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Managing Mega-Project Complexity in Five Dimensions

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Abstract: Traditional project management theory is based on a three-dimensional life cycle approach where the project managerseeks to optimize the dimensions of cost-schedule-technical (quality or design). This paper reports the findings of a case study analysis of two complex mega-projects in Michigan which confirm the findings of previous research and illustrates the use of a framework for five-dimensional project management (5DPM) that is for conceptualizing a complex project's scope of work. The framework elevates the recognition that the project's social/political context and the financial arrangements create complexity adding two new dimensions. This paper also demonstrates a methodology to graphically display a project's complexity to better understand and prioritize the available resources. The result is a "complexity footprint" that may help a complex project manager identify the boundary between controllable and uncontrollable projects impacts. The paper finds that applying 5DPM to the two case study projects has given the project delivery team a tool which is actually adding value to the complex project management process.

Keywords: Complexity; project management; mega-project; infrastructure

I. INTRODUCTION

A. *Defining Complexity*

The College of Complex Project Managers (CCPM) in Australia was established to provide an institution where the emerging field of complex project management could be advanced. It maintains that complex project management is "an emerging natural extension of traditional project management to create a specialist profession…" [1]. Complex projects are differentiated from routine projects due the "… degree of disorder, instability, emergence, non-linearity, recursiveness, uncertainty, irregularity and randomness" found in complex projects. Recent research in the US measured a dynamic complexity stimulated by the quantity of interaction among those facets found during project delivery that are outside the direct control of the project manager [2]. Complex projects also give rise to a high level of "uncertainty about what the objectives are, and/or high uncertainty in how to implement the objectives" [1].

The term "Major Projects" is employed by the United States Federal Highway Administration (FHWA) to characterize projects with a "high level of public or congressional interest; are unusually complex; have extraordinary implications for the national transportation system; or are likely to exceed $500 million in total cost." [3]. Major projects are required to prepare a formal Project Management Plan (PMP) as a precursor to receiving federal funding [3]. The PMP has been found to be a valuable tool for inventorying the aspects of a project that must be carefully managed to achieve successful project delivery.

Unfortunately, the FHWA emphasis on projects greater than $500 million causes US agencies to associate the term "complex project" only with large mega-projects [4]. Research on the topic has shown that project complexity is relative to not only size and scope but also the past experience of the project management team [5]. The CCPM [1] maintains that "the level of uncertainty [i.e. complexity] will vary with the maturity of the individual/organization." Thus, it is the amount of uncertainty that exists in the project that is beyond the project manager's control that makes it complex. While size certainly contributes to complexity, it is not the sole parameter that defines whether or not a given project is complex [6].

B. *Defining a "Mega-Project"*

Capka [4] describes mega-projects as multimillion dollar projects requiring the management of numerous, concurrent, and complex activities constrained by aggressive delivery schedules and fixed budgets. The literature contains other definitions which classify mega-projects as "large scale complex projects that often fail to meet costs estimations, time schedules, and anticipated project outcomes" [7]. Van Marrewijk [8] defines mega-projects as those entailing a strong element of high risk technical innovation and exemplified by the potential for ambiguity and conflict between stakeholders. A paper by Haidar and Ellis [9] proposes that mega-projects be defined based on combination of size and complexity. This rubric measures size not by dollar value but by the constructed area and the time frame in which the project must be delivered. Complexity is split into a qualitative rating of design complexity and managerial complexity. Haidar and Ellis assert that "the meaning of complexity is subjective and it is in the eyes of the beholder" [9]. Taken together leads one to infer that there is no uniformly accepted definition for the term "mega-project" other than it is large and complex.

C. *Research Objective*

Given the above discussion, the objective of this paper is propose a framework with which to apply current principles of complex project management to large,

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complex infrastructure projects, hereafter referred to as mega-projects. The paper seeks to answer the following research questions:

- How can recently developed complex project management theories be used to manage complexity in mega-projects?
- How can complexity be measured?
- Can the measurement be used to track complexity change over time in mega-projects?

II. Five Dimensional Project Management

A. Measuring Dimensional Complexity in Mega-Projects

Recognizing complexity as composed of multiple dimensions was first proposed by Remington et.al.[10]. A dimension was defined as the "source characteristics of complexity." Therefore the analysis reported in this paper was organized to identify appropriate complexity dimensions for mega-projects by building on the three dimensions cited by Marshall and Rousey [11] for mega-projects and adding two more dimensions, context and financing, to specifically account for complexities found outside the traditional cost, schedule, and technical areas managed in routine projects [2].

Before mega-project complexity can be measured it must first be conceptualized. Joham et al. [12] found that complex mega-projects must be approached in a different structure than routine projects and stated that an "important and difficult part of project management is the conceptualization stage." They maintained that the quality of framework used to conceptualize the project "affects how well the project is defined and appropriately scoped." Since quantifying the mega-project's scope is the basis from project management activities are planned and executed, the paper goes on to opine that "the conceptualization stage can be seen as central to project management processes… particularly when dealing with multiple powerful stakeholders and 'messy' situations."

Joham et al. use the term "project scope" as the entirety of project requirements and constraints. The authors specifically recognizes project management process complexity induced by aspects that are outside the traditional three dimensions (cost, schedule, and technical) when they cite 'multiple powerful stakeholders' and 'messy' situations. Thomas and Mengel [13] describe the intersection of the controllable and uncontrollable activities in a project's scope as "the edge of chaos." Taken together, the studies cited above define this state as "complex project management."

1) Benchmarking Mega-Project Complexity

A recent study of managing complex transportation projects posited that degrees of complexity should be measured against the complexity found in routine projects [14]. The salient notion is that public agencies will have different levels of organizational maturity with regard to complex project management. Planning and executing a mega-project may in fact be routine for a large public agency such as the US Army Corps of Engineers where as many US state Departments of Transportation (DOT) have never been exposed to mega-projects. Thus, the benchmarking process is one that is highly dependent upon the experience of the organization that will deliver the mega-project.

The theory of five-dimensional project management (5DPM) seeks to organize project execution around those aspects with which the project manager has the least control and then allocate resources in a manner that addresses project complexities in a proactive manner by addressing uncertainty as early as practical in the project delivery process [2]. As a result, the benchmarking process is functionally an inventory of those project aspects that induce complexities that are not directly controllable by complex project's delivery team. ."

2) Mega-Project Complexity Mapping

The US FHWA is in the process of implementing 5DPM on 20 complex projects in 18 US states [15]. That initiative entails the iterative use of a complexity map for each complex project [2]. The process begins with a workshop where the complex project's delivery team assembles and is led through a standard process by facilitators trained in the implementation of 5DPM. The workshop results in an initial complexity map, which then acts as the benchmark for gauging how project complexity is changing over time. As the project development process proceeds, the team meets at major milestones and repeats the complexity mapping process to develop an updated complexity map.

III. Complex Mega-Project Case Study

A. Case Study Project Information

Two mega-projects worth over $2.3 billion from the Michigan DOT were selected for case study analysis. Both projects are freeway capacity expansion projects in the Detroit urban corridor. The projects and their salient background information are shown in Table I below.

TABLE I
Michigan Mega-Project Information

Area	I-75 Goals	I-94 Goals
Mobility	Maintain regional mobility for public users	Maintain regional mobility for freight users
Budget	Deliver for < $800 million	Deliver for < $1.5 billion
Schedule	Deliver in 4 years	Deliver in 4 years
Competition	Maximize local contractors' opportunities	Maximize local contractors' opportunities
Scope	• 17.7 miles reconstruction and widening; • Add one lane in each direction; • Replace 16 bridges; • Improve drainage	• 6.7 miles reconstruction and widening; • Add one lane in each direction; • Replace 10 bridges; • Add new service drive system on perimeter

The major factor contributing to the complexity of the two case study projects in Michigan was a political decision that the two projects must proceed in lockstep with each other: a typical example of how the context dimension can create complexity beyond the project

manager's control. The project team has met and rated complexity on three occasions.

1) I-75 Expansion Case Project

Table II contains the ratings assigned over that period of time for I-75. It also shows the calculated areas of the complexity maps for each project shown in Figures I. One can see that the complexity footprint for I-75 went up after the initial rating. This was because a local special interest group chose to try and block the project's funding and divert it to a rail transit project that the group favored. This also caused complexity to increase in the finance dimension.

TABLE II
MICHIGAN I-75 MEGA-PROJECT COMPLEXITY RATINGS

Dimension	I-75 Project		
	2012	**2013**	**2014**
Cost	60	60	60
Schedule	85	75	78
Technical	50	70	62
Context	80	85	80
Finance	70	80	75
Area	11,056	12958	11872

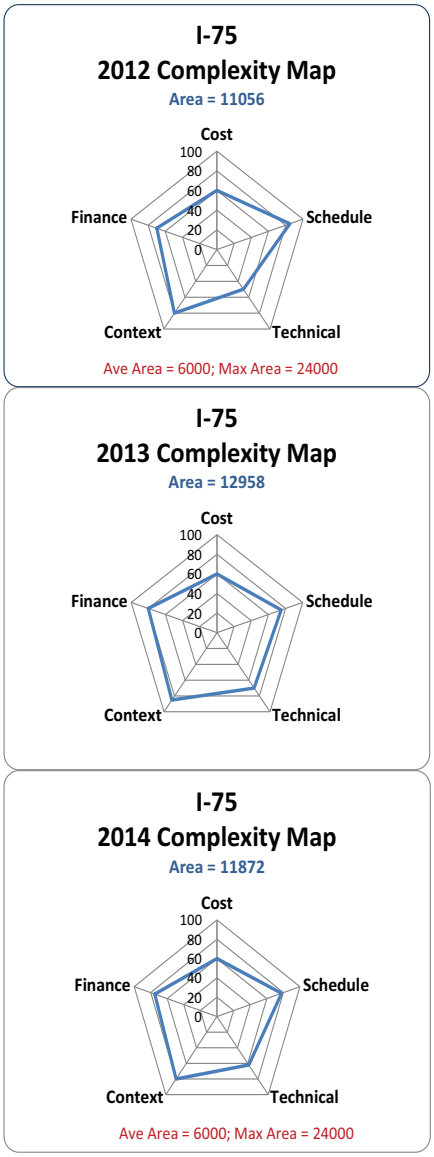

FIGURE I: MICHIGAN I-75 MEGA-PROJECT COMPLEXITY

The team then allocated resources to address the context issue by initiating a plan to "rebrand" the project from an "expansion" to "modernization" project. This neutralized the special interest group's assertion that expanding the interstate system in the urban central business district would merely increase congestion whereas light rail transit would take enough cars of the road that expansion would no longer be needed. At the 2014 meeting, the success of the rebranding initiative was evident in the decrease in perceived complexity in both dimensions shown in Table II.

2) I-94 Expansion Case Project

Table III contains the ratings assigned over that period of time for I-94. This project's complexity footprint decreased each period demonstrating that the project delivery team was effectively dealing with the various complexities in each dimension. Acquiring the necessary right of way was the most complex issue in the project and as a result the context dimension remained constant due the fact that right of way acquisition had not commenced.

TABLE III
MICHIGAN I-94 MEGA-PROJECT COMPLEXITY RATINGS

Dimension	I-94 Project		
	2012	**2013**	**2014**
Cost	80	70	70
Schedule	90	82	85
Technical	70	80	80
Context	100	100	100
Finance	89	85	75
Area	17419	16453	15811

This was also the more expensive of the two projects. Table III shows that both the cost and finance dimensions decreased over time. The issue at hand had to do with size of the project's projected budget. This would tie up a substantial amount of the Detroit Metro Region's available funding for the next decade, making it difficult to fund routine projects. The alternative was to divert funding from other regions to finance I-94, but that move would increase complexity in the context dimension because the citizens in rural areas kept a keen eye on the Michigan DOT's budget allocation formula to ensure that a fair share of available highway funding was being given to the low volume farm to market highway network.

The complexity in the cost and financing dimensions was reduced by deciding to change the planned High Occupancy Vehicle lanes to High Occupancy Toll lanes can generate new revenue to ease the constraints on financing. Additionally, the decision provides the DOT with a politically correct response to the rural concern about finance equity by showing that urban travellers must now pay extra for the project.

3) Case Study Summary and Analysis

The two case study projects clearly illustrate the difference in managing complex mega-projects and routine projects. In both cases, the high degree of dimensional interrelationships is vividly illustrated. The decision to couple the two complex projects has prevented the I-75 project from being advanced until the financing for I-94 is fully arranged. This delay allowed the level of political

opposition to the projects to develop and mature to the point where it became a major influence to the project development process.

The entire process was exacerbated when the City of Detroit declared bankruptcy in 2013 [16]. Opponents to the project claimed that part of the City's demise was caused by the fact that the two freeways split neighborhoods and disrupted community culture, retarding the growth of small business. This is a perfect illustration of the "… degree of disorder, instability, emergence, non-linearity, recursiveness, uncertainty, irregularity and randomness" cited in the CCPM definition for a complex project.

IV. Conclusions and Recommendations

A. Conclusions

Joham et al. [12] maintains that "project management is about resolving a problem need." The two case studies showed that to resolve a complex project's "problem need," the project team must effectively prioritize the given problem's resource needs within the population of other project resource needs because any project's pool of resources is finite [5; 17]. The I-94 financing issues created a schedule delay to the I-75 project and as a result, the context dimension in both projects became more complex has public and political opposition increased. The essence of the 5DPM approach is to restructure the project development process and move the decisions necessary to address complexity to a point as early in the process as practical [2].

Pragmatism implies that conceptualizing a complex project's scope involves being clear about what 'concept' is being used to think about that event [12]. The case studies presented in this paper demonstrate how the 5DPM framework provides a means to increase the clarity of concept by recognizing that project context and project financing can become the factors that literally drive the final project's technical solution as well as its ultimate cost and the actual period necessary to deliver it. The 5DPM concept adds structure to the process of conceptualizing the complex project's scope of work.

Furthermore, the complexity mapping completed on the two case study projects demonstrate that this tool can be used to successfully allocate resources to address complexity and in doing so, the result is the reduction in project complexity necessary to keep from slipping across that line into uncontrollable disorder, a critical skill for a complex project manager. The paper has shown that by viewing a complex project in five rather than three dimensions the project manager can elevate the visibility of complex project context and financing and thereby pragmatically conceptualize a scope of work that embodies both the controllable and uncontrollable factors that will be faced during the delivery of complex projects.

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