An empirical investigation of project complexity from the perspective of a project practitioner

Bassam A. Hussein

Associate professor. Norwegian University of Science And Technology. Trondheim-Norway.

Abstract   Project complexity is comprised of two basic components: 1) the singular elements representing feature or characteristics of the project or its environment including, diversity, existing internal and external constraints, and 2) the complicated situations that arise due to the presence of one or several of these singular elements. It is these situations that project management seeks to address or mitigate. The diversity and intensity of these situations is linked to the stakeholder's expectations of success. This paper provides some practical examples of the situations that results from the presence of one or several singular elements and the project management efforts needed to deal with these situations.
Keywords   project complexity, elements, situations.

1   Introduction

There is an increasing acceptance that an understanding of complexity is important because of the difficulties which it spawns.

According to Geraldi and Adlbrecht [2007] this understanding should help project practitioners to reflect upon circumstance, holistically and pragmatically, in order to be able to navigate complex situations. Bosch-Rekveldt et al. [2011] argues that aiming to understand complexity does not necessarily contribute to the controllable nature of project complexity; it is merely a way to help project practitioners in preparation and readiness for dealing with complex or complicated situations. Richardson [2009] believes that understanding complexity should help managers constrain achievement by planning and control methods (this amounts to reductionist and mechanistic thinking). Others, such as Remington et al. [2009], claim that understanding the source of the complexity and the degree of resultant difficulties might help to determine the skills and capabilities needed to deal with the problem. The term complexity is commonly usage and practitioners have a diverse understanding of this term. Syed et al. [2010] attribute this diversity to the lack of clear distinction between the terms complex and complicated. In literature, there are at least 31 definitions of complexity [Gul and Khan, 2011]. In systems theory, the term complex refers to a system that is composed of interrelated subsystems, each of the latter being, in turn, hierarchic in structure. In practice, common synonyms for the term complex are difficult, complicated, intricate, involved, tangled, and knotty [Whitty and Maylor, 2009]. The term complex is

perhaps used because of the lack of a more appropriate expression describing the interrelated features which effects the project life cycle, subsequently complicating decision making. As a result many perceptions exist towards the meaning of complexity. Broadly speaking, efforts to understand complexity in current project management literature can be grouped into three classes; the first class attempts to examine complex dynamical systems in terms of adaptability, non-linearity, emergence, feedback, self-organizing and dependency and determine how these characteristics can be used to understand singular or multiple project environments [Aritua et al., 2009]. The second class of studies examines singular elements, factors, sources or patterns that contribute to project or managerial complexity. A summary of these studies is given in Table 1.

Table 1. Elements of project complexity in project management literature.

Authors	Factors or elements of Complexity
Baccarini [1996]	Two dimensions of complexities; organizational and technological complexity. Within each, the author distinguishes between the number of elements (differentiation) and the degree of connection amongst those elements (interdependency).
Williams [1999]	Three dimensions of complexities; structural complexity (number of elements and their interdependence, including multiple objectives and a multiplicity of stakeholders) in addition to uncertainty of goals and methods.
Tatikonda and Rosenthal [2000]	Suggested that complexity contributes to uncertainty, a statement that was supported later by Remington *et al.* [2009] who argues that uncertainty causes technical complexity, while goal complexity causes uncertainty. Therefore, existence of uncertainty is not a good reason to consider a project as "complex" because small projects can be classified as complex category by this definition [Whitty and Maylor, 2009]
Geraldi and Adlbrecht [2007]	Three types of complexities; complexity of fact (caused by size and dependency between tasks), complexity of faith (originated because of newness of the project) , and complexity of interaction (interfaces between people and organizations, includes aspects like politics and ambiguity
Maylor et al. [2008]	They introduced dimensions of managerial complexities -Mission, Organization, Delivery, Stakeholders and Team - with sub categories.
Remington *et al.* [2009]	Identified several factors that increases experienced level of complexity (severity factors).
Bosch-Rekveldt *et al.* [2011]	Classified a large number of contributors to complexity (40 elements in total) into three main groups: Technological, Organizational and Environmental. (TEO) framework

The third class of studies includes efforts to propose or examine methods, processes or conceptual models which deal with one or several complexity factors.

The main thesis of these studies suggests that current project management methods fail to appropriately deal with complex projects. Examples include; [Thomas and Mengel, 2008] and [Müller and Turner, 2010]. In contrast, some authors believed that complexity does not necessarily require sophisticated and extra-ordinary control mechanisms. For instance, [Whitty and Maylor, 2009] argue that just because a project is called complex does not mean that complex managerial tools and techniques are required for its control.

This research is exploratory in nature and seeks to identify a project practitioner's perception of complexity/complications among different types of projects. The main interest is to examine the degree to which practitioners differentiate between singular elements of complexity and the complicated situations that arise by virtue of these singular elements. Such situations are those that need to be addressed or mitigated. The research also examines interventions methods that have been used to deal with these situations and their effectiveness. Finally, the paper summarizes types of project management competencies for dealing with these complexities. The data was collected using both interviews and open questionnaires. The pilot stage of the research included 4 exploratory interviews with senior project managers. The objective was to formulate the questions and to test the data collection method. The second stage included both structured interviews and an open questionnaire that was sent to approximately 90 project managers.

2   Findings and Analysis

The data collected from the project practitioners suggest that perception of complexity among project practitioners mixes between singular elements and complicated situations:

Singular elements: includes singular elements that contributed to complexities such as number of stakeholders, number of tasks, interdependencies between tasks, diversity of languages, lack of knowledge, diversity of objectives, diversity of working practices and so on. Altogether, 27 singular elements were inferred from the responses of the informants. the identified singular elements from project managers' point of view largely coincide with results produced by work done by [Bosch-Rekveldt *et al.*, 2011], for example. The elements were grouped into 2 major clusters as shown in Table 2; diversity and additional constraints.

Situations: describing the consequences of having one or several of these elements on the project management effort. A summary of these situations is given in Table 3. Complex or complicated situations can be seen as the difficulties associated with the measures that must be taken in order to deal with the complex elements to ensure success. Project success embodies the perceived value of the project when the result or product is in operation. Project management success on the other hand, is considered the ability to comply with time, cost and scope requirements. For the purpose of clarity, all these situations are formulated as questions in order to distinguish them from the singular elements. The perception of complexity is therefore is strongly linked to the targeted success level of the

project and not limited to the singular characteristics of the project or its environment.

Table 2. Singular elements

Magnitude & Diversity	Additional constraints
Diversity of organizational cultures	Shortage of experienced human resources
Diversity of disciplines	Time pressure
Diversity of skill levels	Lack of financial resources (funding)
Diversity of culture	Political factors
Diversity of locations	Lack of motivation
Diversity of goal awareness	Lack of trust
Diversity of personalities	Lack of support
Diversity of assignments	lack of knowledge about usefulness of suggested solutions to meet requirements
Diversity of requirements/objectives	
Number of partners/sponsors/subcontractors/suppliers	Scarcity of requirements (The data available is not enough, or does not cover all categories of stakeholders
Number of persons in the project organization	Ambiguity of requirements (the data provided is vague or can be interpreted by several meanings)
Number of assignments to be completed	Ambiguity of roles and responsibilities
Number of requirements that should considered	Uncertainty of requirements (lack of knowledge about one or several requirements)

The main conclusion from analyzing the responses of the informants is that the primary component of complexity in the analyzed projects was a combination of magnitude, diversity and additional constraints within the project or its environment. Magnitude reflects the number of stakeholders or scope largeness in the project. The informants have reported that magnitude as a standalone source has very little significance on project complexity if it was not combined with other elements such as diversity or additional constraints.

Diversity reflects the degree of variation among stakeholders or within the project scope. Diversity of stakeholders include diversity of geographical locations, their national cultures, their working practices, their awareness about objectives (goal misperception), variety of skills or disciplines that are used in the project. This conception of diversity corresponds with the concept of differentiation described by Baccarini [1996]. The task that faces project managers is to act in accordance with these diversities since they constitute the point of departure for the project. Diversity is also the source of the contradictory expectations in the project. These contradictory expectations give rise to the complicated situations (managerial complexity) [Maylor *et al.*, 2008] that requires proper decision making.

Table 3. Summary of situations

How to get the stakeholders to understand the potential benefits of the project?	How to define and agree upon priorities of tasks?	How to ensure support and funding for the project?
How to make sure that all the stakeholders feel that their diverse expertise is included?	How to measure and report progress (identifies what was completed)	How to acquiring appropriate expertise/resources?
How to manage communication in light of diversity?	How to manage adjustments, rework and changes?	How to manage and communicate approval processes with external stakeholders?
How to handle interface between the involved parties?	How to managing time, including finding time to meet, creating a better meeting culture?	
How to align the project to get the people to commit to the project?	How to manage practical tasks including: identifying the type of technology/solution needed to achieve the requirements, getting many subsystems to work together, adapting the product to satisfy the requirements, ensuring quality?	
How to create a common culture among diverse working practices		
How to reduce or eliminate personal conflicts?	How to create and maintain a high level of motivation among project members?	
How to guide or support inexperienced resources?		

The complicated situations that appear because of diversity and magnitude are further complicated by another source of complexity in projects; constraints or limitations. Constraints represent external and internal conditions that limit project manager ability to manage these situations. These constraints include; time pressure, lack of funding, lack of clarity (ambiguity) [Duimering et al., 2006] or lack of experienced resources, lack of support, lack of clarity regarding roles and responsibilities, lack of knowledge (uncertainty) [Turner and Cochrane, 1993]. We shall in the following section illustrate with some examples how these elements of complexity give rise to the complicated situations that the project manager has to deal with, and the methods that have been used to deal with these situations.

2.1 Examples

Case 1: Information system project: Developing a nationwide bio-drugs register.
Diversity of working practices
The goal of this project is to establish a nationwide register for bio-drugs. The purpose is to collect in details data about the use and effectiveness of these bio-drugs, and then made the data available for research and further development. In order to ensure project success it was therefore essential that the involved health institutions and their employees in the project commit themselves to the practice of actually collect and register these data. A source of complexity in this project was the large number of specialists involved in the project. In addition, these specialists belonged to different health and research institutions.

They have therefore different working cultures as far as registration is concerned. The project manager reports that a considerable time and effort has been used to harmonize and establish a common working practice for collecting and recording data. These efforts were further complicated by (lack of understanding) about the benefits the project can achieve among the participated institutions. There was also uncertainty (lack of knowledge) about legal requirements that the project had to adhere to. The main effort of the project management was to align the project upwards and downward. Upward with the steering group who was willing but unable or unsure about objectives/expected impact of the project. Aligning the project downwards with the partners in order to harmonize the working practice and to agree on project scope. The project manager reported that these efforts required the implementation of robust communication processes, establishing better meeting culture, and better understanding of group process. And finally (willing to swallow own pride)

Case 2: Major deliverable project. Diversity of skills combined with ambiguity

Major deliverables-project that has some novel product development activities. The product The project manager reported that the source of complexity in this project could be attributed to two main elements. The first element is ambiguity of information about product requirements. The second was the diversity of skills and competencies needed to deliver this product. The product consisted of many components and subsystems that required different types of skills and technologies. The selected developers that were involved were therefore diverse, highly competent with narrow skills. The project manager reported that the complications that arose in this project did not stem from the complications of the technology but rather from the developers involved in the project. It was hard to get these developers to agree on a common solution, there was also very strong resistance to agree or to accept suggested solutions because of professional pride. There were also strong resistance to plan the work or to define measurable mile stones, the involved developers demanded more flexibility/freedom and resisted following the project plan in the project. The situation was further complicated by lack of close follow-up from the top management to bring the project on track. The project was completed but with considerable budget overrun and time delay.

Case 3: Process improvement in the health sector. Diversity of expectations combined with magnitude

The purpose of the project was to improve the existing work flow in order to increase the number of surgeries pr. day in the department. Other expected benefits include reducing the number of days a patient has to stay at the hospital before returning home. The project organizations consisted of large number of stakeholders (Several departments were involved in the project). These stakeholders belonged to different specializations, have different skills, working cultures, and have different academic degrees. This diversity of stakeholders was the source of diversity of expectations (what is important for stakeholders) to the project. The project manager reported that the major effort of project management was therefore to harmonize the expectations of the project and trying to reduce the amount of doubt about the importance of the project.

Case 4. Rig interface. Diversity combined with covert objectives

The goal of this sub-project is to prepare the rig interface so that client
can hire and connect temporary equipment used
for drilling MPD (managed pressured drilling). The project was characterized by large
number of interrelated tasks as well as large number of suppliers/vendors and contractors

who have different types of assignment in the project. This situation was further complicated by lack of understanding about the roles and responsibilities of each contractor in the project. The main focus of the project management was to coordinate communication and interface between the involved parties and defining roles and responsibilities. Stakeholder analysis was performed in order to define who controlled the various stakeholders. But each vendor was not able to control their own internal resources. The project manager reported that stakeholder analysis and distribution of roles and responsibilities had no good effect because departments within the same company have different agendas.

Case 5. Dynamic simulation project. Uncertainty

The project was to conduct a multiphase dynamic simulation in order to verify pipeline design and layout on the seabed from a process perspective. The project manager reported that the main source of complexity in this project was scarcity of actual data/information. The model was established based on unconfirmed assumptions. This caused uncertainty about the accuracy of the recommendations proposed in the study/report and the consequences of these recommendations. Management efforts focused on providing proper expertise/resources for verification of the model, assumptions and the validity of the recommendations. Two experts were appointed to the project although it was enough with one. This was done so that experts could challenge each other's opinions on both the data verification and consequence assessment. They have also changed the roles (modeler - assessor) to create better ownership to the model and recommendations. The project was also carried out with close contact with the customer on a weekly / day basis to ensure that every stone was turned around before important decisions were taken. Progress was slow because all decisions must be reviewed and approved by all three people simultaneously.

There was a consensus among that there is need for softer competencies in addition to applying methodologies of planning and control. In some cases, it was shown that applying only planning and control did not resolve the situation but rather contributed to more delays because of resistance in adhering to the project plans and milestones. Focusing only on developing project management skills such as planning and controlling tools is not sufficient. Several soft skills and competencies are needed. These include human-knowledge, negotiation skills, motivating, and creating trust [Müller and Turner, 2010].

3   Conclusions

In this paper, an empirical investigation was conducted in order to identify how project practitioners understand complexity.

The findings revealed that the perception of complexity is not just limited to singular elements or features such as size, number, diversity and dependencies but also includes the complicated situations that arise due to the presence of these elements. Responses from practitioners further revealed that primary contributor to project complexity is diversity. The intensity of complexity increases because of internal and external constraints. Complicated situations require a combination of softer methodologies and applying the principles of planning and control.

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