manage project complexity effectively.

Keywords: Project Complexity; Complexity Attribute; Complexity Indicator; Project Management

1. Instruction

Project complexity is frequently perceived as a factor imbedded in two major project aspects including project difficulty (how hard the project is to achieve project objectives) and project risks (uncertainties). These two major factors largely influence how a project is managed and executed. However, project difficulty is basically related to project team’s expertise and experience, and project risks are used to describe the unknown features of project.
Whereas, project complexity is generated from known factors that can have additional impacts on projects. Additionally, project complexity typically begets project difficulty, which in turn makes the project harder to complete and requires special effort to keep project risks in check. It is important to acknowledge that difficult project objectives, such as a compressed construction schedule or critical resource shortages, may actually cause a project team to choose methods that are more complex to achieve aggressive project goals. At this point complexity and risk are observed to diverge; that is, the project team can purposely increase the complexity of a project in the form of re-sequenced work, alternate partnerships, different procurement strategies, multi-sourcing of materials, and increased staff or craft levels with little to no impact to the overall project risk profile. Increased complexity is managed by maintaining positive control of new project interfaces. In fact, some risks can be mitigated as a result of the more complex approach. Since complexity and risk can track independent of each other, they can only be categorized as two different properties within a project.

It is necessary to study complexity as a separate factor influencing projects. This includes a need to define project complexity, study the individual and most important attributes of complexity, and identify the indicators that truly reflect complexity of a project. Most attributes of complexity are known to be constantly changing variables such as project type, project size, project location, project team experience, interfaces within a project, logistics/market conditions, geo-political and social issues, and permitting and approvals. Better understanding of project complexity in any phase of the project development process and creating a strategy to manage complexity, influences how efficiently and economically projects are planned, managed, executed.

2. Literature Review

Complexity theory generally defines what a complex system is within a specific area of interest (e.g., natural, biology, eco-system, computer science, human society, or financial market, etc.) and studies the interaction between the elements in that system. The existing theoretical issue of complexity theory is that there is still no commonly accepted definition of complexity, despite there being a large number proposed [2]. As defined by Valle [8], a complex system is a whole that consists of several elements interacting with each other in many different ways. Numerous interdependent elements in a complex system continuously interact and spontaneously organize and reorganize themselves into increasingly elaborate structures over time.

Scholars have focused on the identification of complexity attributes more than any other topic in the field of project complexity. Studies in this area have evolved significantly over the past twenty years. Cicmil et al. [5] identified complexity as a factor that helps determine planning and control practices, hinders the identification of goals and objectives, or a factor that influences time, cost, and quality of a project. Baccarini [1] identified two major attributes of complexity: 1) organizational complexity; and 2) technical complexity. Organizational complexity reflects the view that a project is a task containing many interdependent elements. Technical complexity deals with complexity related to the transformation processes, which convert inputs into outputs. Gidado [7] defined project complexity and identified the factors that influence its effect on project success. Also, the study proposes an approach that measures the complexity of the production process in construction.

Global Alliance for Project Performance Standards (GAPPS) [6] developed a project manager standard in 2007. As a major section of the project performance standard, GAPPS developed a comprehensive project management complexity measurement tool called CIFTER. The Crawford-Ishikura Factor Table for Evaluating Roles (CIFTER) provides a seven-factor model from which project management complexity of projects is assessed. A total project complexity score is created by adding the scores from all seven factors outlined in the CIFTER. The total CIFTER score is used to categorize each project as either below Global Level 1 (scores less than 12), Global Level 1 (scores 12 to 18) or Global Level 2 (score 19 or more). Each of the seven factors in the CIFTER is rated on a point scale of one to four with the total number of points across the seven factors determining whether a project is Global 1, Global 2, or neither.

Generally, several definitions of complexity were found from a wide range of disciplines. However, there is still no widely accepted definition of project complexity used by complexity scholars. While a fair number of papers and books were found around different methods of measuring complexity, it seems that very few scholars have studied project complexity as a separate factor influencing project characteristics in the project management field. A detailed
description of project complexity and complexity attributes may help researchers understand project complexity and
manage it properly.

3. Definition of Project Complexity

One of the difficulties in addressing the topic of project complexity is that the term was broadly and intuitively
applied. Without a standard definition, complexity tends to be a catch-all category that is used when project results
are unpredictable, when a project has many interacting parts, when details of a project are poorly understood, or for
a myriad of other project conditions outside of what is typically perceived as “normal.” Project professionals and
teams have an intuitive sense of when a project is complex, but the reasons for that complexity may be widely
varied and depend on that person’s or project team’s experiences, resource availability, stakeholder considerations,
and many other factors, both objective and subjective. Additionally, the perception of complexity can be
compounded by multiple project factors, which if not managed effectively may have a negative impact on the
project outcome. To address these issues, project complexity is described not in terms of a project’s physical
features (e.g., types of materials, quantities of materials, number of systems, and facility technology) but rather
complexity related to managing projects (e.g., internal project team interfaces, site logistics, permitting, etc.). This
was necessary to ensure that the research results could be generalized across construction industry sectors and within
a construction industry sector with different types of projects.

After a substantial consideration, project complexity was defined as follows: “Project complexity is the degree of
interrelatedness between project attributes and interfaces, and their consequential impact on predictability and
functionality” [3]. This definition attempts to capture the essence of how project attributes, such as project scope,
team organizational dynamics, project location, policies and regulations, unfamiliar technologies, and workforce
skill sets, interact both within a project and with entities outside of the project. Without targeted strategies to manage
complexity, the project’s outcome may be negatively impacted. With proper management strategies in place to
control a diverse set of project attributes and associated interfaces that lead to increased project complexity, the
probability that projects can be both successful and predictable is increased.

4. Complexity Attribute and Indicator

The term “complexity attribute” was used to represent the factors that describe project complexity. Fifty major
complexity attributes were initially identified using complexity theory variables, the literature review results, and
industry experience. The ranking process ultimately resulted in a reduced list of thirty-five complexity attributes.
The complexity attributes were then grouped into categories to aid in understanding the general nature of the
attributes. Eleven categories were proposed including: 1) Stakeholder Management; 2) Project Governance; 3)
Legal; 4) Fiscal Planning; 5) Interfaces; 6) Scope Definition; 7) Location; 8) Design and Technology; 9) Project
Resources; 10) Quality; and 11) Execution Targets. A category can have a number of different complexity
attributes. Table 1 presents an example of two out of eleven categories and associated complexity attributes

<table>
<thead>
<tr>
<th>Category</th>
<th>No</th>
<th>Attribute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stakeholder Management</td>
<td>1</td>
<td>Clarity of business objectives</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Level of stakeholder cohesion</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Public profile</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Social and political influences surrounding project location</td>
</tr>
<tr>
<td>Legal</td>
<td>5</td>
<td>Legal</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Permitting and regulatory requirements</td>
</tr>
</tbody>
</table>

The identified complexity attributes were used to develop the complexity indicators thought to measure the
associated attributes. Each attribute-measuring indicator was then converted to one question for data collection
purpose. 92 complexity indicators were finally identified to measure the 35 associated complexity attributes. Fig. 1 presents the complexity measurement hierarchy for a single category.

![Diagram of Complexity Measurement Hierarchy](image)

**Fig. 1. Complexity Measurement Hierarchy.**

5. Data Collection

After developing the project complexity definition and identifying the complexity attributes and the complexity indicators used to measure each associated attribute, the data collection process was implemented to collect the data that was usable to test the proposed hypothesis and to determine which indicators were really functioning as the measures of project complexity. When considering different data collection approaches, the intent of the data collection, the type of data collected, possible analysis processes, sample sizes, interpretation, and advantages/disadvantages of the approach to derive a set of survey questions were taken into account. The questions used to collect the data were based on the developed complexity indicators central to the measurement of complexity attributes.

The data was collected through a survey to test the relevant hypothesis. Data analysis helped in confirming the definition of complexity including theoretical concepts and complexity’s attributes, determining different levels of complexity, and providing the basis for assessing the impact of project complexity on the use of best practices. To support the survey, different ways of categorizing the level of complexity based on the proposed complexity definition were described. Project Complexity Metrics consisted of 73 questions that required total 92 responses. These 92 responses were used to collect data for 92 developed complexity indicators that measure 35 associated complexity attributes. The intent of the survey was to assess the different complexity indicators based on responses between low complexity projects and high complexity projects. Differences had to be statistically significant to argue that the indicator was a true reflection of project complexity. The survey process was conducted online. The survey transmittal memorandum, survey instructions, and questionnaire were uploaded to the CII online survey system and sent to CII company members. The questionnaire was sent to 140 CII company members to collect data. After two months of conducting the online survey with an intensive follow-up effort to the survey respondents, the researchers received total 44 survey responses. These 44 survey responses represented for the data of 44 historical projects including 30 high complexity projects and 14 low complexity projects. The collected data was cleaned up and then used for the data analysis process.

6. Data Analysis

Since project complexity was measured by different indicators that describe the associated attributes, the statistical analysis was implemented to determine which indicators should be considered as significant and best reflect project complexity. In other words, testing which indicators were statistically significant in differentiating between low complexity projects and high complexity projects helped understand which indicators have an important contribution to describing a project’s complexity.

6.1. Exploratory Statistics

Exploratory statistics in this research were graphical displays including boxplots and bar-chart graphics to visualize the data. Side-by-side boxplots were used whenever the data were counts, dollars, or other numerical...
values. The boxplots illustrated the distribution of the data, indicating minimum and maximum values, first quartile and third quartile, and median. Bar charts were used to describe both likert (seven-point scale) and binary (Yes/No) type data.

6.2. Inferential Statistics

For inferential statistics, depending on the type of data produced from the survey, the methods of analysis varied. This was due to the fact that there are different assumptions and limitations to the statistical analysis tests. Specifically, Two-Sample T-Test was used where the response was a count or numerical value; Kruskal-Wallis/Wilcoxon Test was used for likert data where it could not necessarily be assumed that the data follows a normal distribution; and Chi-Squared Test was used for survey questions with binary responses (“Yes” and “No”). Table 2 summarizes the basic formal statistical methods that were used for data analysis in this research.

Table 2. Statistical Analysis Methods

<table>
<thead>
<tr>
<th>Statistical Test</th>
<th>Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two-Sample T-Test (Adjusted R-Squared): This test was used where the response is a count or numerical value.</td>
<td>Null Hypothesis: The means for high complexity projects and low complexity projects are the same. Alternative Hypothesis: The means for high complexity projects and low complexity projects are different.</td>
</tr>
<tr>
<td>Kruskal-Wallis/Wilcoxon Test: This test was used for liker data (ordinal seven-point scale), where it could not necessarily be assumed that the data follows a normal distribution.</td>
<td>Null Hypothesis: The probability that median of high-complexity projects is greater than median of low-complexity projects on this question is 0.5 (The distributions are the same). Alternative Hypothesis: The probability that median of high-complexity projects is greater than median of low-complexity projects on this question is not equal to 0.5 (The distributions are not the same).</td>
</tr>
<tr>
<td>Chi-Squared Test: This test was used for survey questions with binary responses (“Yes” or “No” response).</td>
<td>Null Hypothesis: The observed frequencies of “Yes” and “No” for high complexity projects are not different from those for low complexity projects. Alternative Hypothesis: The observed frequencies of “Yes” and “No” for high complexity projects are different from those for low complexity projects.</td>
</tr>
</tbody>
</table>

To run the analysis, the Survey Visualization Tool program was used for the statistical approaches. The survey data was initially cleaned up, coded, and then input into the program. The data analysis results were generated regarding the different methods of testing.

7. Research Result and Discussion

The primary goal of this research was to develop a methodology to fully explore and assess project complexity by identifying the complexity indicators used to describe and measure project complexity. In other words, the complexity indicators that were significant in differentiating low complexity projects from high complexity projects need to be identified and tested. The significance level of 0.05 (\(\alpha=0.05\)) was initially chosen to test the significance of each complexity indicator in differentiating low complexity projects from high complexity projects. Twenty-four out of 92 complexity indicators were found significant with the significance level of 0.05 as a result of the analysis. This result was then reviewed with industry perspective. The reviewing of initial analysis result revealed that all aspects of project complexity were not sufficiently described by these twenty-four complexity indicators. Based on industry experience and discussion, several other complexity indicators that had p-values close to 0.05 were important in measuring project complexity and should be included in the list. The significance level was ultimately increased from 0.05 up to 0.1.

With the significance level of 0.1 (\(\alpha=0.1\)), there were 36 complexity indicators (CIs) belonging to 22 complexity attributes that were statistically significant in differentiating low complexity projects from high complexity projects (the indicators that have p-value not greater than 0.1). This result was reviewed again. There were three CIs that
were not statistically significant (p-values greater than 0.1) but important in measuring complexity. These three complexity indicators were then added to the list based on discussion and industry experience after reviewing the analysis result and data supporting the results. Among those 36 statistically significant indicators, there were two indicators that had high correlations with two other indicators. Statistically, two or more highly correlated indicators may measure the same characteristic of project complexity. As a result, those two indicators were excluded from the significant indicator list. Ultimately, a list of 37 complexity indicators that measure 23 complexity attributes was finalized. Table 3 present example of the significant complexity indicators and the associated complexity attributes for two categories. These 37 indicators were considered as the true measures of project complexity.

Table 3. Example of Significant Complexity Indicators

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Complexity Indicator (CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stakeholder Management:</strong></td>
<td></td>
</tr>
<tr>
<td>1. Strategic importance of the</td>
<td>CI-1_Influence of this project on the organization’s overall success (e.g., profitability,</td>
</tr>
<tr>
<td>project</td>
<td>growth, future industry position, public visibility, and internal strategic alignment).</td>
</tr>
<tr>
<td>2. Project impact of local social and political groups (stakeholders)</td>
<td>CI-2_Impact of required approvals from external stakeholders on the original project execution plan.</td>
</tr>
<tr>
<td></td>
<td>CI-3_Impact of required inspection by external (regulatory) agencies/entities on original project execution plan.</td>
</tr>
<tr>
<td><strong>Legal:</strong></td>
<td></td>
</tr>
<tr>
<td>9. Permitting and regulatory</td>
<td>CI-10_Number of total permits to be required.</td>
</tr>
<tr>
<td>requirements</td>
<td>CI-11_Level of difficulty in obtaining permits.</td>
</tr>
<tr>
<td></td>
<td>CI-12_Difficulty in obtaining design approvals.</td>
</tr>
<tr>
<td>10. Legal</td>
<td>CI-13_Impact of external agencies on the project execution plan.</td>
</tr>
</tbody>
</table>

The 37 complexity indicators associated with 23 complexity attributes resulted from the analysis are significant in differentiating low complexity projects from high complexity projects. These indicators can be used to describe and measure complexity of a project. This finding assists researchers and practitioners in identifying blind spots embedded in the project development process, and then developing an appropriate management strategy to deal with project complexity. Implementing proper management strategies relevant to the identified complexity indicators helps organizations in reducing the likelihood that the associated attributes will cause poor project performance.

8. Conclusion

The research proposed a constructive way to assess and measure aspects of project complexity. The root contributors to complexity of projects defined as complexity indicators were identified, and the descriptions of those contributors from the perspective of complexity theory and complexity management were obtained to describe project complexity. In this manner, the research made a contribution to enrichting the theoretical basis in the field of project management. The degree of project complexity was determined by identifying and measuring the complexity indicators. This process helps project participants develop their competencies in managing complex projects in different industry sectors. Moreover, it will lead to some suggestions for project management scholars and practitioners to leverage the positive impacts and reduce negative impacts of project complexity to manage projects in an effective way.

Acknowledgements

The study described in this paper was supported by the Construction Industry Institute (CII RT 305 Research Project). This paper forms a part of the research project titled “Measuring Project Complexity and Its Impact”, from which other deliverables have been produced with common background and methodology. The authors also
acknowledge the contributions of other CII RT 305 Research Team members for providing significant inputs to complete this study.

References