THE UNIVERSITY of ADELAIDE

Exploring project complexities and their problems: a critical review of the literature

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A thesis submitted in fulfilment of the requirements for the degree of

Master of Philosophy

March 2016

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Statement of Originality/ Thesis Declaration

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Acknowledgment

This study is dedicated to my parents for their kindness and love. To my son and wife, Sooshian and Simin, for standing by me through everything.

I have taken efforts in this thesis. However, it would not have been possible without the kind support and help of my supervisors, Professor Vernon Ireland and Dr Barry Elsey who are very kind and supportive. I would like to extend my sincere thanks to all of them. In addition, my gratitude goes to all ECIC staff members for their support and positive energy. Finally, I'd like to thanks Ms Lyn Howland for editing some parts of this study.

PROLOGUE: OVERALL INTRODUCTION OF THIS WORK

It is hard to imagine any simple projects in today's emergence behaviour world. There is varying degrees of complexity in all types of projects. This is evident in the early definition of complexity, which is defined as an entity which consists of many varied interrelated parts and elements such as tasks, components, and interdependence (Hornby & Wehmeier 1995). Thus, every practical project in the world contains a degree of complexity. Complexity is one of the most important and controversial topics in many disciplines, project management included. Interestingly, however, there is no universally accepted definition of complexity (Ireland, 2013). Stephen Hawking has mentioned correctly "I think that the next century (21st) will be the century of complexity." Project Management Institute (PMI) also has concentrated on that recently. "Complexity is not going away and will only increase. Ultimately, how organizations anticipate, comprehend and navigate complexity determines their successes and failures" (PMI 2013a, p. 5). Complex systems display numerous different behaviours. Self-organisation and the emergent properties of them are often counter-intuitive. As a result, opportunities for external or top-down control are very limited (Helbing 2013). This is because of their diverse components' properties and interactions without simple cause-effect relationships. Based on this, "complexity is the inability to predict the behaviour of a system due to large numbers of constituent parts within the system and dense relationships among them" (Sheard & Mostashari, 2012, p. 11).

Although there is extensive research in this area, there is still a lack of understanding on what exactly project complexity is. Accordingly, the purpose of this research is to clarify the epistemology of project complexity and the implication of this definition for complex project management, considering different schools of thought. Thus, the main purpose of this paper is seeking out what factors make a complex project while considering different perspectives. Given the research main aim, this research seeks to answer the following questions:

Q1: What is project complexity and why are some projects complex?
Q2: What factors contribute to project complexity considering different schools of thought?

To answer the research questions above, first of all, we have conducted an in-depth systematic literature review to define complexity in the context of project management. The analysis period is more than 25 years from 1990 to 2015, and covers key developments in project complexity. Then, selected publications have been analysed. Finally three dominant perspectives construct a project complexity framework: the Project Management Institute (PMI) view, the System of Systems view and the complexity theories view. The structural of this thesis has been shown in figure 1.

Publications by the Author since beginning this work:

1. "Exploring project complexities: a critical review of the literature". In Proceedings of Australian Institute of Project Management Conference, At WREST POINT CONVENTION CENTRE, HOBART, AUSTRALIA, 11 Oct 2015 - 14 Oct 2015. (Chapter 3 and 5)

2. "What Is Project Complexity; Past, current and future". International Journal of Project Management, accepted and forthcomig.(Chapter 3, 4 and 5)

3. "Selected major complexity factors to understand project complexities". International Journal of Managing Projects in Business, Ready to submit. (Chapter 5)

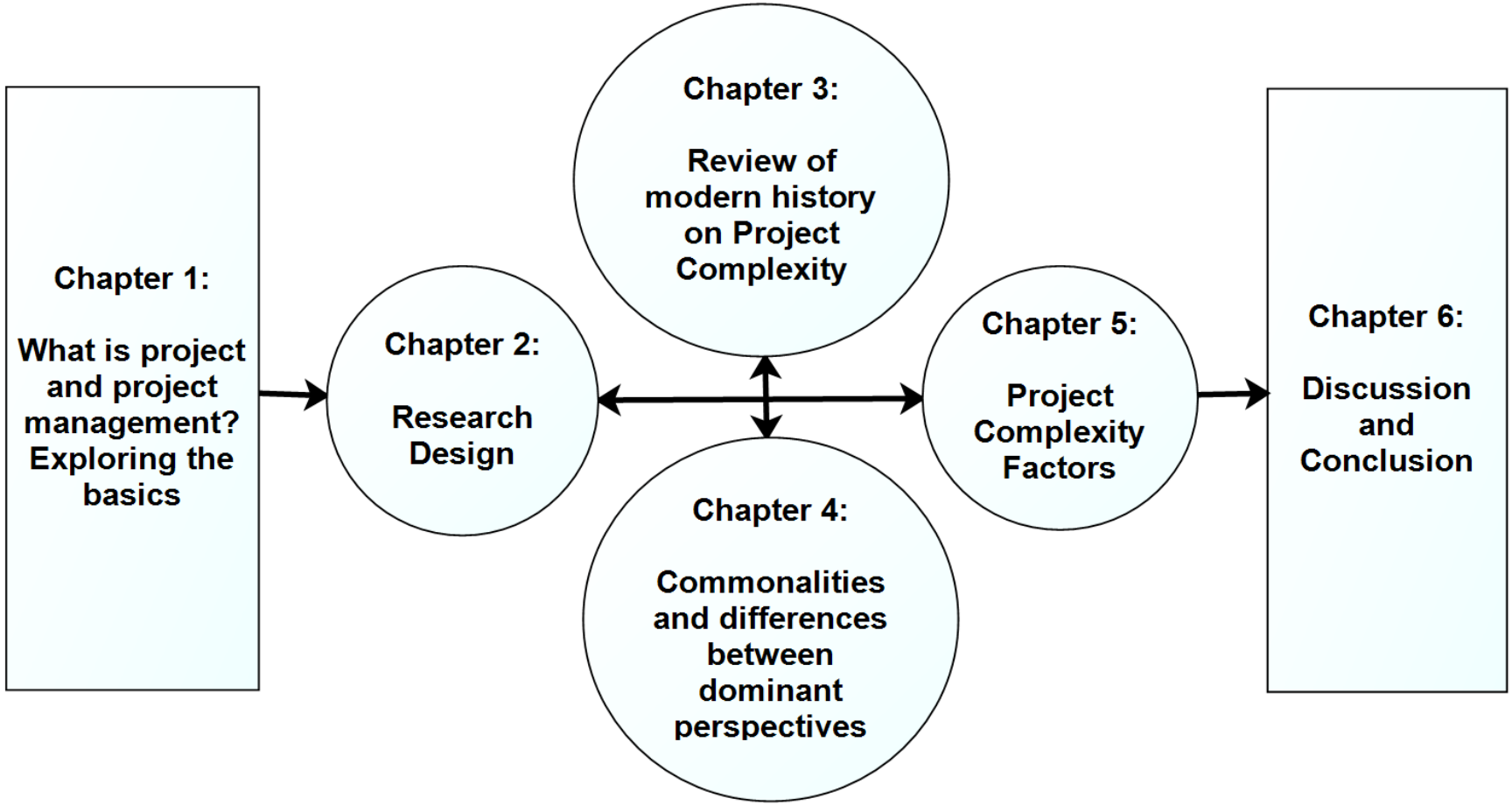


Figure 1. Overall structure of the thesis

Chapter 1 -

What is project and project management? Exploring the basics

Abstract

Project management, undoubtedly, has been one of the most significant and useful branches of management over recent decades. Taking into account various definitions put forward regarding the project, we can regard any unique task with a beginning and an end as a project. And as such, many phenomena, which have occurred in people's everyday lives since the remote past up to now, can, somehow, lie in the realm of the project. Nevertheless, the occurrence of the industrial revolution along with establishment of a new notion, that is production, have been the real reasons attracting scientific attention to management and its related branches. Moreover, corporations and industrial and production units have inevitably pushed for changes in their conventional management procedures and administrative bureaucracy, as the result of this new situation brought about by the development of science and technology and information explosion over the last decades, so as to increase their balance trade as well as their capacity to stay in the competition. These sorts of changes have led managers of different industries to capitalise on the new concepts of management science such as change management and project management (Turner & Keegan, 1999: 1).

This chapter will address fundamental notions of a project and project management after highlighting the necessity of employing project management to accomplish organisations' goals.

Chapter Keywords

Project, project management, change management, operation, project life cycle

1.1. Change management

The administrative bureaucracy is known as the best management method to achieve high efficiency in corporations and organisations with hierarchical and conventional structures. In this management method all decisions are made at top management levels, moving down to lower levels, meaning individuals and work groups are strictly limited in participating in the decision-making process (Weber 1946). It is worth mentioning that, such a system restricts any sort of change and change management in administrative system only to technological issues like office automation system. However, the continuity of this management method has been questioned and believed to be an obstacle for development of corporations and organisations due to rapid growth in science other than the information explosion. This condition can be explained through increasing complexity and pluralism, caused by advances made in science and technology and industrialisation of human society. These are challenging many environmental and social standards and forcing major changes in lifestyle and standards of living. As a result, any new demands have arisen by customers over the course of time endangering unchanging, stable situation of organisations in the way that they felt obliged to do changes in their management and organisational structures (Anderson & Anderson 2010).

Organisations have experienced massive changes over the last four decades. Observing the process of these changes could be effective in understanding the necessity of change management and project management:

- 1960s coincide with the mass production in factories. During these years, managers' main attempt was focused on reaching the highest rate of production. Although they succeeded in their objective - increasing the rate of production - the most noticeable outcome was the low quality products (Morton & Pentico 1993).
- In the 1970s, corporations and companies tried to increase the quality of their products through instituting fundamental change in their objectives. This massive change was due to the increasing competition in the market. Factory managers at this time, managed to maintain their high rate of production, which was the notable achievement of 1960s, by improving the quality of their products (Rothwell 1994).

- In the 1980s, most producers had the idea of developing innovation in their products as the result of a new particular situation brought about by the customers' demand for a bigger product range in the market. The managers responded to the new situation by making a flexible product line. This happened at this time where managers were still committed to maintaining the achievements made in the previous decades (Rothwell 1994).
- In the 1990s, customers' demand for new innovations and a bigger product range was so great that they avoided purchasing old-fashioned products and showed interest only in innovative top-quality products. The situation mounted an unprecedented pressure on corporations and organisations to survive and compete in the market. And the main reason contributed to this situation was the managers' obligation to meet customers' various demands over the shorter course of time. Managers were forced to make the organisational structure of their corporation more flexible to be able to adapt to possible changes easier and faster (Ekstedt et al. 2003).
- In the last century, customers' various demands for purchasing and using high-quality products and services with exclusive characteristics have required corporations and organisations design their organisational structure in a way that enabled them to accommodate any changes with no trouble. To put it differently, the bureaucratic and top-down organisational structures (with one-way communication style) have to be substituted for new organisational structures as the old way ruled out any possibility for creativity and innovation in the organisation. In the near future, products are most likely to be produced based on customised offers and in the form of mini projects (Whitley 1999).

Accordingly, if organisations, in the fast-changing environment of the present, want to respond positively to demands, they have to design their organisational structure based on projects; moreover, managers should develop their skills in the field of project management to bring adequate efficiency in their leadership.

1.2. Project

Before entering into discussion regarding the projects, we must first arrive at a thorough understanding of the notion of the project to find which tasks can be categorised as a project. Given what's recognised as the comprehensive account of project management through descriptions provided by experts and professionals in this field, it has been clarified that the project involves a series of events or activities with a beginning and an end, providing they are not repetitive. Accordingly, many tasks in people's everyday life can be classified as a project since firstly, they have a beginning and an end and, secondly, they are not repetitive. However nowadays, the notion of the project is mostly associated with the fields of research, industry, construction, software and IT, health, defense and so on.

1.2.1. Literal meaning of the project

According to the Zamanpour & Elahi Nezhad (2015), the word "project" is originally derived from Latin word "projectum" which in turn comes from the word "proicere", this word is formed by combing "Pro" and "iacere" which denote "before" and "to do" respectively. Therefore, "project" is a previously-planned movement thrown into the future. In other words, uncertainty is property of a project, regarding what will be care, caused by inability in predicting the future events other than obligation of some sort imposed by the pressure of the competitive situation. In fact, such explanation of the project points to the complexity nature.

1.2.2. Project definition

Lots of various definitions of project management have been provided by the academics and practitioners of this field. Some are referred to below:

- "Project is temporary endeavour undertaken to create unique products, services and results" (PMI, 2013A, p. 3).
- "Project is a unique process consisting of a set of coordinated and controlled activities with start and finish dates, undertaken to achieve an objective conforming to specific requirements including constraints of time, cost and resources" (ISO 10006: 2003, p. 4).

- Project is a series of complicated and unique operations and procedures consisting of logical interrelated activities. They run under the supervision of a certain manager or administrator within the formerly-developed framework of time and budget plan toward achieving previously-determined goal(s) (Kerzner, 2013: 10).
- Project is a temporary endeavour in which resources of various kinds such as human, financial, materials and so forth are coordinated using a novel method to create products or services of certain specifications within the framework of definite time and budget plan, to achieve its objectives taking a certain amount of profit with determined qualitative and quantitative goals (Turner, 1999: 3).

Despite superficial differences between the above-mentioned definitions, experts and professionals in project management are in full agreement on three significant characteristics in scientific definition provided for project management (Müller et al. 2007). These three characteristics hidden at the core of the project management definition are as follows:

- **Temporary:** temporariness of a project indicates that every project has a start date and an end date (Martin & Tate, 2002: 8). In other words, the process of running a project is not a constant and recurring one and has to finish at some point, producing particular results. Of course, it does not imply the short duration of a project and there are projects lasting for many years. To name some –water industry, electricity production, road construction, car manufacturing and power plants. According to the definition, the project is finished when the project team, and above all the sponsors, comes to the conclusion that the project either succeeds in its pre-determined objectives or fails and the necessity to produce a given product is removed.
- **Unique:** uniqueness of a project means that the project's end result would be in the form of a product or service which has never existed before and is to be offered for the first time. Despite many probable similarities between projects, there are still fundamental effective differences between them, for example differences regarding project's owner, design, location, beneficiary, contractor and so on. Uniqueness and lack of experience in a project give rise to uncertainty in achieving the project's objectives. So, a flexible type of planning should be used in the project to allow modification and alteration in the face of unexpected situations and unknown risks.

- **Novelty:** the novelty in the product of the project is due to its economic justification. In a process characterised by novelty, new methods should be employed to achieve objectives as there is no prior experience. Hence, there should be particular integrity between the given methods in the way that it cannot be maintained until specifications of a product is determined precisely (Turner, 1999: 5).

1.3. Comparison between the Project and Operations

Nowadays organisations objectives, that is to gain benefit, are mostly accomplished through undertaking continuous operations or projects. There are similarities as well as differences between these two ways of getting benefit which will be addressed as follows.

Similarities between them are due firstly to their characteristic to be a consumer of the organisation's resources and secondly, the characteristics of their activities to be pre-determined and then being carried out and monitored at the end. Finally, the characteristic of their resources needs to be constrained (PMI, 2013A).

Differences between them are that the continuous operation consists of a series of continuous activities recurring in a parallel time period, while the projects are temporary and will finally come to an end and produce relatively unique products (Forsberg et al, 2000). Another difference to be mentioned is that the continuous operations can make a quick return, that is the interval between investment and gaining benefit or the return of investment is short. However there is usually a long period between gaining the benefit from result of the project and investment time in the projects and this period is still different based on the type of the project. The amount of using organisational resources is considered another important difference between the continuous operation and the project. While the amount of using the organisational resources in the former remains relatively unchanged over the course of time, the latter takes advantage of these resources to varying degrees in different phases of the project (Turner, 1999: 7). The difference between the project and the continuous operation is further clarified through an example.

Assume that a car manufacturer tries to design, produce and sell a new automobile with specific features to gain higher benefit. Therefore, the phases of studying the feasibility, planning, designing, manufacturing and testing the prototype are regarded as projects. Since, besides having all the characteristics of a project, that is temporary, unique and novel, these

phases firstly, do not consist of consecutive recurring activities (because the manager's goal is simply producing an early prototype). Secondly, there is a long period between investment and gaining of the benefit (given that the benefit can only be obtained after launching the new production line). Thirdly, the amount of use of organisational resources is not fixed, increasing to its maximum during the manufacturing phase.

If the car manufacturer begins to launch the production line after confirming the final deliverable of the project, the continuous operation will be started. The most important supports for this statement are: firstly, the manufacturing operation is initiated as a continuous operation; secondly, there is a relatively short period between investment and gaining benefit (selling the automobiles); and thirdly, the amount of using the organisational resources is fixed as input and output of the production line have an equal loading.

Deciding on the projects to be carried out in organisations is made based on key necessities felt in the organisation. It could be fundamental diversities between these projects. They may be run by a person or a group of hundreds of people. Moreover, project duration may vary from weeks to years. Following are some types of the projects:

- Civil engineering and construction projects (dam, power plant, highway, oil and gas, housing, high-rise building)
- Software, IT, IS
- Promotion and training of staff
- Re-engineering
- Health problems
- Making aircraft

At the end, the process of producing a new result or product during a limited period of time can be considered as a project. Although performing continuous activities and sticking to fixed repeating schedules like manufacturing processes in a motor vehicle production or steelmaking factory, accounting, banking and office tasks are categorised as continuous operations (Martin and Tate, 2002).

1.4. Paradox between System, System of System and Project

In order to better understand the concept of project we can define the project as a system form and based on that we can identify the nature of projects and manage them efficiently (Ireland, Rapaport & Omarova, 2012; Vidal, Marle & Bocquet, 2011b). As described by Ackoff (1994):

> *"A system is a whole defined by one or more functions, that consists of two or more essential parts that satisfy the following conditions, each of these parts can affect the behavior or properties of the whole; none of these parts has an independent effect on the whole; the way an essential part affects the whole depends on what other parts are doing; and every possible subset of the essential parts can affect the behavior or properties of the whole but none can do so independently of the others".*

Based on the definition above, Shenhar (2001) believes that system of system (SoS) is "a large widespread collection or network of systems functioning together to achieve a common purpose" (p.46) (for more information refer to chapter 4). We can use five different characteristics to distinguish between systems, system of system and project which is shown in Table 1-1: Autonomy, belonging, connectivity, diversity, and emergence (Boardman & Sauser 2006). Autonomy is exercised by constituent departments, teams or partners in order to fulfil the purpose of the project. Constituent departments/partners choose to be involved because there is a cost benefit for them to do so, but also because they believe in the overall project and it assists them with fulfilling their own independent objectives. The ability of a department/group to link with other parts of the project is connectivity. Diversity can be defined as "distinct or unlike elements or qualities in a group – the variation of social and cultural identities among people existing together in the project" (Sauser et al. 2009, p. 200). The appearance of new properties/behaviours in the course of development or evolution is considered emergent (Boardman & Sauser 2006; Ireland et al. 2015).

Element	System	System of Systems	Project	Cross References
Autonomy	Autonomy is ceded by parts in order to grant autonomy to the system.	Autonomy is exercised by constituent systems in order to fulfil the purpose of the SoS	Autonomy is exercised by constituent departments, teams or partners in order to fulfil the purpose of the project; the ability to make independent choices.	Directed, Planned Embedded, Autonomy
Belonging	Parts are akin to family members; they did not choose themselves but came from parents. Belonging of parts is in their nature.	Constituent systems choose to belong on a cost/benefits basis; also in order to cause greater fulfilment of their own purposes, and because of belief in the SoS supra purpose.	Constituent departments/partners choose to belong on a cost/benefits basis; also in order to cause greater fulfilment of their own purposes, and because of belief in the project supra purpose.	Enterprise, Shared Mission, Sharing
Connectivity	Prescient design, along with parts, with high connectivity hidden in elements, and minimum connectivity among major subsystems.	Dynamically supplied by constituent systems with every possibility of myriad connections between constituent systems, possibly via a net-centric architecture, to enhance SoS capability.	The ability of a department/group to link with other parts of the project is connectivity.	Interdependence Distributed, Networked, Multiple Solutions, Loose Coupling, Integration, Interoperability, Synergism
Diversity	Managed i.e. reduced or minimized by modular hierarchy; parts' diversity encapsulated to create a known discrete module whose nature is to project simplicity into the next level of the hierarchy.	Increased diversity in SoS capability achieved by released autonomy, committed belonging, and open connectivity.	Diversity can be defined as distinct or unlike elements or qualities in a group; the variation of social and cultural identities among people existing together in the project.	Independence, Diversity, Heterogeneous
Emergence	Foreseen, both good and bad behavior, and designed in or tested out as appropriate.	Enhanced by deliberately not being foreseen, though its crucial importance is, and by creating an emergence capability climate, that will support early detection and elimination of bad behaviours.	The appearance of new properties/behaviours in the course of development or evolution considered as emergence	Evolving, Intelligence, Sum is Greater than Parts, Behaviours, Emergence, Dynamic, Adaptive

Table 1-1. differentiating of System, System of systems and Project adapted from Boardman & Sauser (2006)

1.5. Concept of the project management

The project management includes a group of knowledge, skills, tools and techniques employed in managing a project's activities to achieve the project's objectives and meet its requirements through adopting and harmonising the processes of project management – including starting, planning, running, monitoring and ending the project (PMI, 2013A). Managing a project without taking the techniques and knowledge of the project management into account resembles playing football with no tactic. A football coach must encourage cooperation between players and always ask himself "how should we play in the game to score more than our rival?" Addressing this issue is a key point every member of the team should have in mind to achieve the project goal (Martin and Tate, 2002).

Dealing with the issue concerning elements contributing to the team's success is considered critical in managing projects. Employing the techniques and knowledge of the project management allow developing particular tactics to achieve success, implementing the tactics consistently and uniformly and undertaking process of adapting the tactics.

Many project teams adopt a method similar to that of a football team in working out different projects, in the way that they are responsible for accomplishing the project. Lack of teamwork, caused by lack of familiarity with principles of teamwork, is one of the most dangerous problems threatening the work of the project team. After completing the project, the team breaks up, but members must assess and document their work experience before doing so. Learning from the experiences of the past and using this knowledge in the projects of the future, decreases common planning time as well as resources drawn on for planning the project. In addition, reviewing experiences gathered at the end of a given project leads the members to the conclusion that allocating time for planning the project results in shorter duration of the project.

The knowledge of project management including of processes with a series of questions, for succeeding in the project, given to the members before the start of the project, to help the project directors steadily complete the project on the course of efficiency by answering these questions. In the following, we provide you with some of these questions:

- What is (are) result(s) of the project?
- What are the needs of the project's stakeholders (i.e. customers, community, etc.)?
- What is the cost of the project?

- What is the time needed for each phase of the project to be completed?
- What phase of the project is more likely to run into difficulty?
- How could the project team avoid known problems?

The project management knowledge, as mentioned before, is a tool to help project managers in the planning process, managing the project precisely and coping with problems as they arise. The project management knowledge also allows the project's directors and team to perfectly implement the process of likely changes and, finally, documents the project's events from beginning to end to take advantage of previously-acquired experiences in future projects.

At the start of the project, the director must be able to develop a framework of the following characteristics:

- Identify the requirements underscoring the needs for initiating a project
- Formulate project's objectives in a clear, realistic and feasible way
- Create a balance between scope, cost, time and quality of the project
- Adjust the project's characteristics, features, designs and policies with requirements and expectations of beneficiaries of the project (Kerzner, 2013; PMI, 2013A).

Most project managers put emphasis on the cost, time and scope of the projects as the most effective factors on the process of project management. Meanwhile quality, whether it is the quality of project's components or the quality of the final deliverable, gains influence from the other three factors. Therefore a quality project regarding implementing the process of the project management should be considered with certain specifications, within the previously-planned cost, time and scope framework. Indeed, holding such a view on the quality is choosing a systematic approach in the project management (Turner, 1999: 149).

Organising the project's activities, administrative team of the project and paying attention to the uncertainties and complexities in the project life cycle are among the important issues in the field of project management.

1.5.1. Approaches to project management

Traditional approach: traditional approach to the project management exploits conventional methods to lead the project's team. At the core of this approach, it is assumed that the manager is the most qualified person to plan, monitor and manage the team. The manager, in this approach, is responsible for planning the activities, and then delegating the tasks to the members to carry them out on time. There is typically a one-way communication style between the manger and members and it is the manager who is responsible for dealing with any problems that occur during the project.

The traditional approach has particular advantages and disadvantages. Among its advantages, is the duration of planning phase is decreased. Also, its main disadvantages are outlined as follows:

- The total duration of the project is increased. This increase is mostly experienced in the project execution phase due to factors like duplication of work, confusion and misunderstanding of the members (Wysocki 2011).
- Members have little understanding of their own position and duty in the project owing to their limited participation in the decision-making and task division processes (Wysocki 2011).
- Members have low sense of belonging to and ownership of the project (Payne & Turner, 1999).

Participatory approach: participatory approach to the project management is a new method in this field. According to this approach, the manager is responsible for facilitating the management of the project's process, that is, to employ a step-wise project management method to assess the project's process and articulate the desired results. Various decisions in this method are made through participation of all the members and there is also a two-way communication style between the manager and members and among the members themselves. Advantages of this approach are as follows (Kerzner 2013):

- Each member of the team can have clear understanding of their position and duty in the whole project as they all participated in the planning process of the project.
- There is always creativity in the planning process of projects because of the exchanging ideas between almost all members.

- Better decisions are made as a result of the participation of members' involvement in the planning process of the project.
- There is high sense of belonging to the project between the members due to their participation in the decision-making process and this in turn leads to increasing responsibility and commitment among them.
- There is always high teamwork morale in the project.
- There is less duplication of work.
- The positive performance of members boosts both individually and together.

Finally, it can be stated that the reliance of either approach to cooperation between the project team for success is so great that no progress can ever made in any process of the project without the members' mutual efforts (Martin and Tate, 2002: 11-14). Role and importance of the members in the project team will be considered in the following project complexity factors chapter (chapter 5).

1.5.2. Project life cycle

Organisations and project managers can divide projects into different phases to manage them with more ease and comfort and to make more logical and appropriate communication with other processes of the organisation. These phases and steps are called the project life cycle. Project managers could mitigate some major project complexity factors with managing project life cycle (For example, duration of the project is one of the key project complexity factors refer by a vast number of researchers).

1.5.2.1. Characteristics of the project life cycle

The project life cycle, in fact, forms a link between the start and the end of the project. For example, if an organisation is to set up a project in response to a given situation, the first step is to conduct a feasibility study of the project. Therefore, the project life cycle shows whether this phase (performing a feasibility study) should be undertaken as a separate project or as a part of a main project. (It is suggested for those activities that their output cannot be

determined clearly to be treated as a separate project). It must be noted that the phases of the project life cycle should not be seen as similar to the project management process group.

While transferring from one phase to another, there is always a change at the level of technology in use in the life cycle of every project. Moreover, there are some assessments regarding the level of preciseness and output of a given phase to be performed, and necessary conformations to be obtained before travelling from one phase to another. But in some projects, it is possible to initiate a new phase before completing the previous one by assuming reasonable level of risks; such an action is called fast tracking. This is in fact an example of shortening the project schedule through overlapping among the phases of the project (PMI, 2013A).

Introducing a project life cycle as the most perfect and ideal one is impossible due to the various kinds of fields of professions and expertise, internal policies in organisations, project team, project type, management levels and so forth.

Despite differences recognised in any of the mentioned cycles, they must be able to provide viable solutions regarding the following issues. They must determine:

- what is going to happen in each phase as well as their inputs and outputs
- what requirements should be provided to deliver each phase product besides suggesting guidelines regarding how to assess, monitor, review and confirm products
- what group and at which stage of the project should cooperate with the project team
- how to monitor and confirm each phase.

Despite noticeable disparities in the life cycles of different projects, there are still similarities between many of them; some of these similarities are as follows:

- The project phases are sequential and there is usually no change at the level of technology in use while transferring the project from one phase to another.
- The level of using resources (financial, human, material and equipment) is generally low in the initial phases then increasing to the maximum in the intermediate phase and experiencing a sudden drop in the final phases of the project.
- The level of ambiguities and uncertainties about the achievement of the project objectives is high in the initial phases of the project. Nevertheless, as times goes by and the project progresses, the control of the project team on the project

environment will increase and, consequently, the level of uncertainty will decrease. It is worth mentioning that at the start of the project the level of optimism in achieving objectives increases as the result of concealment of the project's characteristics.

- The ability of beneficiaries of the project, in the initial phases, to force changes to the project scope is high, though it diminishes as the project progresses. This is because of the increasing dominance of the project team over the project environment. Moreover, cost of doing alterations and changes in the project will rise by the progress of the project over the course of time. The direct relationship between the project progress and the level of using resources is the contributing factor to this rise. Therefore, the project team must mainly focus on the initial phases to develop designs that exactly match customers' needs. The cost of making changes in the execution and intermediate phases is higher than that of the initial phases (Khan, 2006; PMI, 2013A)

To manage their projects, most project managers are interested in using cycles including four-to-five phases. But as illustrated in other cycles, there are also cycles consisting of nine to ten phases. The number of these phases is decided upon based on the condition of the project (i.e. size, complexity…) and the parent organisation.

1.5.2.2. Characteristics of project phases

A phase is mostly named after an output it has produced, as the output of each phase can provide a good account of its characteristics. Namely: feasibility study phase, planning phase, manufacturing phase, installation phase, testing phase and so on. Outputs like reporting on the feasibility study, designing, manufacturing the project prototype and so forth are always measureable and assessable. Therefore outputs expected from each phase must have such characteristics to make the assessment and justification process at the end of each phase (output of one phase and input of the next phase) which is called decision point, viable (PMI, 2013A).

Giving the main phases of the project more careful consideration, we can divide them into smaller phases based on various characteristics of the project such as complexity, level of risk, cash flow, finance. Each divided phase, called sub-phases, needs outputs to be easily assessed and monitored by the managers (Martin and Tate, 2002: 26).

1.5.3. Project management processes

The project management, as mentioned previously, is indeed, application of knowledge, skills, tools and techniques to regulate the project activities by using and integrating the project management processes. Going through such a process is to achieve the project goals and meet project requirements; that is to produce the final deliverable of the project. Therefore, the project team begins to manufacture the expected outcomes by applying such knowledge and receiving proper inputs.

To succeed in executing the project, the project team must:

- choose proper processes corresponding to project management process groups
- employ a defined process and approach to come to compromise between project requirements and previously-planned designs so as to meet the project requirements
- address needs and requirements of the project beneficiaries
- create a balance between scope, cost, time, risks, quality and resources of the project to produce a good product (Koskela & Howell 2002).

All implications mentioned, as the essential requirements of a successful project in the previous sections, can be materialised through undergoing the project management processes. The manner of working of such a process is sequential and consecutive, because the output of each process is used as input of the next process to produce the final deliverable at the end.

In general, the project management processes includes five-process groups which are as follows:

- Initiating process group
- Planning process group
- Executing process group
- Monitoring and controlling process group
- Closing process group

Further explanation on this issue is beyond the scope of this research (for more information refer to PMBOK fifth edition).

1.5.4. Initiating the Project

First stage of the project is called initiation phase. It usually begins after receiving the approval of organisation's top managers on the execution of the project (don't confuse the initiation phase of the project with the project initiation process group). However, it may include establishing feasibility study. The final output of the initiation phase is considered as achieving limitations and taking direction of the project. The limitations, indeed, are things forced by competent persons on the project. These limitations are filed in a document called "project charter" is the authority to proceed. As mentioned in the previous section, the project sponsor is someone influential from the management team in the organisation who guarantees that firstly, the organisation achieves its strategic objectives through executing the project and, secondly, the organisation will gain more advantages from the project than the cost of its execution.

1.5.4.1. Project charter

Limitations and direction of the project, which are determined by competent persons, is explained in detail in a document known as the project charter (PMI, 2013A). This document also outlines responsibilities of the sponsor.

The project charter should respond to following questions:

- What are the presumptions of specifications of the project's final deliverable?
- Who is the customer and who is the user of the project?
- When and based on what cost and under which quality license will the project's final product be delivered to the customer? (Martin and Tate, 2002: 29-30).

Sections to be considered in drawing up the charter are as follows:

- Project charter scope
- Resources in the project charter

- Priority of the limitations
- Signing the charter and amending it

1.5.4.2. Project charter scope

The first section of the project charter to be drawn up is the project charter scope. The project charter scope refers to specifications of project product, and characteristics of customer and user.

The first clause to be involved while drawing up the project charter is “project title”. The title chosen for the project should include content of the project and being as short and simple as possible.

The next clause should set out justifiable reasons explaining how a given project can succeed in strategic objectives of the parent organisation.

The clause relating to the project’s final product and what to deliver to the customer is another important issue that must be mentioned in the project charter scope; in fact, this clause is to introduce the project’s final product. Also, if there is more than one product decided on to be produced, each of them must be introduced precisely; in other words, those who draw up the project charter scope must ensure the inclusiveness of the charter regarding all given products.

Introducing the project’s customer is another clause to be determined in the project charter scope. It should be noted that the project’s customer and user are sometimes the same person (PMI, 2013A). The customer determines the project, and it is the answer to the question: who is to receive the project result?

Another clause to be included in the project charter scope is concerning specifications of the final deliverable. Responding to questions such as “What is the customer demand during the execution of the project results?” Or “What is the main component of the customer’s need after initiating the project?” can help to identify the project characteristics. Of course, it should be noted that these characteristics should be described as accurately as possible.

One of the most important issues concerning the specifications of the project’s final product is the fact that some specifications of the customer’s required product may be changed over the course of time (Turner, 1999: 150) –such change is more noticeable in software projects and IT. Therefore it would be beneficial if the project team was informed of

the key requirements of customers, enabling changes in the specifications of the final deliverable in due time. Generally what is needed is to reach an agreement upon items the project requires to meet the needs of the customer (Larson, 2004: 1). The best way to find the required specifications of customers is to make direct or face-to-face contact with them.

Another clause, which must be included in the project charter scope, is concerning the customer's requirements. To put it differently, the subject of the project provides a solution for a problem facing the customer through which the requirements are fulfilled. By referring to this clause, we want to state that customers are mostly not able to mention their required specifications and the project team also, rarely has the capacity to fully understand the required specifications of the customer (Turner, 1999: 149-150). Therefore, it is better to provide a clause concerning the customer's requirements to empower the project team to understand the core of the customer's required specifications. Accordingly, having information on the customer requirements, which contributes to the rise of the project's subject, the project team can easily provide essentials to satisfy the customer. Similarly, the manager can recognise that the project is on the wrong track and changes should be undergone in the project charter if customer satisfaction is not gained.

The final clause of the project charter scope is identifying the project beneficiaries. They are divided into two groups, namely key and non-key beneficiaries. Identifying the beneficiaries and making proper effective contact with them can increase the project problems in many cases (Martin and Tate, 2002: 34-35).

1.5.4.3. Resources in the project charter

The second section to be noted in drawing up the project charter is collecting the project resources. This section addresses the size and time of exploitation on the parent organisation's resources - for example human, financial and equipment – in the project. The first clause to be cited in this section is defining the required professions or, in other words, human force in the project. Considering information gathered from this clause, the managers can decide on the required professions and people among the project beneficiaries. It is worth mentioning that the project sponsor might sometimes have no particular comments on this issue.

Another clause is concerning organisational limitations of the project's parent organisation. Organisations and corporations employing a matrix organisational structure to manage their project activities, are likely to put limitations on allocation of particular human resources in projects. It is better therefore to mention these limitations and their reasons in the project charter resource section to allow the manager to take advantage of them in due time (i.e. resource allocation).

In the next step, the clause relating to the project limitations should be drawn up. Deadline times and dates for producing the final deliverable is considered as one of the project limitations. If there is no time specified for delivering the project's product, it is better to agree on an approximate time. Moreover, it is of great use if other unclear times (i.e. end of planning phase, end of execution phase, purchasing time of some costly equipment, deliverance of reports, meeting with beneficiaries and so on) are also cited, along with a brief description about each one, to inform the research team.

The amount of financial resources available for the project should be cited in the clause concerning financial limitations. This clause should inform the manager, as far as possible, about the amount of available financial resources for the project. Moreover, to bring comfort in the phase of project planning, it is practical to cite the maximum amount of financial resources which can be allocated for the project. Providing the reasons contributing to the financial resources is also of great use. In most organisations, it is the manager who is responsible for distributing the financial resources.

1.6. Differences between Traditional Project and Complex Project

Indeed, it can be said that traditional projects and complex projects have significant differences which can be determined by different criteria such as: environment effect, project goal, project control, management style etcetera, which is shown in Figure 1.1. (Shenhar, Dvir, Morris & Pinto, 2004). It is worth mentioning no one project can be easily put completely on one side of the spectrum.

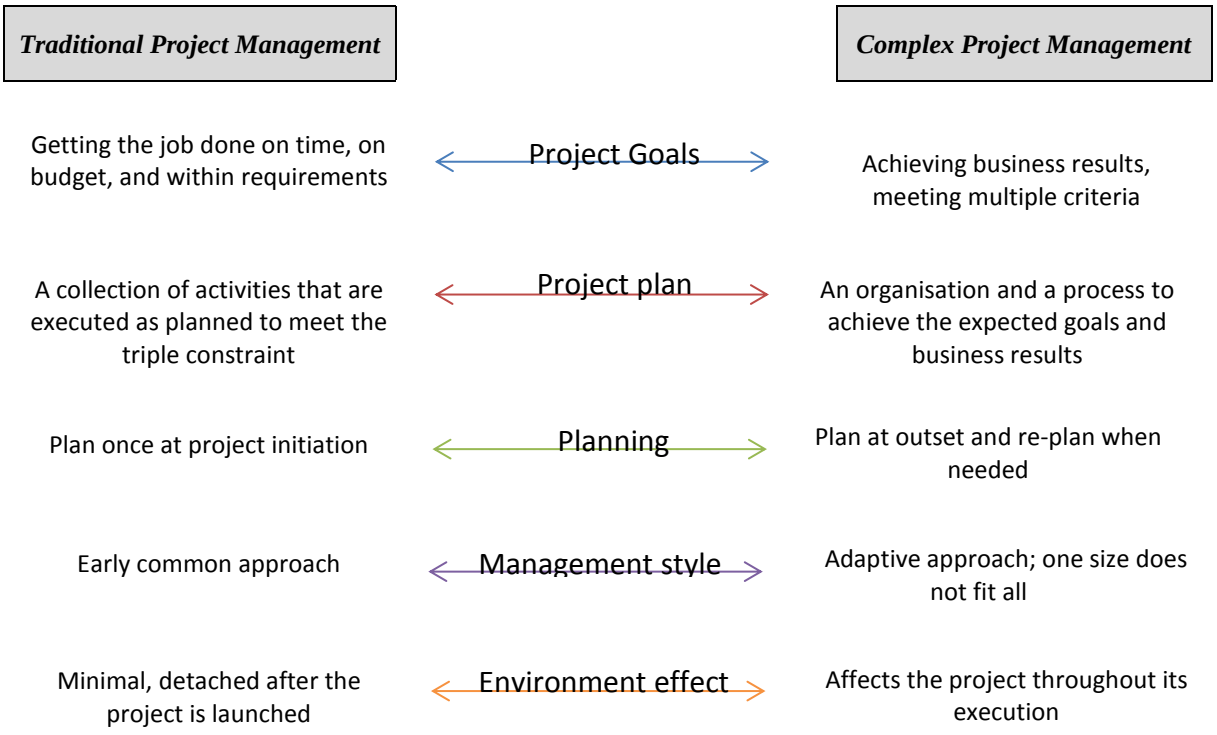


Figure 1-1. Some differences between Traditional Project and Complex Project adapted from (Gorod, 2014)

Based on this we can divide the complex projects into three categories (Ireland et al. 2012):

1. Type A projects which are famous as traditional SoS projects and include building existing projects for other goals in the new project. For example we can point to the Air and Space Operations Centre (AOC) in the USA which prepares the tools for planning, tasks and monitoring the operations in Iraq and Afghanistan.
2. In the second category there is a project which pointed to different aspects of systemic concept. Important goals are unclear and needs to be identified in climate change for instance. These aspects can include the definitions of stakeholders and boundaries of system or using system dynamics in order to develop the appropriate solution (type B).
3. Third category or Project type C is projects that combine independent assets within a large system. For example, we can point to Global Distribution Centres which come under systems of many components and while independent, are part of a larger enterprise.

Based on these concepts it is specified that other techniques and tools for management of the traditional projects cannot easily be used as complex projects. This principal is not only because of the difficulty in understanding issues within the projects or unfamiliarity with different phenomena (complicated Projects) but also because of the autonomy and non-linear relationship between the components, capacity to adapt as conditions changes and also unpredictable behaviours or emergency (Geraldi, Maylor & Williams, 2011; Glouberman & Zimmerman, 2002; Ireland et al., 2012).

So it can be concluded that SoS approach can be appropriate in dealing with complex projects. Systems of systems are "large-scale integrated systems that are heterogeneous and independently operable on their own, but are networked together for a common goal" (Jamshidi 2008, p. 2). There are numerous examples in this area such as Utility-Scale Wind Plant System, United States Air Power Command and Control etcetera (Gorod et al., 2014).

Unfortunately in literature there are not many theories on how to develop and manage SoS and for better understanding we can use science such as complexity management and networks (Gorod, Sauser & Boardman, 2008; Sauser, Boardman & Gorod, 2009).

In total, it could be proposed that the process of growth complexity in all aspects of projects is undeniable. From other hand because of unpredictable conditions, criteria and ambiguous projects we cannot use easily from approaches and tools of traditional management of projects. Therefore, for facing with this phenomena we should stronger the rule of leadership and also develop leadership skills to understanding project complexity mechanism (PMI, 2013B).

1.7. Defining Complexity in the Context of Project Management

Before exploring historical development of project complexity, it could be useful to look at projects as a hierarchy of simple, complicated, complex and chaotic. We can define simple projects as temporary activities undertaken to create products or services with clear cause-effect relationships. It means that everyone who participates in a project can appropriately respond to the different situations by accessing the necessary information. This is the domain

of “known knowns” which is self-evident, predictable and repeatable. Making food, manufacturing simple house appliances and small constructions are often good examples of simple projects. In complicated projects, there are still cause-effect relationships between tasks and elements, however, they are disputed. Knowledge and expertise are essential for understanding complicated projects and eventually require good practices in order to overcome their problems (Snowden & Boone 2007). In other words, According to Glouberman & Zimmerman (2002) “complicated projects contain subsets of simple projects but are not merely reducible to them” (p. 1). The nature of complicated projects is not always related to their scale, but to the issue of coordination or specialised expertise (Glouberman & Zimmerman 2002). Sending a rocket to the moon, producing aircraft or jet engine and most large construction projects are complicated. In some cases, we don’t know what we don’t know. This is the domain of “unknown unknowns”.

Unavoidably, complex projects consist of large elements of ambiguity and uncertainty, interdependency, non-linearity, unique local conditions, autonomy, emergent behaviours and unfixed boundaries. Most defence projects in the USA, UK and Australia, as well as most health projects, communications satellites, and nuclear-powered submarines are very good examples of complex projects because they include autonomous and independent system. It is worth mentioning that, based on the definitions above, familiarity and lack of knowledge are not part of project complexity. It is true that managing complex projects is hard but most project managers will succeed by understanding their patterns and focusing on project complexity factors. However, chaotic projects are not manageable immediately such as most crises and disasters throughout the world (Bakhshi et al. 2015). It is worth mentioning that many projects lie somewhere along the spectrum, rarely at one end or the other (see Figure 1.2).

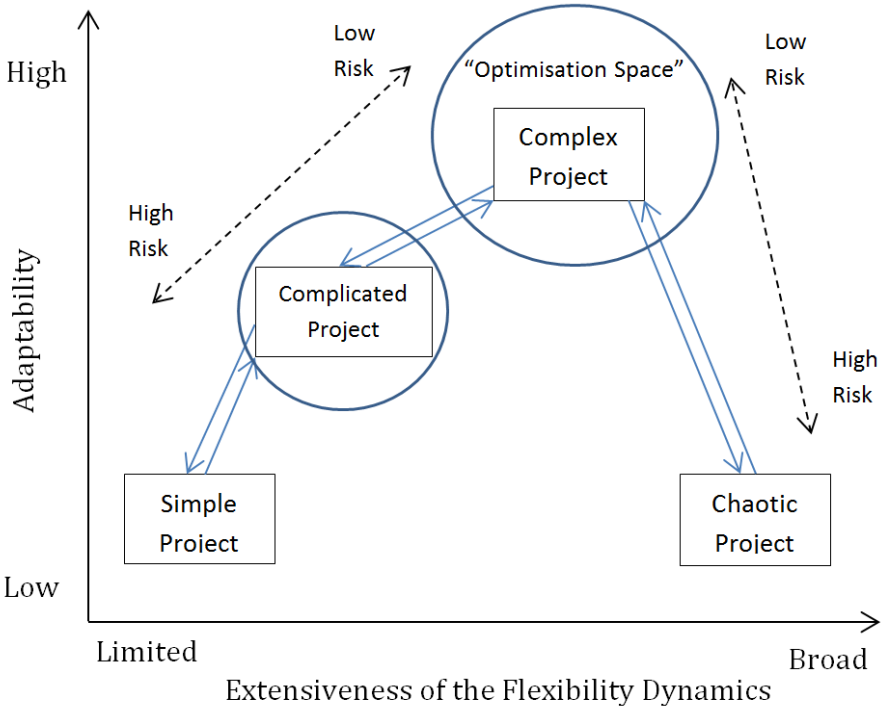


Figure 1-2. A typology of projects adapted from Gorod, Gandhi, Sauser, & Boardman (2008)

1.8. Conclusion

In this chapter, I briefly introduced some basics about project and project management. Imagine when a building is being built, a fence be raised to define boundaries of the construction site (Khan 2006). It is fundamental to know what is the project boundary and requirements. However, this is not easy and sometimes the project could have unclear boundaries (Ireland et al. 2013). Thus, using a project management approach based on model-based methodologies cannot be fixed in any types of project. In other words, project management standards should not ignore the characteristics and needs of different types of projects. For this reason, Project Management Institute (PMI) also has mentioned that the knowledge described in PMBOK guide should not always be applied uniformly to all projects (PMI, 2013A). For example, if we consider managing terrorism in Afghanistan as a project, the project doesn't share a common conceptual basis and has no common control or

management (Norman & Kuras 2006). This is area of complexity in projects which will describe in next chapters.

Chapter 2 -

Research Design

Abstract

This chapter presents briefly the research philosophy, approach, procedure and design, and methods use to address the research problem outlined in previous section. Research methodology and method have been explained in this chapter, as "method and methodology are different concepts and should not be used interchangeably. Method is a tool and technique used to model of makes sense of a problem, whereas methodology is a framework in which methods are positioned as part of the broader research strategy" (Saunders et al., 2003, p. 84), (Azim 2010, p.93-94). This study has benefited from an in-depth systematic review to seek reasonable answers to the research questions.

Chapter Keywords

Research design, philosophy, methodology, method, systematic review

2.1. Aims/Objectives of the research

This research project has the following objectives:

1. To review the existing theoretical perspective of project complexity in order to understand its concepts and to investigate the differences between schools of thought
2. Determine factors that would be needed on a System of Systems project to determine how complex it is
3. To investigate factors that contribute to complexity in complex projects
4. To identify core complexity factors (CCF) required for project managers and system engineers to manage complex projects

2.2. Research questions

Given the aim mentioned above, this research seeks to answer the following questions:

Q1: What is Project Complexity and why are some projects complex?

Q2: What factors contribute to project complexity in different schools of thought (commonality and differences between research)?

Q3: How do these factors relate to system of systems, especially autonomy, independence and emergence aspects?

2.3. Research motivation

Although there is extensive research in the field of complex project management, there is still a lack of understanding about what exactly project complexity factors are. In other words, there is no agreement within academics and practitioners on what complexity is. Thus, this dissertation undertakes a systematic literature review to summarise the existing evidence of characteristics and limitations of project complexity. Based on this, this research tries to identify any gaps in current research according to various aspects of complexity and different

schools of thought. The main aim of this research would be the formulation of a framework addressing project complexity factors. “The challenge is moving from things to integrated collections of things” (Norman and Kuras, 2006, p. 242). It is important to investigate complexity factors in terms of an integrated system (Flood & Jackson 1991). Thus, I try to address an integrated framework which is shown in the chapter 5.

2.4. Significance/ Contribution to the discipline

This research provides important insights into project complexity factors that can help project management academics and practitioners to better manage uncertainty and complexity. In particular, this research will:

1. assist management of complex projects to improve rate of success
2. identify key project complexities, useful for practitioners managing complex projects
3. provide a framework for project complexity factors which will be helpful in decision making processes

The next sections present details on the research methods and methodology which have been discussed in the context of the research aim by examining the most appropriate techniques for this research.

2.5. Theoretical framework

Project complexity can be divided into two streams of work: the first stream is “complexity in projects” which looks at projects with different complexity theories and paradigms. The second stream which is “complexity of projects” seeks to identify the characteristics of complex projects and ways of response to this complexity (Geraldi et al., 2011, p. 968). This study focus on both streams of project complexity and tries to provide a framework to understand project complexity clearly.

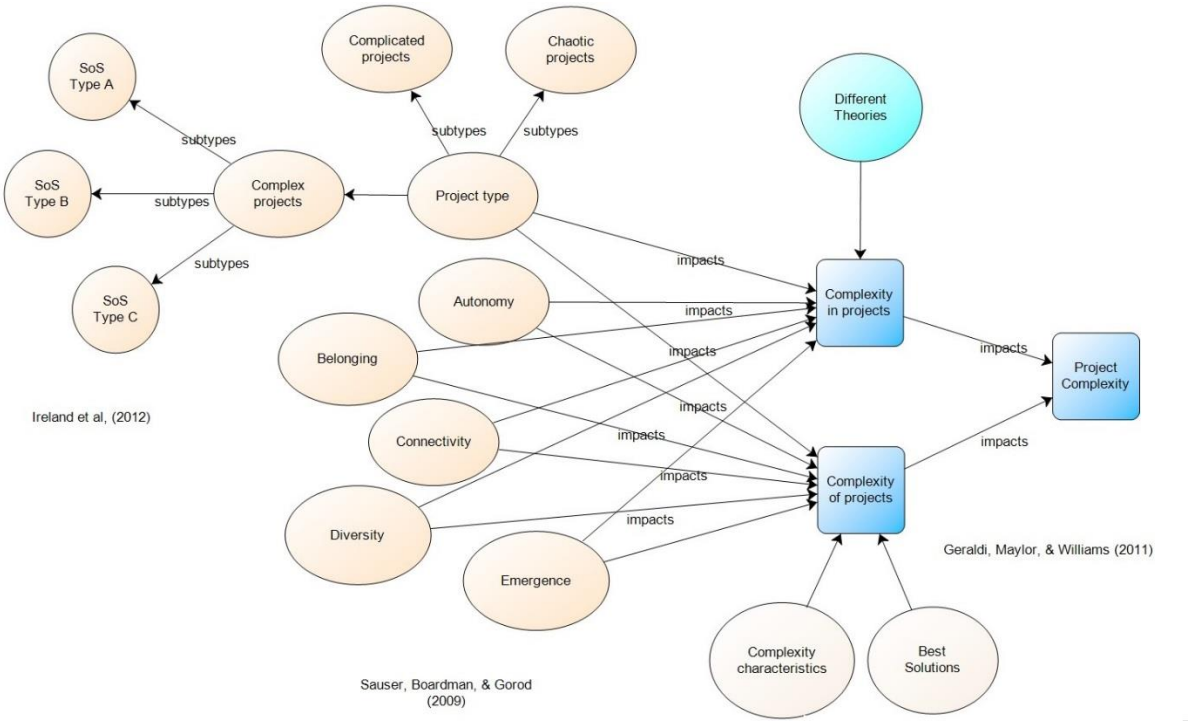


Figure 2-1. Research theoretical framework

2.6. Research Process

This section highlights the rationale for the research and presents the sequence of the studies which is conducted, as shown in Figure 2.2. This research is divided into three phases. The first phase which is exploratory phase, tries to identify and investigate different research related to project complexity and interpret them with a systematic review. “A systematic review attempts to collate all empirical evidence that fits pre-specified eligibility criteria in order to answer a specific research question”(Higgins & Green 2008, p. 6). The objectives of the first phase studies are to establish a basis for the comprehensive perception of project complexity by considering different schools of thought. The second phase, an analytical phase, will anlayse the relation between project complexity factors and complexity theory, system of systems and system thinking principles. The last phase is evaluating and reporting phase. After analyzing project complexity factors, I justify them in order to face with different aspects of complexity especially system of systems view. At the end, this research provides a conceptual framework according to findings and this framework could evaluate and validate by case studies in future studies.

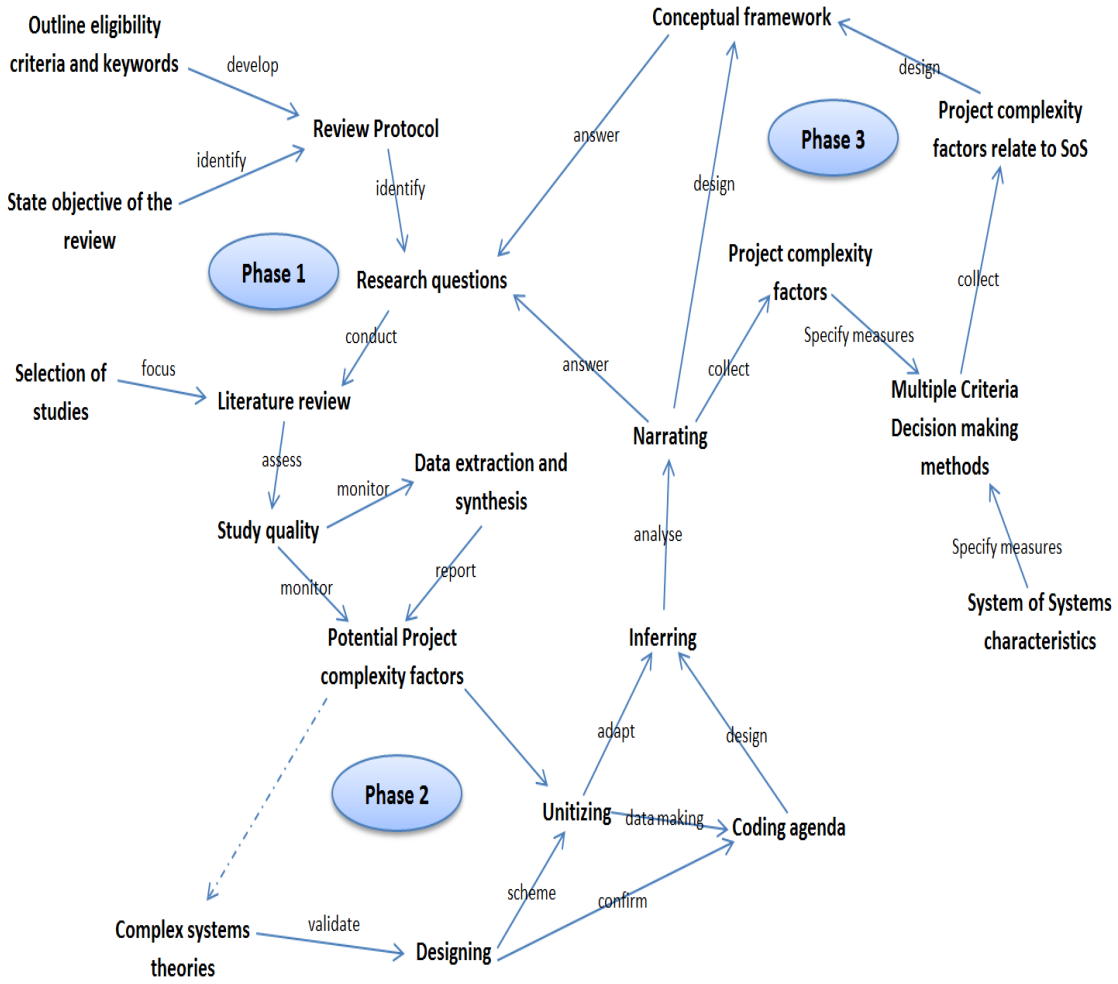


Figure 2-2. Research process chart

2.7. Research Philosophy

This research takes a social constructionist perspective (Brown et al.1989; Ackerman 1996). For social constructionists, "reality is not something that we can discover, because it does not exist prior to our social invention of it" (Kukla 2000, p. 3). Kukla also argues that "reality is constructed by our own activities and that people, together as members of a society, invent the properties of the world" (p. 3).

The ontological premise in this research method is an expressed reality that can be described by the use of a mixed method (qualitative and quantitative method). This method is significantly aimed at determining the nature of reality (Picard & Velautham 2014).

2.8. Systematic Literature Review

To achieve the research aims, we review the evidences to evaluate and interpret all related documents within the different databases. In this regards, we have benefited from The Cochrane Handbook for Systematic Reviews (2008) and The Australian National Health and Medical Research Council guidelines (2000). Researchers have used systematic literature reviews to answer their scholarly research questions with an explicit, reproducible methodology (Geraldi, Maylor, & Williams, 2011; Tranfield, Denyer, & Smart, 2003). "A systematic review attempts to collate all empirical evidence that fits pre-specified eligibility criteria in order to answer a specific research question" (Higgins & Green 2008, p. 6). According to the systematic review process which is shown in Figure 2.3, a number of discrete steps are conducted. As clearly shown in the figure, a reasonable and explicit consensus has emerged as to its desirable methodological characteristics (Higgins & Green 2008; Ghapanchi & Aurum 2011; Parris & Peachey 2013).

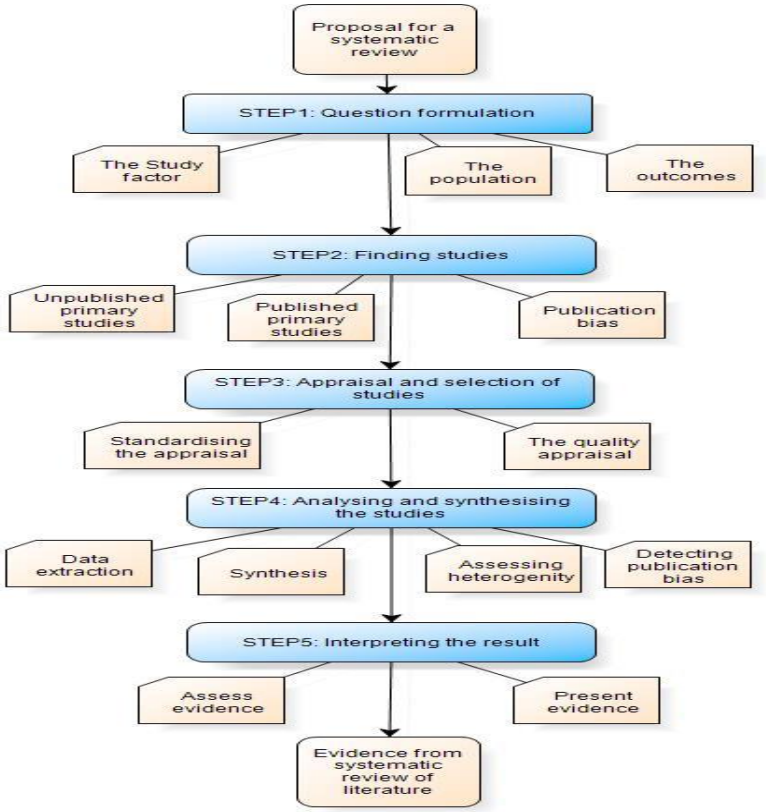


Figure 2-3. Systematic review steps adapted by The Australian National Health and Medical Research Council guidelines

2.8.1. Search terms

In order to construct a systematic search that attempts to identify all studies, first of all, we broke down research questions into three keywords as shown in Figure 2.4. Then, we formulated the main "search string" which is: **(Complex* OR unknown OR "unk unks") AND (project OR "project management") AND (system OR theory)**

The search process was validated by comparing both the automated and manual searches in different databases. Then, the best way has done according to the each single bibliographic database (Kitchenham et al. 2010). Moreover, the keywords have been discussed in the expert panel of the University of Adelaide.

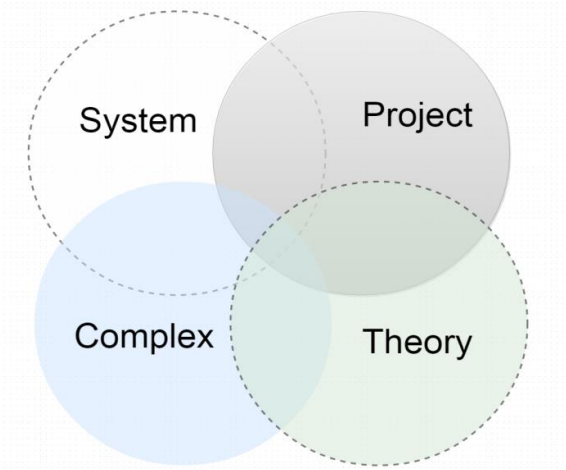


Figure 2-4. Venn diagram for search keywords about project complexity (source: authors)

2.8.2. Databases searched

After finding research terms, keywords searched on the bibliographic and full text databases include Scopus, Web of Science, Google scholar, Inspec, Business Source Premier, Business Source Complete, ProQuest Science journals, Springer Link, ACM Digital library, and IEEE Explore with consideration of Engineering, Business and Management, Decision Science and Construction Building Technology. All databases were selected with attention to coverage of the scientific literature and level of overlaps (Kousha & Thelwall 2008; Spink et al. 2006).

2.8.3. Inclusion/exclusion criteria

After finding research keywords, we completed seven steps to select related publications. We included studies:

(1) Published from 1990 to April 2015 focused on Engineering, Business and Management, Decision Science and Construction Building Technology;

(2) Where all the articles came from peer reviewed journals related to Project Management including International Journal of Project Management, Project Management Journal, International Journal of Project Organisation and Management, International Journal of Managing Projects in Business, International Journal of Information Technology Project Management, Journal of Project Program & Portfolio Management, International Journal of Construction Project Management and Built Environment Project and Asset Management Journal (for more information refer to Appendix II);

(3) Which focused on the all articles that were written by top researchers (50 top researchers who have more than 5 publications related to the topic);

(4) Where all articles had more than 5 citations or published after 2013. Then we excluded publications:

(5) Where results were limited by just English academic articles or if Full text was not available in English through the database engine

(6) If abstract, keywords and citation information were downloaded to Endnote and doubled publications were deleted;

(7) Where there was filtering and identifying of all related articles which present definition about project complexity and factors contributing to complexity.

We used Endnote software for storing and managing different publications. In addition, we benefited from NVIVO software for cataloguing, organising, analysing, and synthesising of the set of data. A vast number of resources have been content analysed and found the connections among publications through NVIVO.

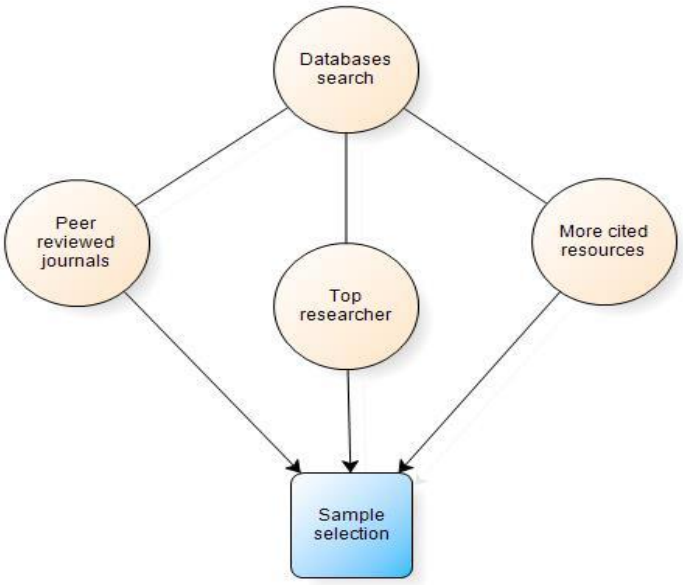


Figure 2-5. Sample section criteria

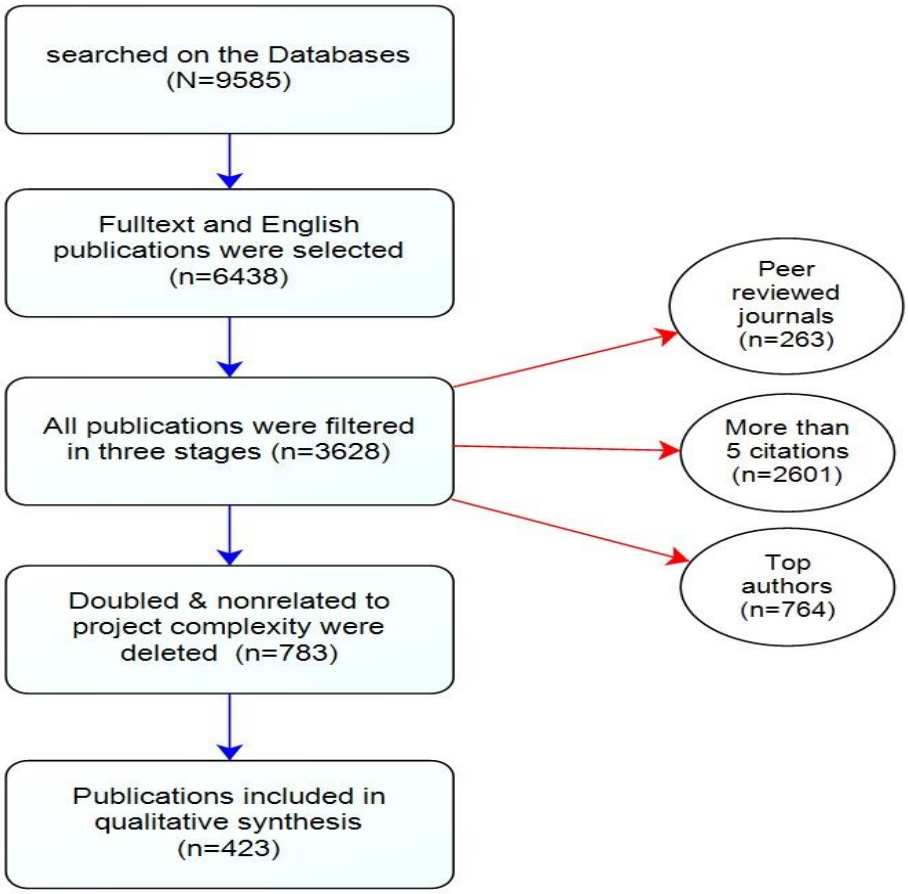


Figure 2-6. Stages of the study selection process

Table 2.1. Number of articles identified from each database/journal

Databases/Journal	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Scopus	3272	1493			
Web of Science	5097	4218	3365	520	285
Other databases	1216	727			
Int. J. Proj. Manag.			127	127	67
Proj. Manag. J.			54	54	32
Int. J. Proj. Org. Manag.			9	9	5
Int. J. Manag. Proj. Bus			39	39	18
Int. J. Info. Tech. Proj. Manag.			11	11	4
J. Proj. Prgm. Port. Manag.			0	0	0
Int. J. Cons. Proj. Manag.			8	8	3
Blt. Env. Proj. Ast. Manag.			15	15	9
Total	**9585**	**6438**	**3628**	**783**	**423**

2.9. Conclusion

The most challenging part of this research was the selection process without a doubt. More than 10,000 publications was found related to the keywords and that was absolutely critical to create an effective strategy to select samples which represent the total population. We benefited from a creative approach to select the final samples. Using peer-reviewed journals, top authors' publications, and those publications which have more than 5 citations could be validated the final results.

Chapter 3 -

Review of modern history on Project Complexity

Abstract

This chapter explores historical development of project complexities. Projects are becoming more complex due to unexpected emergent behaviour and characteristics. Complexity has become an inseparable of systems and also one of the important factors of projects' failure. While much has been written about project complexity, there is still a lack of understanding of what exactly project complexity is, and this makes it an interesting research project. Moreover, there are not sufficient exploration to investigate different aspects of project complexity with distinct schools of thought. This study has conducted a systematic literature review to show commonalities and differences between research in the related literature. More than 420 sources have been included in the analysis to explore the history of project complexity from 1990-2015. In this journey, this study presents a coherent systemic framework with the aim of to understanding project complexities which integrates three different perspectives.

Chapter Keywords

Project Complexity, Complex projects, system of systems, systematic review, histogram analysis

3.1. Introduction

This chapter has investigated the historical development of project complexity that was shown in figure 3.2. The research have focused on the following criteria to create inclusion in the investigation:

1. Definitions for project complexity
2. Characteristics of complex projects
3. Factors contributing to the complex projects (Chapter 5)

It is worth noting that the analysis is not organised or differentiated by the different types of projects (e.g., engineering & construction, IT, industrial and business, defence, etc.). This level of analysis, while important, is beyond the scope of this research. The percentage of publications related to the different projects in literature review is shown in Figure 3.1. In addition, frequency of the papers per year is also considered in figure 3.3.

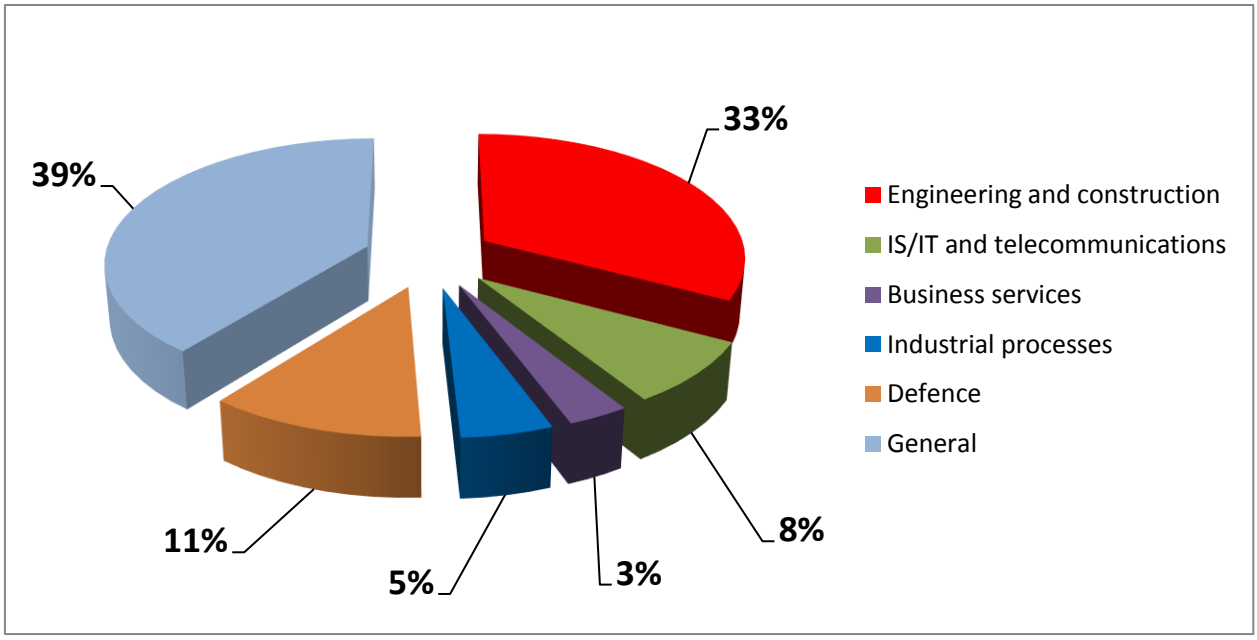


Figure 3-1. Percentage of different projects in the literature review

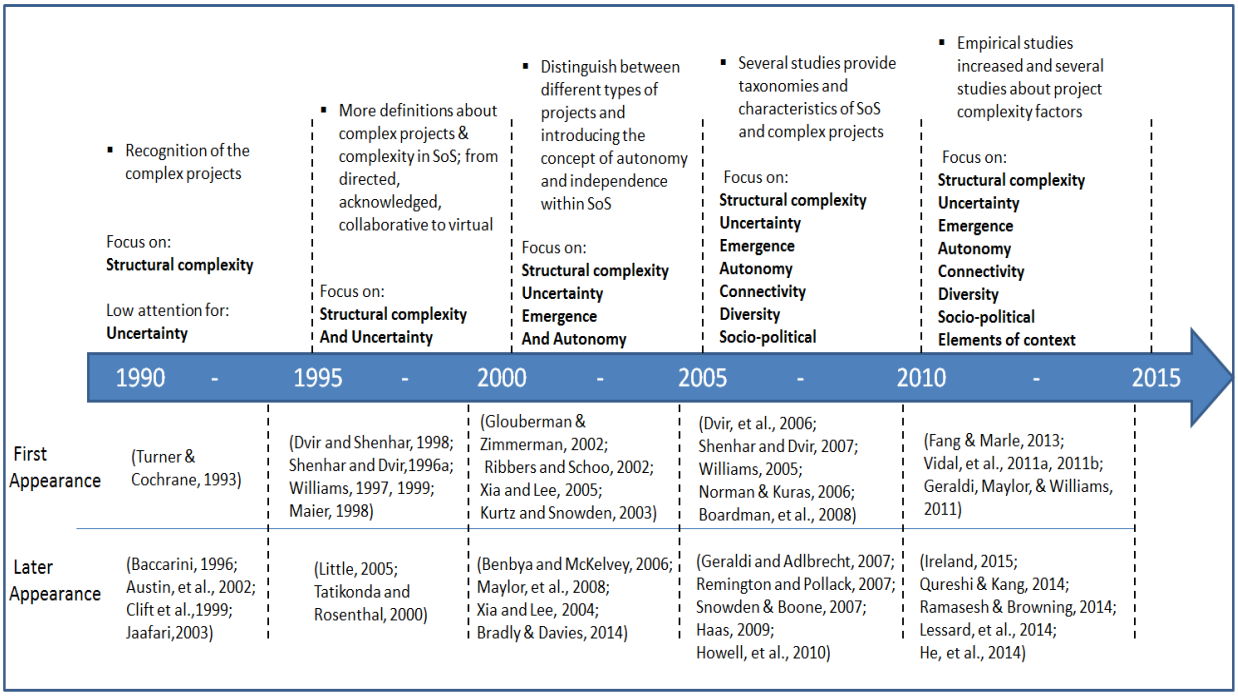


Figure 3-2. Milestones of project complexity history (source: authors)

The histogram analysis clearly shows that the highest frequency, as well as the highest cumulative value, is relative from 2009 until 2013. These years can be considered as a revolution in project complexity research. In addition, there are so many valuable publications that have a vital role to the development of complex project concepts from 2001 to 2009. We also called this period an exploration of project complexity.

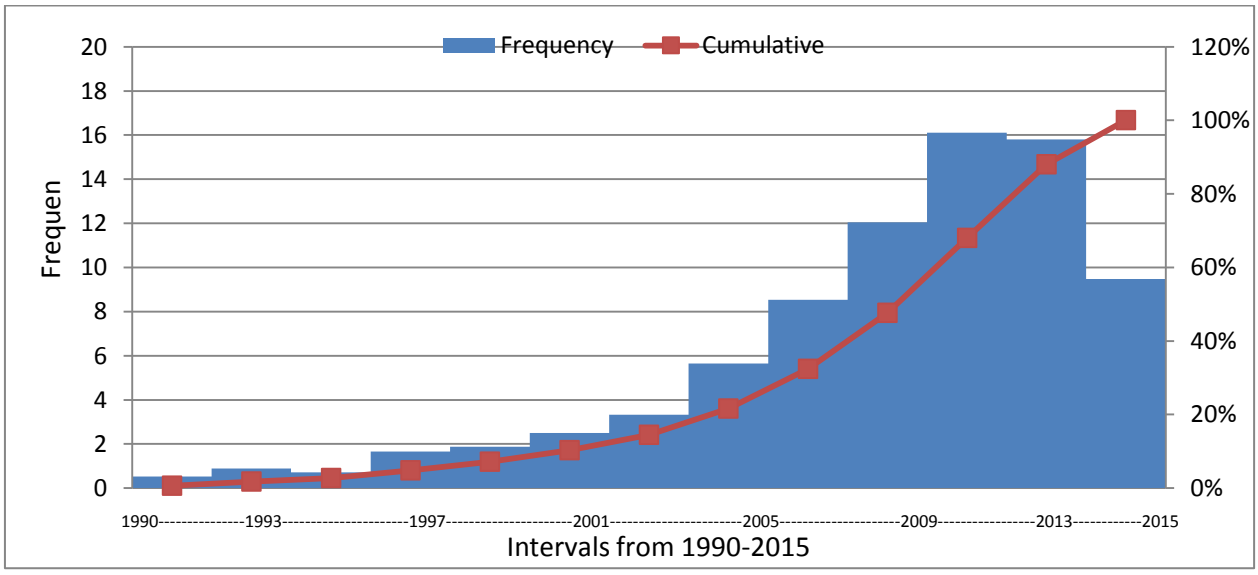


Figure 3-3. Histogram analysis for project complexity development

3.2. Historical Development of Project Complexity

Adam Smith introduced division of labour principle in 1776. His principle focused on simplification of tasks and allocates specific tasks to individuals. This principle led to great developments in business in different sectors, and new approaches and theories of management. These developments were based on experiences and experiments of management scientists who were looking to establish a relationship between cause and effect of phenomena, identification, analysis and classification (Wren & Bedeian 1994). Their concerns are always to analyse and comprehend the known or unknowns in relation to a certain topic, but the work does not end here. Issues are not always simple, transparent and linear. In other words, sometimes “we don’t know what we don’t know”. This is what the blanket term “complexity” of all issues means.

Project management has not also been excluded and complexity has had a crucial effect on it. For instance, these are two typical example of complex project if we consider the World Health Organisation (WHO) as the main governing body for the project of Ebola virus outbreak and US lead coalition as the accountable body for harnessing the penetration of terrorist group called Islamic state. Many particularities are included in the complex projects, in contrast with traditional ones such as being self-organizing, unpredictable, uncontrollable, flexible, and autonomous (Ireland, 2012). Although many efforts to explain and apply knowledge and best practices of project management are ongoing, that does not mean that they can be applied in every situation (PMI, 2013A). Complexity affects the entire life cycle of a project; ambiguous and unpredictable conditions in different projects have become one of the main concerns of researchers and practitioners (Giezen 2012; Curlee & Gordon 2010; Gransberg et al. 2013). Complexity is also one of the important factors of a project’s failure (Sheard & Mostashari, 2012; Standish Group, 2009; Williams, 2005).

Many definitions of complexity and project complexity are in the literature review which briefly comes in the following:

- One of the first attempts related to the project complexity introduced by Turner & Cochrane (1993). In this article, the uncertainty in the objectives and methods of achieving projects is considered as one of the important factors of the project's complexity. The authors focused on construction projects and made four different kind of project. On one side of spectrum, projects type-1, where the goals and methods are well defined, on the other side, where the goals and methods are not well defined, projects type-4 has taken place. Although this article rely on one characteristics of project complexity and has a reductionist approach, it could be useful and fundamental background to the complex project area. It is clearly reveal that this article only focus on Uncertainty.

- In 1996, Baccarini came up with defining complexity in projects. In fact, this article is the first attempts to present project complexity characteristics. Baccarini has two angles define the project complexity. In the first sector emphasize on differentiation and connectivity, and in the second sector, introduce complexity as a subjective concept donating based on difficulty and understand the object. In general, his emphasis on the structural complexity and the project complexity can be inferred that the integrity of the communication, coordination and control. For this research, the article is of great help because it provides the basic information about project's complexity. The Structural aspect is key element of complexity. However, there are still further perspectives which should be considered.

- Base on two definitions (Baccarini 1996) and (Turner & Cochrane 1993), William (1999) presents a new definition of project complexity. He defines the two factors of two structural uncertainly mean numbers and interdependencies of elements taken from first definition and also the uncertainty of objectives and methods base on the achievement of the second research as complexity of projects. Based on this article, it is clear that author seeks to understand what constitutes complexity and this is very important for the literature. The negative point of this research is lack of sufficient contribution to the body of knowledge.

- Technological complexity in projects could be considered as attractive perspective especially degree of newness of them. Tatikonda & Rosenthal (2000) have been considered relation between technology novelty and project complexity with project performance. Since this article was written in 2000, the authors have failed to clarify elements of project complexity. Unfamiliarity factors such as process technology novelty introduced in project complexity factors which seems more exploration. In addition, the data collection approach relies on one respondent in each project that is a big problem. According to the technological complexities, three aspects including Uncertainty, dynamic and Pace have been considered in this article.

- Shenhar (2001) indicates that there is no one way to manage different projects with using both qualitative and quantitative research methods. According to the systems thinking view, he has mentioned to three levels of complexity in projects. His research focuses on two databases which at the first consist of 26 projects and the second one has 127 projects. The article findings show that some projects such as construction has lower degree of uncertainty and on the other hand projects which represent innovation involve higher degree of uncertainty. This article can help academics and practitioners to understand the basic concepts about different projects and their degree of uncertainty. It is noticed that most aspects of the project complexity have been considered except Scio-political.

- Snowden (2002) define the difference between complicated and complex projects in his article. He uses knowledge management and presents four categories of projects. He argues that projects can be classified based on degree of knowledge. Thus, projects are divided on known, knowable, complex and chaos divisions. The limitation of this article could be concentrating on just role of informational aspect of projects. This article is a fundamental research in the project complexity literature as well as (Ireland et al. 2012) and (Snowden & Boone 2007).

- Xia & Lee (2004) focus on IS development project with considering of their complexity. In fact, the authors mentioned that although the technological complexities is clearly

apparent, but, the organisational complexities play a vital role to the outcome of IS projects. They studied 541 Information System development project in the North America and came to this conclusion. This research is so interesting because they have presented their results based on empirical study and it could be beneficial to address to their results. Technological complexity was first mentioned in this article as well as (Tatikonda & Rosenthal, 2000).

- In line with previous attempts, Williams (2005) tries to have a positivist view of complex project. He explains three aspect of project including structurally complex, uncertain, and heavily time-limited to explanation of project behaviour. In addition, he investigates on how managers could select appropriate management styles in order to degree of complexity in projects. At the end, he addresses different kind of project base on literature review with considering project's behaviour. This paper because of basic concepts about complex projects can play a significant role in the project complexity literature. And also most aspects of complexity have been considered in it.

- Snowden & Boone (2007) use Cynefin model to prepare flexible scenarios for managing organisations. The authors focus on leadership role with facing complexity in projects. They present a new definition for simple, complicated, complex and chaotic projects. Then, they define some role for leaders in terms of four project type. In addition, they elaborate some danger signals for each type of project and how we should to response them. This article is very useful for the literature because there are lots of fundamental concepts which could be inseparable part of the literature. In general, according to this article, it can be said that traditional projects and complex projects have significant differences which can be determined by different criteria such as environment effect, project goal, project control, management style an etcetera.

- Vidal & Marle (2008) attempt to identify complexity characteristics in projects and present an interesting framework. They classify project complexity into four dimensions including "project size, project variety, project interdependencies and

elements of context". In addition, they propose one of the first systematic definitions about project complexity. "Project complexity is the property of a project which makes it difficult to understand, foresee and keep under control its overall behaviour, even when given reasonably complete information about the project system" (p. 1101). It is worth mentioning that there are many questions about this definition such as they have not distinguished differences between complicated projects from complex projects. Difficulty to understanding should be mentioned in complicated projects.

- Remington, Zolin & Turner (2009) talk about one critical aspect in project complexity which is relationship between size and budget. Firstly, the authors provide a historical journey within project complexity and investigate characteristics which contributing to complexity. They use complexity theory and based on, distinguish dimensions and severity factors. After that, they interviewed with 23 leaders in Defence Materiel Organisation. The findings of survey show that "goals, stakeholders, interfaces and dependencies, technology, management processes, work practices and time" are the most important factors contributing to project complexity (p. 14). It seems that the number of sample for interview is not sufficient. So, the results are not reliable so that they can be extended to other projects. The study focuses on Pace and Uncertainty.

- In another research case study methodology in UK construction projects is used to show how social and organisational complexities could effect on projects' performance. The authors try to define more than 20 complexity characteristics and find reason why they arise (Antoniadis et al. 2011). The results illustrate that the increase in the elements of complexity grow up the interconnections. Furthermore, they verified that socio-organisational issues are positive relation with project performance. The article is useful to my research field, as the authors suggest that possible solutions could be considered on systems control theory. The main limitation of the article is that the survey focus on only construction projects with low level of complexity compared with other kinds of projects such as defence or information system projects. This research has been placed as part of Structural complexity characteristics.

- In 2011, some authors consider large engineering projects and try to understand their complexities matters (Bosch-Rekveldt et al. 2011). They arrange some case studies and held 18 semi-structured interviews. After that, with combination of their surveys and experts' opinions in the literature, they have proposed "TOE (Technical, Organisational, and Environmental)" framework in terms of project complexity. The limitation of this research is just focusing on technical, organisational and environmental aspects and they ignore other elements such as informational, structural and especially autonomous and independent aspects. However, that was a good attempt in order to concentrate on large engineering projects which was not considered in the previous researches. In general, the article concern on Structural complexity and Uncertainty and in some part on Dynamic aspects.

- Geraldi, Maylor & Williams (2011) focus on project's complexity with a systematic review of the literature. In fact, they investigate on academic articles which have presented complexity of projects stream rather than complexity in projects stream which has quite differences. The authors have collected all articles related to complexity of project with using Scopus and Web of science databases and they select 25 papers from the results based on a systematic approach. Regarding to 25 articles, they try to clarify the epistemology of complexity and divide types of complexity into five indicators including structural complexity, uncertainty, dynamic, pace and socio-political. The article is useful to the current research because they attempt to historical development of complexity and I can address their classifications and attributes in this research. The main limitation of the research is the number of articles which have considered and lack of distinguishing between complex and complicated projects. This article forms the basis of the current research as our literal criticism section and it will be useful for taking some points about systematic reviewing and sample selection. It is one merely attempts that has considered most aspects of complexity including Structural, Uncertainty, Dynamic, Pace and socio-political.

- In 2011, with connection to the previous research, Vidal, Marle, and Bocquet (2011a) assess the complexity of projects with using AHP technique. Before evaluating, they look at the complexity measures in the literature and argue that there are many limitations within them such as non-reliability, non-intuitive for end users and refer to a project model. Then, they use Delphi methods with a panel consist of 38 experts (19 men and 19 women) and identify 71 complexity measures such as "Number of decisions to be made, Duration of the project, Variety of financial resources and etcetera" (p. 722). And also they explain a system thinking approach to make clarification all aspect of project. Finally, the authors evaluate 7 projects and rank them with Analytic Hierarchy Process.

- Vidal, Marle, and Bocquet (2011b) continue the investigation of the project complexity factors. It seems that there is no any new contribution within it compare with authors' previous article. They have used Delphi method to building up project complexity factors and have evaluated 7 projects same as previous research. This three articles (Vidal & Marle 2008; Vidal et al. 2011b; Vidal et al. 2011a) are very close together.

- Ireland et al. (2012) define the projects as a system form and authors argue that mangers can understand better the nature of complex projects and manage them efficiently. They suggest 3 kinds of complex projects. Type A projects which famous as traditional System of Systems projects and include or the build of exist projects for other goals in the new project. For example, the "Air and Space Operations Centre (AOC)" in the USA. In the second category there is a project which pointed on different aspects of systemic concept. These aspects can include the definitions of stakeholders and boundaries of system or with using system dynamics in order to develop the appropriate solution (type B). Third category or Project type C is projects that combine independent assets arise within a large system, for example, "Global Distribution Centres". The article is very relevant to my research in terms of defining different types of complex projects. However, they have not mentioned project complexity characteristics or factors. We can take place this article as line of some articles such as Snowden (2002) and Snowden & Boone (2007) in terms of distinguishing complex projects from other types of projects.

- In 2013, Project Management Institute published an in-depth report called “Navigating Complexity”. The report shows that multiple stakeholders and ambiguity are two key characteristics of project complexity. This report highlighted the role of leadership skills as the most important skills to managing successfully complex projects.

- Another research presented bases on answering to this question that can advance in technology mitigate complexity in projects? (Cooke 2013). It is a viewpoint article and it tries to highlights the role of informational aspect in facing with complexity. This article has not achieved specific results and can only be chosen as a study concerning on the role of information systems. Cooke focus on Structural and Uncertainty perspective as same as (Bosch, et al., 2001)

- Understanding the organizational perspective of projects is important in explaining the projects complexity. In this regard, Qureshi & Kang (2014) only focus on organisational complexity in projects and propose a new model. They have used (Vidal et al. 2011a) model and design five hypothesis. For example, they examine whether project size has positive effect on complexity or not. That would be a great contribution and help the literature to draw a good picture of project complexity. There is a controversial argument between academics and practitioners about relationship between project size and complexity that this article could help to make clear its ambiguities. However, it is not sufficient to only focus on organisational complexity aspects and other aspects are also important. As we can see, the article concentrates more on Structural complexity and Uncertainty compare with other complexity aspects. In this regard, it takes place with researches such as (Baccarini 1996) and (Antoniadis et al. 2011).

- Ramasesh et al., (2014) provide a new term in project complexity and that is “unk unks”. It means unknown unknowns and they try to reduce it by decreasing amount of complexity, complicatedness, mindlessness and project pathologies. They also pay

attention on equivocality and dynamism in terms of complexity. In addition, they try to assist project managers to choose best project risk management styles. Their results reveal that there are many drivers of unk unks in complex project management. Although the article well defined and discover many aspects of complexity in projects, but, the authors mostly argue from their experiences and analysis of existing theories. On the other hand, they have a reductionist approach to face complexity in projects which could be considered as their limitations. They pay attention on Structural, Uncertainty, and Dynamic and pace complexity factors.

3.3. Project Complexity definition

There are several definitions of project complexity as the most reputed definitions listed in table 3.1. However, it is difficult to present an exact and comprehensive definition for complexity that can encompass all its various aspects and boundaries. Moreover, formal approaches share little commonality among them. As a result, the understanding of this concept may get obscured to the non-specialist audience (Grisogono 2006). Hence, using a pragmatic point of view, the most frequently mentioned key words were extracted via the analysis of the literature and are applied for defining complex projects- as following:

a) interdependence of the elements such as tasks, teams and inputs is present
b) causality is networked and simple cause-effect relationships between parts do not apply
c) dynamic emergence context exist
d) predictability and control is reduced
e) the project scope and boundaries are unclear
f) project governance is decentralised and autonomous teams exist
g) the number of plausible options and references is vast
h) the project is self-organised and adaptable
i) transparency is low including objectives, process, methods etc.
j) diversity of resources is heterogeneous

After considering all features above, we define project complexity as *an intricate arrangement of the varied interrelated parts in which the elements can change and evolve constantly with effect on the project objectives.*

Study	Study type	Industry	Project complexity definition	Characteristics/keywords	Cited by✳
Turner & Cochrane (1993)	conceptual	construction	degree of whether the goals and methods of achieving them are well defined	uncertainty of goals - uncertainty of methods	404
Baccarini (1996)	review	general	"consisting of many varied interrelated parts and can be operationalised in terms of differentiation and interdependency"	operational interdependencies - multi-organisational structure - technological complexity	610
Cicmil & Marshall (2005)	empirical study	construction	"invokes ambiguity, paradox and the dimensions of time, space and power of the organising processes in project settings"	flux and change - radical unpredictability - conversational and power relating - ambiguity of process - social interaction	125
Hatch & Cunliffe (2012)	conceptual	general	"consists of many different elements with multiple interactions and feedback loops between elements"	nonlinear - multiple components and interactions - change and evolve constantly - emergence	3564
Vidal, Marle & Bocquet (2011)	case study	manufacturing	"the property of a project which makes it difficult to understand, foresee and keep under control its overall behaviour, even when given reasonably complete information about the project system"	organisational complexity - technological complexity - interdependencies - property of project - project difficulty	61
Tatikonda & Rosenthal (2000)	case study	product development	"the nature, quantity and magnitude of organisational subtasks and subtask interactions posed by the project"	technology interdependence - objectives novelty - project difficulty	377
Ribbers & Schoo (2002)	case study	information systems	variety, variability and integration of system	variety - variability - integration	123

✳**Number of citations is taken from Google scholar on 15/08/2015**

Table 3-1. Most cited different project complexity definitions in the literature

Study	Study type	Industry	Project complexity definition	Characteristics/keywords	Cited by
Maier (1996)	conceptual	general	operational and managerial interdependence of the elements - evolutionary development - emergent behaviour - geographic distribution	interdependence - evolutionary development – emergence - geographic distribution	1066
Jaafari (2003)	conceptual	general	---	open systems - chaos - interdependence - self-organisation	159
Benbya & McKelvey (2006)	conceptual/ interviews	information systems	---	structural- organisational- dynamic	140
Remington, Zolin, & Turner (2009) and Remington & Pollack (2007)	conceptual/ interviews	general	"a number of characteristics to a degree, or level of severity, that makes it extremely difficult to predict project outcomes, to control or manage project"	hierarchy - communication - addictiveness - fitness landscape - edge of chaos	159
Geraldi & Adlbrecht (2007)	empirical study	plant engineering	complexity of fact, faith and interaction	dynamics - uniqueness & customisation - immaturity interdependence - size - sources - transparency - reference - empathy	68
Grisogono (2006)	report	defence	"the ratio of the number of ways of getting the wrong outcome to the number of ways of getting it right"	coherent behaviour - networked causality - vast options - unpredictable - unfixed rules	12
DeRosa, Grisogono, Ryan, & Norman (2008)	conceptual	defence	the complexity of a problem situation stems from its openness, interdependence of contributing factors and multi-scalarity	autonomous agents - adaptation - self organisation - phase changes	42

Continued table 3-1. Most cited different project complexity definitions in the literature

3.4. Conclusion

After analysing more than 420 publications, this study proposed a new definition of project complexity. This concept describes as an intricate arrangement of the varied interrelated parts in which the elements can change and evolve constantly with effect on the project objectives. It is accepted that complexity is inseparable part of a system or project, however, the degree of complexity is varied depends on a vast number of factors which will describe in chapter 5. Hence, using a pragmatic point of view, the most frequently mentioned key words were extracted via the analysis of the literature and are applied for defining complex projects. In this regard, a project to be complex when it at least has interdependence of the elements, networked causality, dynamics emergence context, unclear scope and boundaries, decentralised governance, autonomous teams, self-organised, and adaptable.

Chapter 4 -

Commonalities and differences between dominant perspectives

Abstract

We found that there are three dominant schools of thought within the construct of complex projects: the Project Management Institute (PMI) perspective, the System of Systems (SoS) perspective, and the complexity theories perspective. PMI view represents all academics and practitioners who follow the project management standards and body of knowledge. The second group comes from the system thinking approach. They consider project as a system of systems which consist of different sections co-operate together even with various purposes. The complexity theories view of points focus on relationship between different theories and project management. To better understand project complexity aspects and characteristics, it is essential to investigate all three views. These three perspectives have similarities and differences and they look at project complexity in various aspects. This kind of classification is new and belongs to the current research.

Chapter Keywords

Project Complexity, commonalities, dominant perspectives, PMI view, SoS view, complexity theories view

After analysing related publications, this study found that there are three dominant schools of thought within the construct of complex projects: the Project Management Institute (PMI) perspective, the System of Systems (SoS) perspective, and the complexity theories perspective. To better understand project complexity aspects and characteristics, it is essential to investigate all three views.

4.1. The Project Management Institute (PMI) view

One of the first attempts to systematically define project complexity is provided by Baccarini (1996). He uses two angles to define project complexity. The first emphasises differentiation and connectivity, and the second introduces complexity as a subjective concept focusing on difficulty of understanding the object (Baccarini 1996). According to Baccarini (1996), structural complexity and project complexity can be inferred based on integrity of communication, coordination and control. In another research, the uncertainty of objectives and methods of achieving project outcomes are also considered important factors contributing to a project's complexity (Turner & Cochrane 1993). We argue that these two research streams are the foundations of PMI's further research and practice. Based on two previous definitions, Williams (1999) presents a new definition of project complexity. He defines the two factors of two structural uncertainties, such as numbers and interdependencies of elements taken from the first definition, and also the uncertainty of objectives and methods based on the achievement of the second research, as complexity of projects (Williams 1999). After this, numerous studies which have focused on structural complexity and uncertainty aspects can be included in the PMI perspective (Austin, Newton, Steele, & Waskett, 2002; Clift & Vandenbosch, 1999; Jaafari, 2003; Little & Graphics, 2005; Tatikonda & Rosenthal, 2000). In 2001, Shenhar came up with a new paradigm by introducing "One size does not fit all projects". His research focuses on two databases, the first consisting of 26 projects and the second, 127 projects. The findings show that some projects, such as those in the construction industry, have a lower degree of uncertainty, while projects which represent innovation have a higher degree of uncertainty (Shenhar 2001a).

Despite extensive general research, until 2002 there were few studies which defined and distinguished complex projects from other types of projects. Snowden (2002) introduced a decision-making framework that recognises that causal differences exist between system

types. He employed the theory of knowledge management to develop four categories of organisational context: simple, complicated, complex and chaotic. Snowden and Boone (2007) use the Cynefin (pronounced ku-nev-in) model as a leader's framework for decision-making with regard to different contexts (see Figure 4.1). They also present new definitions for simple, complicated, complex and chaotic contexts and distinguish their boundaries (Snowden & Boone, 2007).

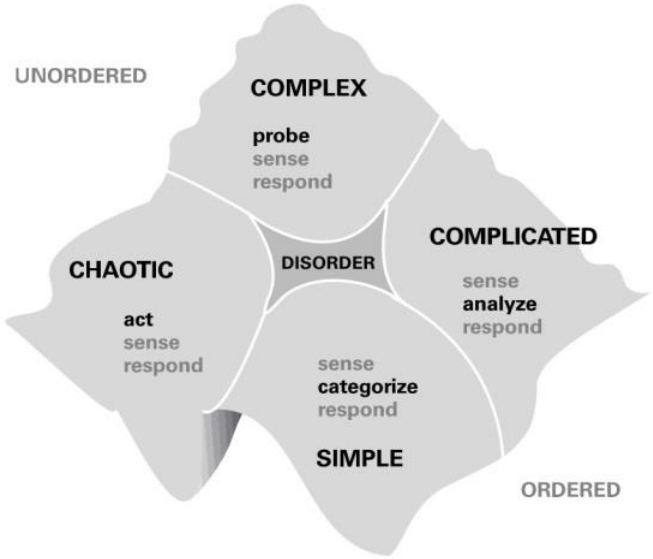


Figure 4-1. Different types of projects by Cynefin framework adopted from Snowden & Boone (2007)

Overall, most researchers who tend towards the PMI perspective concentrate on structural complexity, uncertainty and socio political rather than other complexity dimensions (Geraldi et al., 2011). The PMI published an in-depth report, "Navigating Complexity", which indicates multiple stakeholders and ambiguity as two key characteristics of project complexity (Project Management Institute, 213B). This approach has also been followed by a vast number of researchers and other aspects of complexity have been neglected in the PMI's perspective.

4.2. The System of Systems (SoS) view

The Snowden and Boone (2007) approach to complexity, more readily articulated in Kurtz and Snowden (2003), supports the System of Systems view of inclusion of autonomous and independent systems, and the issue of not being able to control autonomous and independent systems in the same way that control is exerted on projects in the Ashby's requisite variety space (Ashby 1958; Ashby & Goldstein 2011). An extreme example of a SoS is the Air Operations Center in the USA which has 80 autonomous and independent systems (Norman & Kuras 2006).

Based on the SoS perspective, we can divide complex projects into three categories (Ireland et al. 2012):

1. Type A projects are traditional SoS projects which include or build on existing projects for other goals in the new project. For example, the Air (and Space) Operations Center (AOC) in the USA prepares the tools for planning, carrying out tasks and monitoring operations in Iraq and Afghanistan.
2. In the second category, Type B, which primarily describes wicked problems, the approach concerns different aspects of the systemic concept. The real issue is that the solution is difficult to determine. Checkland's soft system methodology and possibly system dynamics could be used to develop an appropriate solution.
3. The third category, Type C, is projects that combine independent assets arise within a large system, for example, we can point to Global Distribution Centres which come from other systems and many components while independent are part of a larger enterprise.

Systems of Systems are "large-scale integrated systems that are heterogeneous and independently operable on their own, but are networked together for a common goal" (Jamshidi 2008, p. 2). Maier (1998) attempts to explain complexity in SoS in terms of characteristics such as operational and managerial interdependence of the elements, evolutionary development, emergent behaviour, and geographic distribution. Maier (1998) then introduces four types of SoS that include Directed, Acknowledged, Collaborative and Virtual. In another study, Norman and Kuras (2006) investigate independent systems

integrated into a SoS. The research result shows that all of these autonomous independent systems serve various divergent purposes but also continue to satisfy the original purpose. In other words, they were not built for the same purpose, or used within specific AOC workflows. Autonomy, belonging, connectivity, diversity and emergence are foundations and characteristics of the SoS that have been considered by many researchers (Ireland et al. 2015; Sauser et al. 2009; Braha et al. 2006).

Based on the SoS perspective, complex projects spontaneously organise themselves to "cope with various internal and external perturbations and conflicts. This allows them to evolve and adapt" (Heylighen 2011, p. 2). There are varieties of complexity aspects that deserve greater attention with regard to the project management context (for more information see Ireland, 2015).

4.3. The complexity theories view

This group looks at projects through the lenses of various theories (Geraldi et al., 2011). There are numerous publications that consider project or systems complexities with regard to various theories such as complexity theory (Cooke-Davies et al. 2007; Whitty & Maylor 2009; Shenhar & Dvir 1996; Pollack 2007), co-evolutionary theory (Benbya & McKelvey 2006), organisational social theory (S. Cicmil & Marshall 2005), contingency theory (Levitt et al. 1999; Keller 1994; Baccarini 1996; Ireland 1985), theory of constraints (Rand, 2000), systems theory (Checkland 1999), network theory (Pryke 2005; Rowley 1997), nonlinearity and chaos theory (Singh & Singh 2002), and adaptive self-organisation theory (Aritua et al. 2009; Jaafari 2003; DeRosa et al. 2008).

It is worth noting that a vast number of complexity theories related to project management have focused on a functional perspective of the project (Shenhar & Dvir 1996). In addition, all the features and characteristics discussed in theories are time-dependent, observer-dependent and problem-dependent. How these characteristics operate in various types of projects requires exploration.

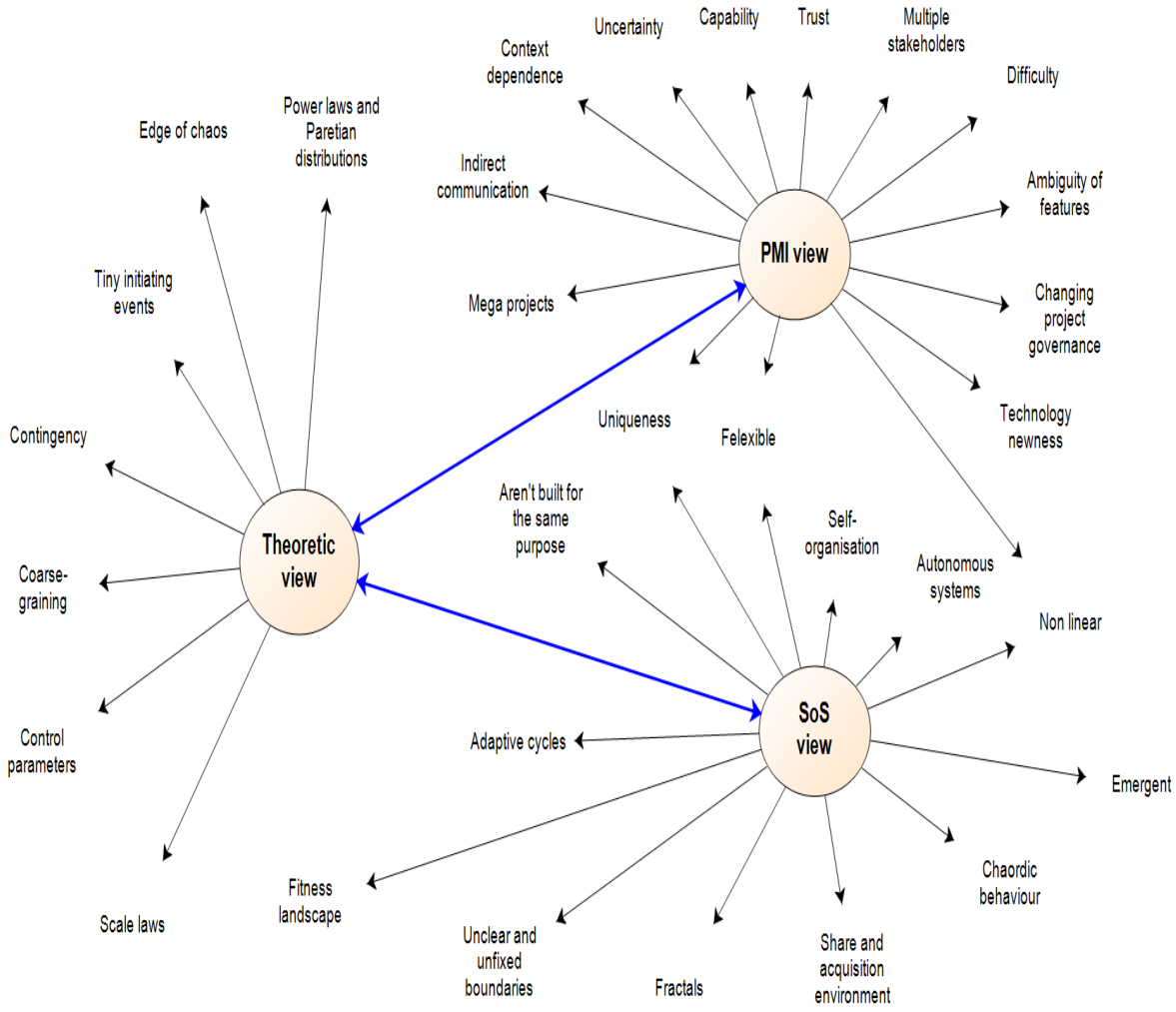


Figure 4-2. Different characteristics of complex projects in three schools of thought (source: authors)

4.4. Conclusion

As clearly seen in figure 4.2, there some commonalities between three mentioned perspectives. For example, all researchers are agree with some characteristics in complex projects such as flexibility, uniqueness, non-linearity, self-organising and so on. On the other hand, some characteristics have been neglected in PMI and SoS views. Edge of chaos, tiny initiating events, scale laws, control parameters, contingency actions, fractals, and fitness landscape need more exploration in the project management context.

Chapter 5 -

Project Complexity Factors

Abstract

This chapter examines project complexity factors and what makes a complex project. A vast number of factors seem to be contributing to project complexity, but some of them are unknown. Projects are becoming more complex due to unexpected emergent behaviour and characteristics. Complex projects can be seen as autonomous and independent systems which are often defined as self-organising, unpredictable, network-centric and flexible. Complexity is one of the most important variables contributing to a project's failure and it has become the main concern of the project management field. Although there is extensive research in this area, there is still a lack of understanding on project complexities. Numerous authors have considered the lack of knowledge and unfamiliarity with the system as a fundamental aspect of complexity. This chapter proposes that this is a misunderstanding of the issues at hand. Thus, this paper provides an overview of integrated collections of complexity factors that can support both researchers and practitioners to understand and manage complex projects. To do this, a systematic literature review has been conducted, which includes peer reviewed journal articles, theses, books and unpublished materials. More than 420 sources have been included in the analysis to explore the development of project complexity. Overall, this study provides a framework which includes more than 125 project complexity factors which are critical to understanding the complexity concept. Owing to the limitations of projects, project managers are able to consider only those factors which play a critical role in helping them to achieve their goals. Selected major complexity factors provide inputs to decision analyses and eventually ask for the right resources.

Chapter Keywords

Project complexity factors, fuzzy, ranking, major factors, classification

5.1. Project complexity factors (PMI Classification)

Over the last 30 years, project complexity factors have been collected and applied in numerous academic and practical researches. However, there is no an international agreement on this and there are many ambiguity points to face with complexity in projects as a result. In this section, I have collected more than 125 factors from a comprehensive literature review which comes in table 5.1. In order to help the audience to increase awareness of factors when dealing with the project complexity, it is important to define clearly a framework for it. Based on, I develop two new framework considering PMI view and SoS view by using some past research (Boardman & Sauser, 2006; Cicmil, 1997; Ireland et al., 2015; Ireland, 2015; Norman & Kuras, 2006; Sauser et al., 2009; Vidal et al., 2011a; Vidal & Marle, 2008).

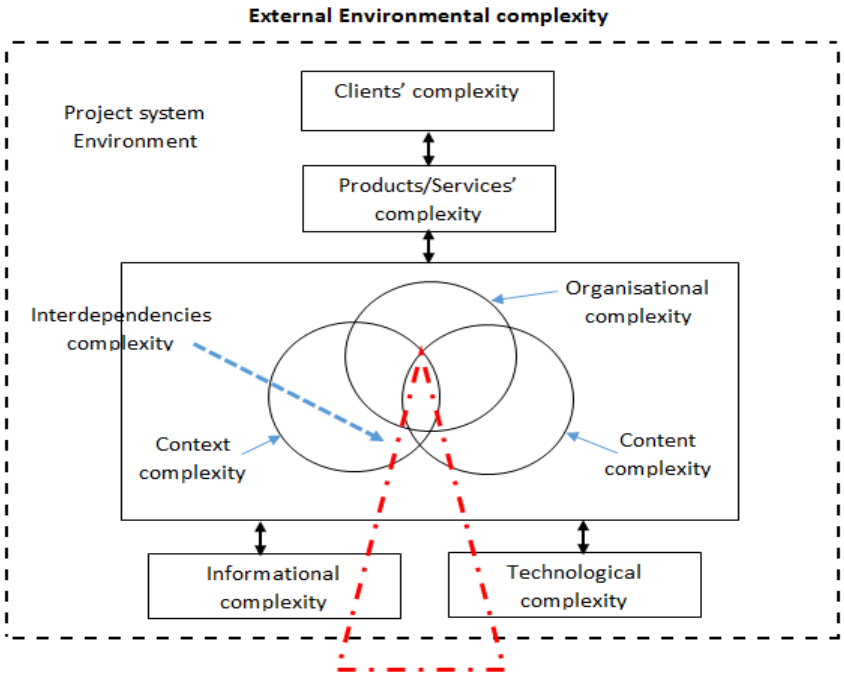


Figure 5-1. Project complexity factors framework based on process approach (source: authors)

Project Content complexity (31.7%)		Factors/characteristics	Referred to by	% of citations	Rank
	1	Number of decisions to be made	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Qureshi & Kang 2014)	7%	10
	2	Duration of the project	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010), (Xia & Lee 2003), (Leung Wing Tak 2007), (Little & Graphics 2005), (Maylor et al. 2008), (Remington et al. 2009), (Santana 1990), (Shenhar et al. 1995), (Sinha et al. 2006)	21%	2
	3	Specific requirements/standards	(Azim 2010), (Bosch-Rekveldt et al. 2011), (Geraldi & Adlbrecht 2007), (Vidal & Marle 2008), (Gidado 1996), (Hussein 2012)	13%	7
	4	Requirements capture	(Azim 2010)	2%	13
	5	Technical capability of team	(Azim 2010), (Antoniadis et al. 2011), (Little & Graphics 2005), (Maylor et al. 2008)	7%	10
	6	Unusual type of design process	(Azim 2010), (Akintoye 2000), (Austin et al. 2002)	5%	11
	7	Unknown / poorly defined requirements	(Azim 2010), (Maylor et al. 2008), (Ramasesh & Browning 2014), (Remington et al. 2009)	7%	10
	8	Number of deliverables/ disciplines	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010), (Geraldi & Adlbrecht 2007), (Baccarini 1996), (Williams 1999), (Bosch-Rekveldt et al. 2011), (Hussein 2012), (Lessard et al. 2014), (Maylor et al. 2008)	20%	3
	9	Number and quantity of resources	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010), (Akintoye 2000), (Maylor et al. 2008)	11%	8
	10	Number of activities	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Qureshi & Kang 2014), (Doyle & Hughes 2000), (Green 2004), (Baccarini 1996), (Nassar & Hegab 2006), (Ramasesh & Browning 2014)	16%	5
	11	Largeness of capital investment	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Qureshi & Kang 2014), (Santana 1990)	9%	9
	12	Variety of financial resources	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Qureshi & Kang 2014), (Geraldi & Adlbrecht 2007), (Müller et al. 2007), (Thomas & Mengel 2008), (Bosch-Rekveldt et al. 2011)	14%	6
	13	Variety of organisational skills needed	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Qureshi & Kang 2014), (Baccarini 1996), (Svetlana Cicmil & Marshall 2005), (Hussein 2012)	13%	7
	14	Variety & number of the project management methods and tools applied	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (HE et al. 2012), (Xia & Chan 2012), (Qureshi & Kang 2014), (Akintoye 2000), (Akintoye 2000), (Bosch-Rekveldt et al. 2011), (Geraldi & Adlbrecht 2007), (Camci & Kotnour 2006), (Ramasesh & Browning 2014)	21%	2
	15	Bespoke software or hardware	(Azim 2010)	2%	13

Table 5-1. Factors contributing to Project Content Complexity based on process approach (source: authors)

		Factors/characteristics	Referred to by	% of citations	Rank
Project Content complexity	16	Variety of resources to be manipulated	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Ramasesh & Browning 2014)	7%	10
	17	Availability of people, material and of any resources due to sharing	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (HE et al. 2012), (Qureshi & Kang 2014), (Baccarini 1996), (Thomas & Mengel 2008), (Bosch-Rekveldt et al. 2011), (Antoniadis et al. 2011), (Maylor et al. 2008)	18%	4
	18	Interconnectivity and feedback loops in the task and project networks	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (HE et al. 2012), (Qureshi & Kang 2014), (Williams 1999), (Bosch-Rekveldt et al. 2011), (Favari 2012), (Gidado 1996), (Green 2004)	18%	4
	19	Level of interrelation of between phases	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008)	5%	11
	20	Demand of creativity	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008)	5%	11
	21	Scope for development	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008)	5%	11
	22	Institutional configuration	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Qureshi & Kang 2014)	7%	10
	23	Significant on public agenda	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008)	5%	11
	24	Team/partner cooperation and communication	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010), (HE et al. 2012), (Xia & Chan 2012), (Qureshi & Kang 2014), (Geraldi & Adlbrecht 2007), (Bosch-Rekveldt et al. 2011), (Antoniadis et al. 2011), (Svetlana Cicmil & Marshall 2005), (Kennedy et al. 2011), (Maylor et al. 2008), (Senescu et al. 2013), (Sinha et al. 2006), (Wood & Gidado 2008)	29%	1
	25	Degree of project flexibility (in scope, process, organisation…)	(Geraldi 2008), (Little & Graphics 2005), (Maylor et al. 2008)	5%	11
	26	HSSE issues	(Bosch-Rekveldt et al. 2011)	2%	13
	27	Diversity of tasks	(HE et al. 2012), (Bosch-Rekveldt et al. 2011), (Williams 1999), (Hussein 2012), (Ramasesh & Browning 2014)	9%	9
	28	Dynamics of the task activities	(HE et al. 2012), (Ramasesh & Browning 2014)	4%	12
	29	Decision making process challenges	(Calinescu, Efstathiou, Schirn, & Bermejo, 1998), (Maylor et al. 2008)	4%	12
	30	Repetition of similar type of projects	(Xia & Chan 2012)	2%	13

Continued table 5-1. Factors contributing to Project Content Complexity based on process approach (source: authors)

		Factors/characteristics	Referred to by	% of citations	Rank
Project Content complexity	31	Cost restraints (cost and financing)	(Xia & Chan 2012), (Hussein 2012), (Remington et al. 2009)	5%	11
	32	Quality requirements	(Xia & Chan 2012), (Bosch-Rekveldt et al. 2011)	4%	12
	33	Capability (knowledge, experience, education, training, etc.)	(Qureshi & Kang 2014), (Hussein 2012), (Hussein et al. 2013), (Baccarini 1996), (Little & Graphics 2005), (Maylor et al. 2008), (Xia & Lee 2004)	13%	7
	34	Number of different occupational specialisations	(Baccarini 1996), (Green 2004)	4%	12
	35	Number and diversity of inputs and/or outputs	(Baccarini 1996), (Gidado 1996), (Green 2004)	5%	11
	36	Largeness & uncertainties of scope (number of components, etc.)	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010), (Bosch-Rekveldt et al. 2011), (Geraldi & Adlbrecht 2007), (Akintoye 2000), (Maylor et al. 2008), (Müller et al. 2007), (Senescu et al. 2013), (Shenhar 2001a), (Yugue & Maximiano 2012)	21%	2
	37	Size in CAPEX (Capital expenditures)	(Bosch-Rekveldt et al. 2011)	2%	13
	38	Face to face relationship between project team members	(Maylor et al. 2008), (Kennedy et al. 2011)	4%	12
	39	Levels of management are involved in project decision-making	(Maylor et al. 2008)	2%	13

Continued table 5-1. Factors contributing to <u>Project Content Complexity</u> based on process approach (source: authors)

		Factors/characteristics	Referred to by	% of citations	Rank
Project Context complexity (23.6%)	1	Geographic location of the stakeholders (and their mutual disaffection)	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Qureshi & Kang 2014), (Lessard et al. 2014), (Little & Graphics 2005)	11%	9
	2	Number of stakeholders	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010), (HE et al. 2012), (Xia & Chan 2012), (Qureshi & Kang 2014), (Bosch-Rekveldt et al. 2011), (Geraldi & Adlbrecht 2007), (Baccarini 1996), (Williams 1999), (Frame 2002), (Hussein 2012), (Lessard et al. 2014), (Maylor et al. 2008), (Crawford 2005), (Remington et al. 2009)	30%	1
	3	Number of companies/ projects sharing their resources	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010), (Xia & Chan 2012), (Qureshi & Kang 2014), (Baccarini 1996), (Camci & Kotnour 2006), (Doyle & Hughes 2000), (Frame 2002)	18%	6
	4	Number of formal units & departments involved	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010), (HE et al. 2012), (Xia & Chan 2012), (Baccarini 1996), (Calinescu et al. 1998b), (Camci & Kotnour 2006), (Doyle & Hughes 2000), (Frame 2002), (Green 2004), (Müller et al. 2007), (Crawford 2005), (Ramasesh & Browning 2014), (Sinha et al. 2006)	29%	2
	5	Internal politics Issue (ambiguity, hidden information)	(Azim 2010), (Geraldi & Adlbrecht 2007), (Bosch-Rekveldt et al. 2011), (Hussein 2012), (Müller et al. 2007), (Remington et al. 2009)	11%	9
	6	Number of objectives	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010), (Qureshi & Kang 2014), (Müller et al. 2007), (Geraldi & Adlbrecht 2007), (Hussein 2012)	14%	7
	7	Number of investors	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Qureshi & Kang 2014), (Remington et al. 2009), (Santana 1990)	11%	9
	8	Staff quantity	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010)	7%	11
	9	Variety of the interests of the stakeholders	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010), (Qureshi & Kang 2014), (Bosch-Rekveldt et al. 2011), (Frame 2002), (Hussein 2012), (Hussein et al. 2013), (Maylor et al. 2008), (Remington et al. 2009), (Sinha et al. 2006)	21%	4
	10	Diversity of staff (experience, social span ...)	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010), (HE et al. 2012), (Antoniadis et al. 2011), (Santana 1990)	13%	8
	11	Variety of the stakeholders status	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Remington et al. 2009)	7%	11
	12	Combined transportation	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008)	5%	12
	13	Cultural configuration and variety	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010), (HE et al. 2012), (Geraldi & Adlbrecht 2007), (Hussein 2012), (Hussein et al. 2013), (Koivu et al. 2004), (Lessard et al. 2014), (Maylor et al. 2008), (Remington et al. 2009), (Sinha et al. 2006)	23%	3
	14	Environment complexity (networked environment)	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Qureshi & Kang 2014), (Favari 2012), (Gidado 1996), (Wood & Gidado 2008)	13%	8
	15	The amount of overlap and interactions	(Xia & Chan 2012), (Gidado 1996), (Pich et al. 2002), (Remington et al. 2009), (Wood & Gidado 2008)	9%	10

Table 5-2. Factors contributing to Project Context Complexity based on process approach (source: authors)

Project Context complexity		Factors/characteristics	Referred to by	% of citations	Rank
	16	Trust in stakeholders	(Qureshi & Kang 2014), (Alderman & Ivory 2007), (Geraldi & Adlbrecht 2007), (Bosch-Rekveldt et al. 2011), (Svetlana Cicmil & Marshall 2005), (Hussein 2012), (Maylor et al. 2008)	13%	8
	17	Form of contract	(Bosch-Rekveldt et al. 2011), (Müller et al. 2007), (Crawford 2005), (Remington et al. 2009)	7%	11
	18	Number of different languages	(Bosch-Rekveldt et al. 2011), (Geraldi & Adlbrecht 2007), (Maylor et al. 2008), (Remington et al. 2009)	7%	11
	19	Overlapping office hours	(Baccarini 1996), (Bosch-Rekveldt et al. 2011)	4%	13
	20	Stability project environment	(Bosch-Rekveldt et al. 2011), (Senescu et al. 2013)	4%	13
	21	Experience with parties evolved	(Bosch-Rekveldt et al. 2011), (Wood & Gidado 2008)	4%	13
	22	Project drive	(Bosch-Rekveldt et al. 2011)	2%	14
	23	Commercial newness of the project (new partners, team, process, etc.)	(Geraldi & Adlbrecht 2007), (Bosch-Rekveldt et al. 2011), (Maylor et al. 2008)	5%	12
	24	Uncertainty & clarity of objectives or goals	(HE et al. 2012), (Geraldi 2009), (Bosch-Rekveldt et al. 2011), (Crawford 2005), (Geraldi & Adlbrecht 2007), (Hussein et al. 2013), (Little & Graphics 2005), (Maylor et al. 2008), (Müller et al. 2007), (Remington et al. 2009), (Turner & Cochrane 1993)	20%	5
	25	Goals/interests alignment	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Qureshi & Kang 2014), (Bosch-Rekveldt et al. 2011), (Williams 1999), (Baccarini 1996), (Geraldi & Adlbrecht 2007), (Lessard et al. 2014), (Maylor et al. 2008)	18%	6
	26	Multiple time zones	(Maylor et al. 2008)	2%	14
	27	Conflict between stakeholders	(Maylor et al. 2008)	2%	14
	28	Level of competition between stakeholders (members, teams, etc.)	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Qureshi & Kang 2014), (Bosch-Rekveldt et al. 2011), (Maylor et al. 2008)	11%	9
	29	Lack of support (top management, users, staff members, etc.)	(Xia & Lee 2004)	2%	14

Continued table 5-2. Factors contributing to Project Context Complexity based on process approach (source: authors)

Project Organisational complexity (9.8%)		Factors/characteristics	Referred to by	% of citations	Rank
	1	Project Manager competencies	(Azim 2010), (Maylor et al. 2008), (Ramazani & Jergeas 2014)	5%	6
	2	Responsibility & Accountability	(Azim 2010), (Maylor et al. 2008)	4%	7
	3	Number of structures/ group/ team to be coordinated	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010), (HE et al. 2012), (Xia & Chan 2012), (Qureshi & Kang 2014), (Baccarini 1996), (Xia & Lee 2003), (Williams 1999), (Thomas & Mengel 2008), (Bosch-Rekveldt et al. 2011), (Camci & Kotnour 2006), (Doyle & Hughes 2000), (Frame 2002), (Hussein 2012), (Hussein et al. 2013), (Leung Wing Tak 2007), (Little & Graphics 2005)	34%	1
	4	Number of hierarchical levels	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010), (Qureshi & Kang 2014), (Baccarini 1996), (Green 2004), (HE et al. 2012)	14%	2
	5	Variety of hierarchical levels within the organisation	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010), (Baccarini 1996)	9%	4
	6	Number of interfaces in the project organisation	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008)	5%	6
	7	Dynamic and evolving team structure	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Antoniadis et al. 2011), (Hussein et al. 2013), (Maylor et al. 2008)	11%	3
	8	Relations with permanent organisations	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Ramasesh & Browning 2014)	7%	5
	9	Organisational degree of innovation	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Qureshi & Kang 2014)	7%	5
	10	Functional role	(Azim 2010)	2%	8
	11	Oraganisational risks	(Bosch-Rekveldt et al. 2011)	2%	8
	12	Team transparency, empathy (the personal and intangible matter that improves cooperation)	(Geraldi & Adlbrecht 2007), (Vidal & Marle 2008)	4%	7

Table 5-3. Factors contributing to Project Organisational Complexity based on process approach (source: authors)

Project Interdependencies complexity (11.4%)	Factors/characteristics		Referred to by	% of citations	Rank
	1	Dependencies with the environment	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Qureshi & Kang 2014), (Favari 2012), (Gidado 1996)	11%	6
	2	Variety of organisational interdependencies	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010), (HE et al. 2012), (Xia & Chan 2012), (Qureshi & Kang 2014), (Baccarini 1996), (Remington et al. 2009), (Wood & Gidado 2008)	18%	2
	3	Variety of technological dependencies	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010), (Gidado 1996), (Hussein et al. 2013), (Yugue & Maximiano 2012)	13%	5
	4	Interdependencies between sites, departments and companies	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010), (Baccarini 1996), (Bosch-Rekveldt et al. 2011), (Williams 1999), (Geraldi & Adlbrecht 2007), (Green 2004), (Lessard et al. 2014), (Little & Graphics 2005), (Maylor et al. 2008), (Yugue & Maximiano 2012)	23%	1
	5	Interdependencies of objectives/interests	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Qureshi & Kang 2014), (Bosch-Rekveldt et al. 2011), (Williams 1999), (Baccarini 1996), (Geraldi & Adlbrecht 2007), (Lessard et al. 2014), (Maylor et al. 2008)	18%	2
	6	Process interdependence	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010), (Qureshi & Kang 2014), (Baccarini 1996), (Svetlana Cicmil & Marshall 2005), (Hussein et al. 2013), (Senescu et al. 2013)	16%	3
	7	Stakeholders interrelation/interdependencies	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Qureshi & Kang 2014), (Bosch-Rekveldt et al. 2011), (Maylor et al. 2008)	11%	6
	8	Interdependencies between actors	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Qureshi & Kang 2014), (Baccarini 1996), (Little & Graphics 2005), (Xia & Lee 2004)	13%	5
	9	Specifications interdependence	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Baccarini 1996)	7%	8
	10	Interdependence between components of the product	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Senescu et al. 2013)	7%	8
	11	Technological process dependencies	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010), (HE et al. 2012), (Bosch-Rekveldt et al. 2011), (Tatikonda & Rosenthal 2000), (Gidado 1996)	14%	4
	12	Resource and raw material interdependence	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Baccarini 1996)	7%	8
	13	Dependencies between schedules	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Qureshi & Kang 2014), (Williams 1999), (Bosch-Rekveldt et al. 2011), (Remington et al. 2009)	13%	5
	14	Interdependencies of information systems	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Qureshi & Kang 2014), (Baccarini 1996)	9%	7

Table 5-4. Factors contributing to Project Interdependencies based on process approach (source: authors)

		Factors/characteristics	Referred to by	% of citations	Rank
Technological complexity (5.7%)	1	Variety of the technologies used during the project	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (HE et al. 2012), (Castejón-Limas et al. 2010), (Gidado 1996)	11%	3
	2	Variety of technological skills needed	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010), (Antoniadis et al. 2011), (Gidado 1996), (Hussein 2012), (Hussein et al. 2013), (Wood & Gidado 2008), (Xia & Lee 2004)	18%	2
	3	Technological degree of innovation	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Tatikonda 1999), (Castejón-Limas et al. 2010), (Remington et al. 2009)	11%	3
	4	Interaction between the technology system and external environment	(HE et al. 2012), (Hussein et al. 2013)	4%	5
	5	Risk of highly difficult technology	(HE et al. 2012), (Bosch-Rekveldt et al. 2011), (Remington et al. 2009)	5%	4
	6	Technological newness of the project	(Bosch-Rekveldt et al. 2011), (Vidal & Marle 2008), (Geraldi & Adlbrecht 2007), (Tatikonda 1999), (Shenhar et al. 2004), (Camci & Kotnour 2006), (Castejón-Limas et al. 2010), (Hussein et al. 2013), (Maylor et al. 2008), (Remington et al. 2009), (Yugue & Maximiano 2012)	20%	1
	7	Uncertainty in technical methods	(Qureshi & Kang 2014), (Williams 1999), (Geraldi 2009), (Müller et al. 2007), (Bosch-Rekveldt et al. 2011), (Hussein 2012), (Hussein et al. 2013), (Little & Graphics 2005), (Turner & Cochrane 1993), (Wood & Gidado 2008)	18%	2

Table 5-5. Factors contributing to Project Technological Complexity based on process approach (source: authors)

		Factors/characteristics	Referred to by	% of citations	Rank
Informational complexity (4.9%)	1	Variety of information systems to be combined	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (HE et al. 2012), (Qureshi & Kang 2014)	9%	2
	2	Number of information systems	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010), (Xia & Chan 2012), (Qureshi & Kang 2014), (Frame 2002)	13%	1
	3	Information uncertainty	(HE et al. 2012), (Ahern et al. 2013), (Hussein et al. 2013), (Remington et al. 2009)	7%	3
	4	Capacity of transferring information	(HE et al. 2012)	2%	5
	5	Level of processing information	(HE et al. 2012)	2%	5
	6	Degree of obtaining information	(HE et al. 2012), (Baccarini 1996)	4%	4

Table 5-6. Factors contributing to Project Informational Complexity based on process approach (source: authors)

Products/ Services complexity (1.6%)	Factors/characteristics		Referred to by	% of citations	Rank
	1	Variety of the product components	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Ramasesh & Browning 2014)	7%	1
	2	Highly customized products	(Maylor et al. 2008)	2%	2

Table 5-7. Factors contributing to Project's Products/Services Complexity based on process approach (source: authors)

		Factors/characteristics	Referred to by	% of citations	Rank
Clients' complexity (2.4%)	1	Client transparency, empathy (the personal and intangible matter that improves cooperation)	(Qureshi & Kang 2014), (Alderman & Ivory 2007), (Geraldi & Adlbrecht 2007), (Bosch-Rekveldt et al. 2011), (Svetlana Cicmil & Marshall 2005), (Hussein 2012)	11%	1
	2	Clients with unrealistic goals	(Remington et al. 2009)	2%	3
	3	Multiple suppliers, contractors, vendors, etc.	(Remington et al. 2009), (Xia & Lee 2004)	4%	2

Table 5-8. Factors contributing to Project's Client Complexity based on process approach (source: authors)

External environment complexity (8.9%)	Factors/characteristics		Referred to by	% of citations	Rank
	1	New laws and regulations	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010), (Qureshi & Kang 2014)	9%	3
	2	Local laws and regulations	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Azim 2010), (HE et al. 2012), (Xia & Chan 2012), (Qureshi & Kang 2014), (Bosch-Rekveldt et al. 2011), (Lessard et al. 2014), (Maylor et al. 2008)	18%	1
	3	Level of competition	(Vidal et al. 2011a), (Vidal et al. 2011b), (Vidal & Marle 2008), (Qureshi & Kang 2014), (Bosch-Rekveldt et al. 2011), (Maylor et al. 2008)	11%	
	4	Environment of changing technology, economy and nature	(HE et al. 2012), (Geraldi & Adlbrecht 2007), (Bosch-Rekveldt et al. 2011), (Frame 2002), (Xia & Lee 2004)	9%	3
	5	Multiple participating countries/location	(HE et al. 2012), (Bosch-Rekveldt et al. 2011), (Müller et al. 2007), (Hussein 2012), (Lessard et al. 2014), (Maylor et al. 2008), (Remington et al. 2009)	13%	2
	6	Neighboring environment (including the site access/location)	(Xia & Chan 2012), (Bosch-Rekveldt et al. 2011), (Leung Wing Tak 2007)	5%	4
	7	Geological condition/ difficulty of location	(Xia & Chan 2012), (Baccarini 1996), (Bosch-Rekveldt et al. 2011), (Lessard et al. 2014), (Leung Wing Tak 2007), (Sinha et al. 2006), (Wood & Gidado 2008)	13%	2
	8	External politics Issue	(Azim 2010), (Bosch-Rekveldt et al. 2011), (Hussein 2012)	5%	4
	9	Union power	(Bosch-Rekveldt et al. 2011)	2%	5
	10	Market uncertainty	(Little & Graphics 2005)	2%	5
	11	Number of governmental people who involved in projects	(Remington et al. 2009)	2%	5

Table 5-9. Factors contributing to Project Extenal environment Complexity based on process approach (source: authors)

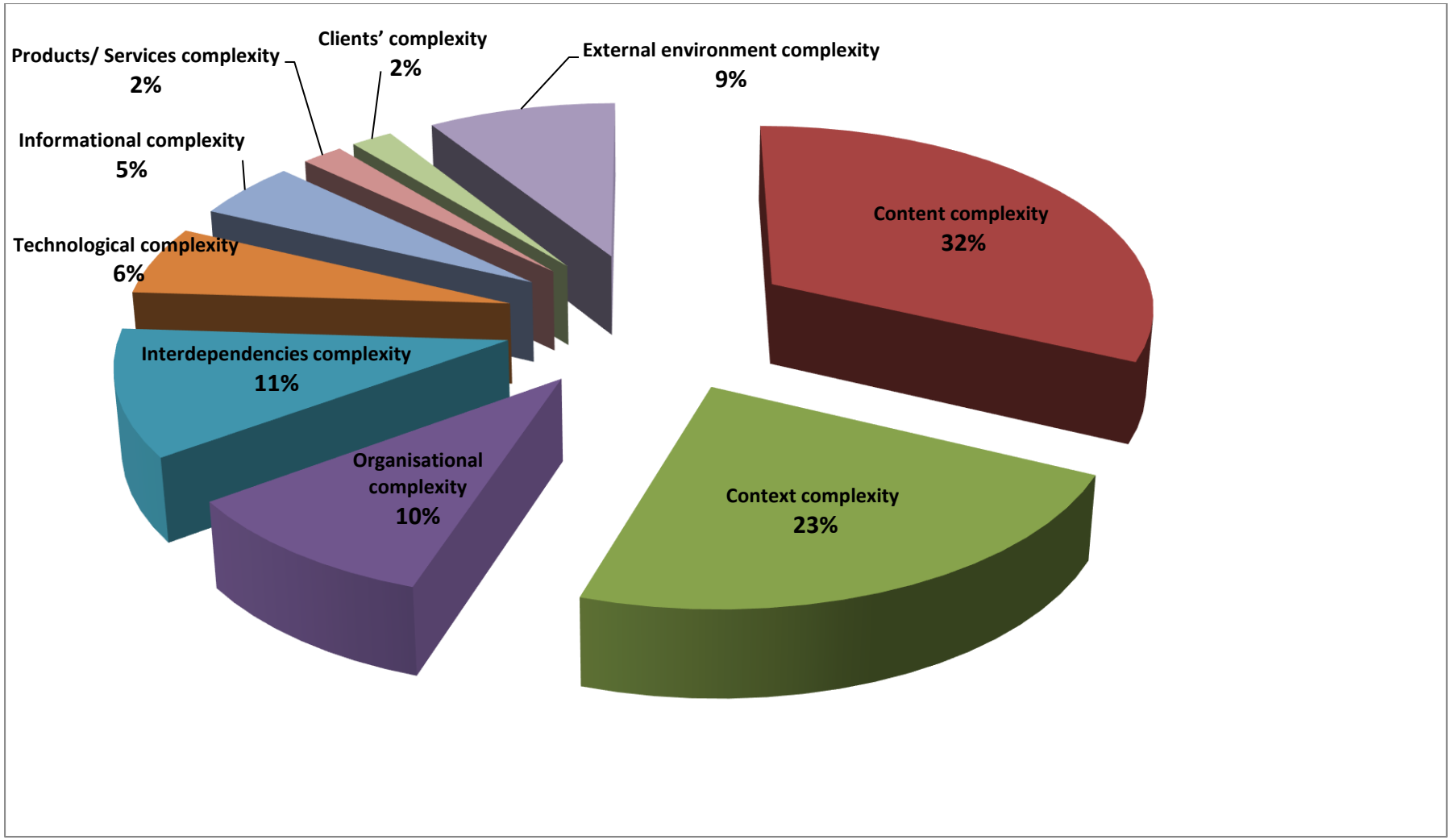


Figure 5-2. Percentage of project complexity dimensions based on number of factors (source: authors)

5.2. Project complexity factors (SoS Classification)

After analysing three schools of thought, distinctions between their perspectives are unavoidable. Although many characteristics are important to be considered in the context of project management in different views, I choose six dominant elements to compare them in the three positions. In our opinion, differentiation between each project can be analysed by context, autonomy, belonging, connectivity, diversity, emergence and size. From these descriptors, each complex project consists of autonomous and independent parts and different structures that belong to the same project and are connected to the other parts and departments of the project. Furthermore, the collection of actors, tasks and departments in the project is diverse in some sense and can generate unexpected emergent properties (Ireland et al. 2015). But these concepts require qualification. A project's context, including its environment and project organisation, is related to the nature, scope, environment where needs for and expectations of the project (Cicmil, 1997). Autonomy is exercised by constituent departments, teams or partners in order to fulfil the purpose of the project. Constituent departments/partners choose to be involved because there is a cost benefit for them to do so, but also because they believe in the overall project and it assists them with fulfilling their own independent objectives. The ability of a department/group to link with other parts of the project is connectivity. Diversity can be defined as "distinct or unlike elements or qualities in a group – the variation of social and cultural identities among people existing together in the project" (Sauser et al. 2009, p. 200). Apparently, "the appearance of new properties/behaviours in the course of development or evolution is considered emergent" (Sauser et al. 2009, p. 200).

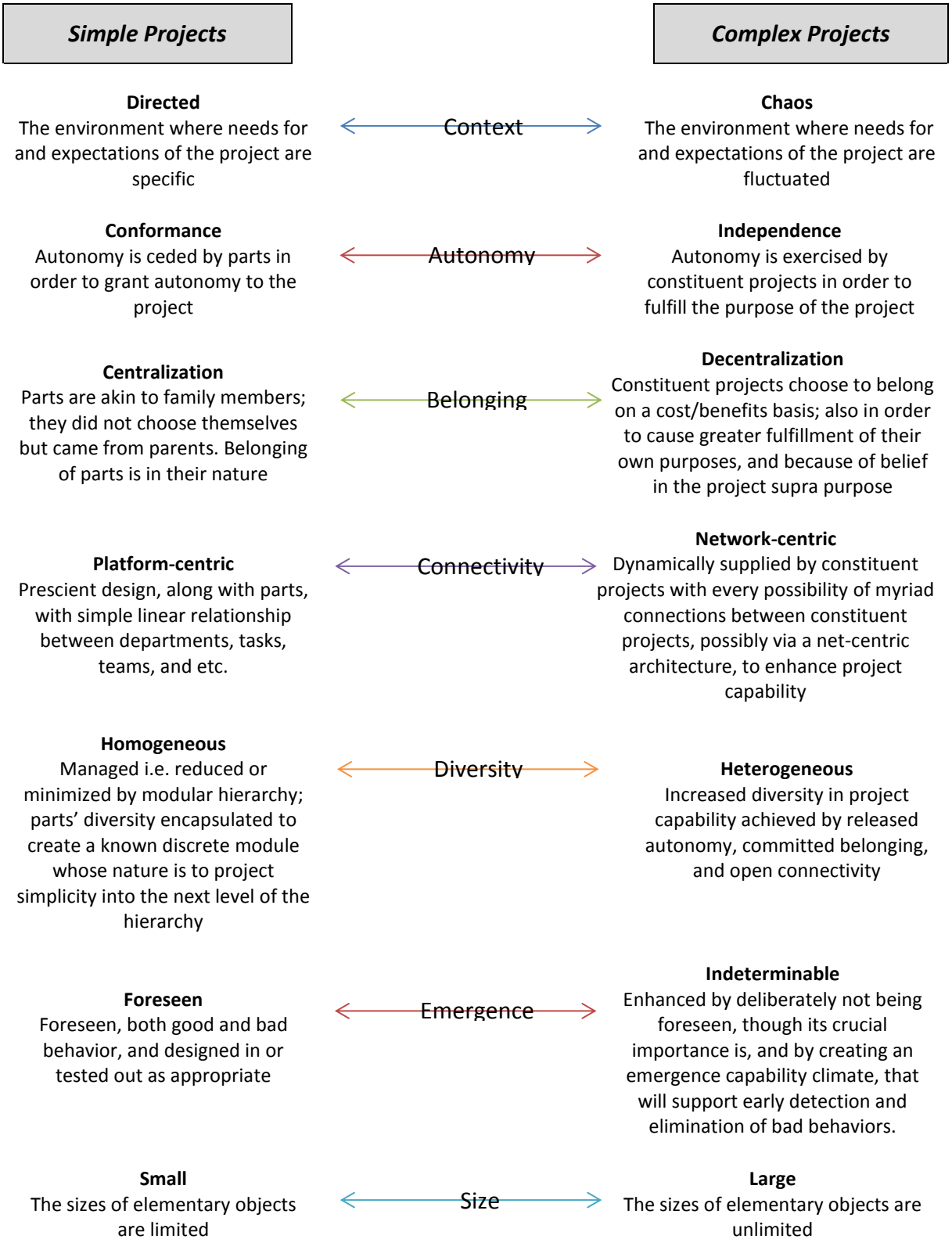


Figure 5-3. Project characteristics and their paradox adapted from (Sauser et al., 2009)

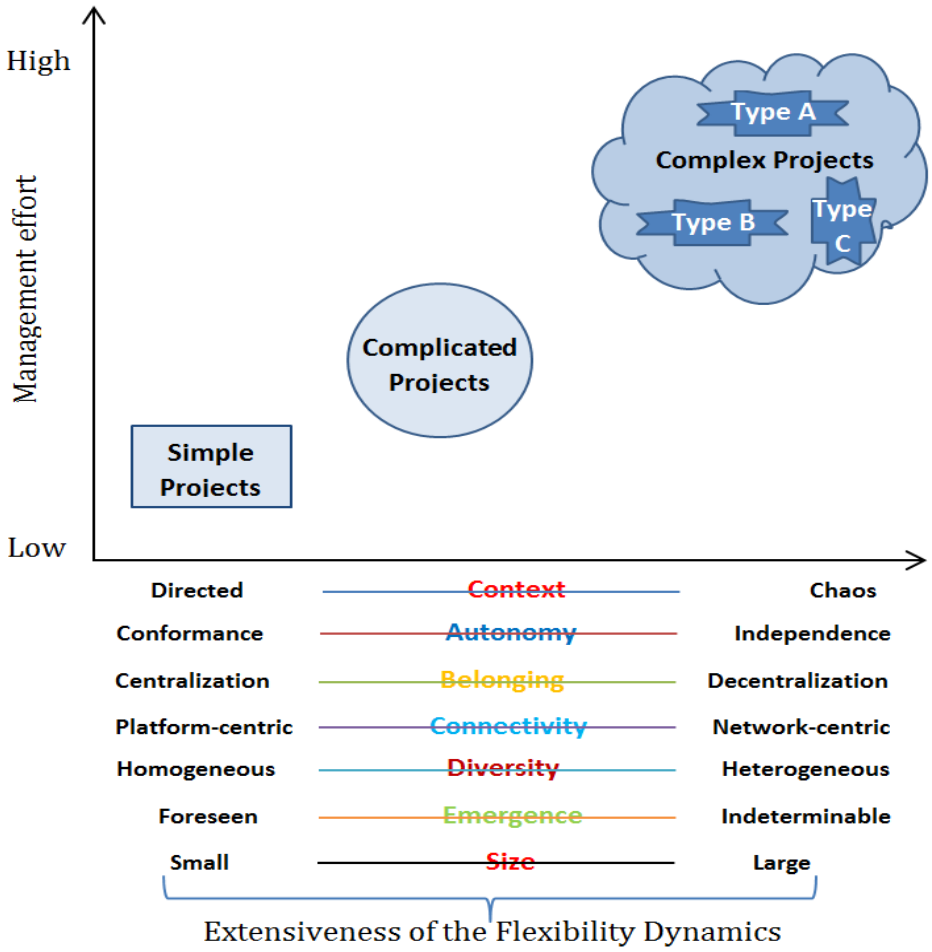


Figure 5-4. A typology of projects adapted from (Ireland et al., 2013)

Nevertheless, there are a vast number of factors that affect these characteristics. In other words, there are a variety of factors that change the degree of complexity. Over the last 25 years, project complexity factors have been collected and applied in numerous academic and practical researches. However, there is no international agreement on this and there are many ambiguous points to face with project complexity as a result. In the following, we have presented more than 125 factors that have been reported in different publications from a comprehensive literature review (Table 5.10). In order to help the audience to increase awareness of factors when dealing with the project complexity, it is important to define a clear framework for it. Based on this, we develop a new framework by using some past research (Sauser et al., 2009; Vidal, Marle, & Bocquet, 2011b) (Figure 5.5).

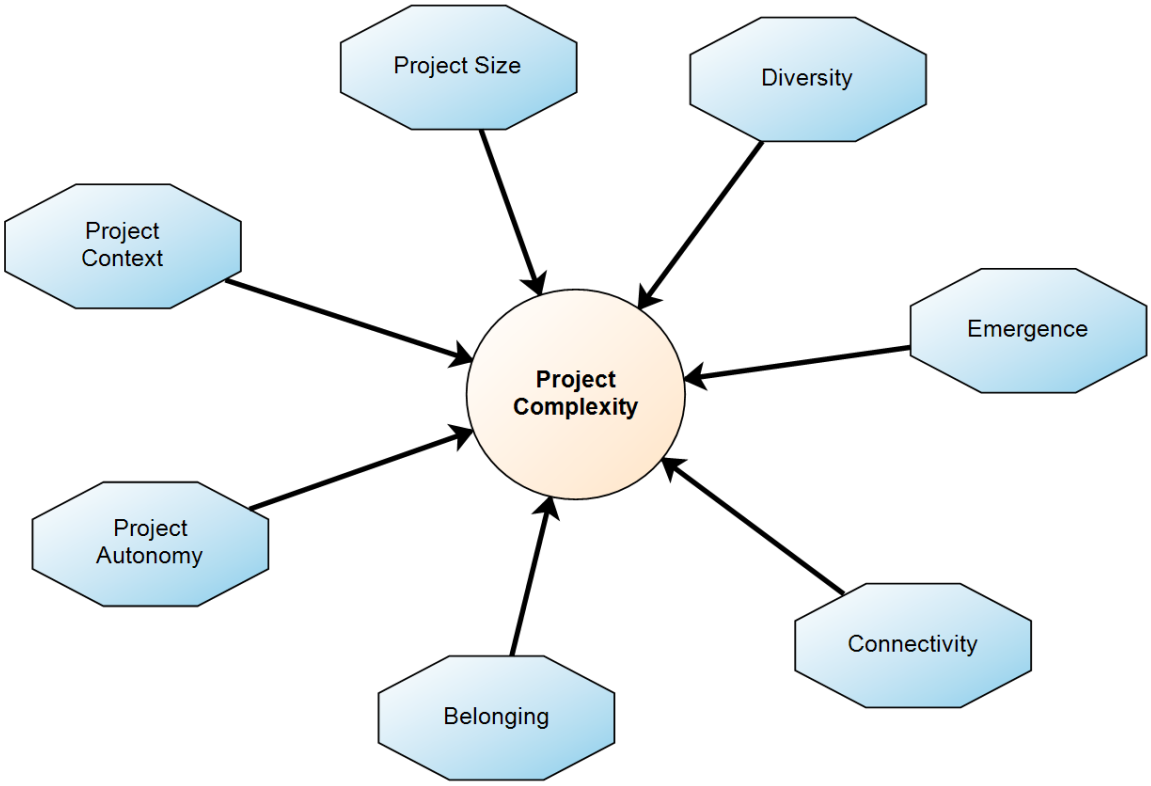


Figure 5-5. Drivers of project complexity based on SoS view (source: authors)

Dimension	Project complexity factors (provenance of complexity)	Number of referred	%	Rank	Referred to by
Context	Unusual type of design process	9	18	**7**	(Azim 2010; Akintoye 2000; Austin et al. 2002; Vidal et al. 2011a; Vidal & Marle 2008; Qureshi & Kang 2014; Geraldi 2008; Little & Graphics 2005; Maylor et al. 2008; Bosch-Rekveldt et al. 2011; Calinescu et al. 1998b; Xia & Chan 2012; Geraldi & Adlbrecht 2007; Hussein 2012; Müller et al. 2007; Favari 2012; Gidado 1996; Wood & Gidado 2008; HE et al. 2012; Hussein et al. 2013; Koivu et al. 2004; Lessard et al. 2014; Remington et al. 2009; Sinha et al. 2006; Crawford 2005; Baccarini 1996; Senescu et al. 2013; Xia & Lee 2004; Frame 2002; Leung Wing Tak 2007)
	Demand of creativity	9	18	**7**	
	Scope for development	7	14	**9**	
	Institutional configuration	10	20	**6**	
	Significant on public agenda	9	18	**7**	
	Degree of project flexibility (in scope, process, organisation…)	9	18	**7**	
	HSSE issues	7	14	**9**	
	Decision making process challenges	8	16	**8**	
	Repetition of similar type of projects	7	14	**9**	
	Internal politics Issue (ambiguity, hidden information)	12	24	**4**	
	Environment complexity (networked environment)	13	27	**3**	
	Cultural configuration	19	39	**1**	
	Form of contract	10	20	**6**	
	Overlapping office hours	6	12	**10**	
	Stability project environment	4	8	**12**	
	Experience with parties involved	5	10	**11**	
	Project drive	7	14	**9**	
	Commercial newness of the project (new partners, teams etc.)	9	18	**7**	
	Conflict between stakeholders	7	14	**9**	
	Level of competition between stakeholders	12	24	**4**	
	Lack of support (top management, users, staff members etc.)	7	14	**9**	
	Organisational degree of innovation	10	20	**6**	
	New laws and regulations	11	22	**5**	
	Local laws and regulations	16	33	**2**	
	Level of competition	12	24	**4**	
	Environment of changing technology, economy and nature	11	22	**5**	
	Functional role	7	14	**9**	
	Degree of obtaining information	5	10	**11**	
	Interaction between the technology system and external environment	5	10	**11**	
	Organisational risks	7	14	**9**	
	Neighbouring environment (including the site access/location)	9	18	**7**	
	Geological condition/difficulty of location	13	27	**3**	
	External politics issue	9	18	**7**	
	Union power	7	14	**9**	
Belonging	Quality requirements	8	16	**7**	(Xia & Chan 2012; Bosch-Rekveldt et al. 2011; Hussein 2012; Remington et al. 2009; Azim 2010; Geraldi & Adlbrecht 2007; Vidal et al. 2011b; Vidal et al. 2007; Vidal & Marle 2008; Gidado 1996; Qureshi & Kang 2014; Hussein et al. 2013; Baccarini 1996; Little & Graphics 2005; Xia & Lee 2004; Maylor et al. 2008; Antoniadis et al. 2011; Ramasesh & Browning 2014; Alderman & Ivory 2007; S. Cicmil & Marshall 2005; Tatikonda 1999; Castejón-Limas et al. 2010; Shenhar et al. 2004; Camci & Kotnour 2006; Yugue & Maximiano 2012)
	Cost restraints (cost and financing)	9	18	**6**	
	Specific requirements/standards	13	27	**2**	
	Capability (knowledge, experience, education, training etc.)	11	22	**4**	
	Technical capability of team	10	20	**5**	
	Unknown/poorly defined requirements	10	20	**5**	
	Bespoke software or hardware	1	2	**10**	
	Trust in stakeholders	13	27	**2**	
	Team transparency, empathy (the personal and intangible matter that improves cooperation)	8	16	**7**	
	Project Manager competencies	9	18	**6**	
	Technological degree of innovation	12	24	**3**	
	Risk of highly difficult technology	9	18	**6**	
	Technological newness of the project	17	35	**1**	
	Highly customised products	2	4	**9**	
	Responsibility & Accountability	8	16	**7**	
	Requirements capture	3	6	**8**	

Table 5-10. Project complexity factors based on SoS view (source: authors)

Dimension	Project complexity factors (provenance of complexity)	Number of referred	%	Rank	Referred to by
Autonomy	Availability of people, material and of any resources due to sharing	16	33	**3**	(Vidal et al. 2011a; Vidal et al. 2007; Vidal & Marle 2008; Vidal et al. 2011b; HE et al. 2012; Qureshi & Kang 2014; Baccarini 1996; Thomas & Mengel 2008; Bosch-Rekveldt et al. 2011; Antoniadis et al. 2011; Azim 2010; Xia & Chan 2012; Geraldi & Adlbrecht 2007; S. Cicmil & Marshall 2005; Kennedy et al. 2011; Senescu et al. 2013; Sinha et al. 2006; Wood & Gidado 2008; Gidado 1996; Pich et al. 2002; Remington et al. 2009; Hussein et al. 2013; Maylor et al. 2008; Favari 2012; Williams 1999; Green 2004; Lessard et al. 2014; Little & Graphics 2005; Yugue & Maximiano 2012; Tatikonda & Rosenthal 2000; Maier 1998)
	Level of interrelation of between phases	9	18	**10**	
	Team/partner cooperation and communication	22	45	**1**	
	Levels of management are involved in project decision-making	5	10	**12**	
	The amount of overlap and interactions	11	22	**8**	
	Dynamic and evolving team structure	12	24	**7**	
	Dependencies with the environment	12	24	**7**	
	Interdependencies between sites, departments and companies	19	39	**2**	
	Interdependencies of objectives/interests	16	33	**3**	
	Process interdependence	15	31	**4**	
	Stakeholders interrelation/interdependencies	12	24	**7**	
	Interdependencies between actors	13	27	**6**	
	Specifications interdependence	10	20	**9**	
	Interdependence between components of the product	5	10	**12**	
	Technological process dependencies	14	29	**5**	
	Resource and raw material interdependence	10	20	**9**	
	Dependencies between schedules	13	27	**6**	
	Interdependencies of information systems	11	22	**8**	
	Number of governmental people who involved in projects	7	14	**11**	
	Combined transportation	9	18	**10**	
Connectivity	Interconnectivity and feedback loops in the task and project networks	16	33	**1**	(Vidal et al. 2011a; Vidal & Marle 2008; HE et al. 2012; Qureshi & Kang 2014; Williams 1999; Bosch-Rekveldt et al. 2011; Favari 2012; Gidado 1996; Green 2004; Kennedy et al. 2011; Ramasesh & Browning 2014; Lessard et al. 2014)
	Face to face relationship between project team members	4	8	**6**	
	Number of interfaces in the project organisation	9	18	**3**	
	Relations with permanent organisations	10	20	**2**	
	Capacity of transferring information	5	10	**4**	
	Level of processing information	5	10	**5**	
	Goals/interests alignment	16	33	**1**	
Emergence	Dynamics of the task activities	8	16	**5**	(Janus et al. 2001; HE et al. 2012; Ramasesh & Browning 2014; Vidal et al. 2011a; Vidal & Marle 2008; Azim 2010; Bosch-Rekveldt et al. 2011; Müller et al. 2007; Geraldi et al. 2011; Geraldi & Adlbrecht 2007; Akintoye 2000; Maylor et al. 2008; Senescu et al. 2013; Shenhar 2001b; Yugue & Maximiano 2012; Crawford 2005; Turner & Cochrane 1993; Wood & Gidado 2008; Little & Graphics 2005)
	Uncertainties of scope	18	37	**1**	
	Uncertainty & clarity of objectives or goals	17	35	**2**	
	Uncertainty in technical methods	16	33	**3**	
	Information uncertainty	10	20	**4**	
	Clients with unrealistic goals	7	14	**6**	
	Market uncertainty	5	10	**7**	

Continued table 5-10. Project complexity factors based on SoS view (source: authors)

Dimension	Project complexity factors (provenance of complexity)	Number of referred	%	Rank	Referred to by
Diversity	Variety of financial resources	14	29	**4**	(Vidal et al. 2011a; Vidal et al. 2007; Vidal & Marle 2008; Vidal et al. 2011b; Azim 2010; Qureshi & Kang 2014; Geraldi & Adlbrecht 2007; Müller & Turner 2007; Thomas & Mengel 2008; Bosch-Rekveldt et al. 2011; Baccarini 1996; S. Cicmil & Marshall 2005; Hussein 2012; HE et al. 2012; Xia & Chan 2012; Akintoye 2000; Camci & Kotnour 2006; Ramasesh & Browning 2014; Williams 1999; Gidado 1996; Green 2004; Frame 2002; Maylor et al. 2008; Sinha et al. 2006; Santana 1990; Remington et al. 2009; Yugue & Maximiano 2012; Castejón-Limas et al. 2010; Xia & Lee 2004; Wood & Gidado 2008; Lessard et al. 2014; Maier 1998)
	Variety of organisational skills needed	13	27	**5**	
	Variety of the project management methods and tools applied	18	37	**2**	
	Variety of resources to be manipulated	10	20	**8**	
	Diversity of tasks	11	22	**7**	
	Diversity of inputs and/or outputs	9	18	**9**	
	Variety of the interests of the stakeholders	18	37	**2**	
	Diversity of staff (experience, social span ...)	13	27	**5**	
	Variety of the stakeholders status	10	20	**8**	
	Cultural variety	19	39	**1**	
	Number of different languages	10	20	**8**	
	Multiple time zones	5	10	**11**	
	Variety of hierarchical levels within the organisation	11	22	**7**	
	Variety of organisational interdependencies	16	33	**3**	
	Variety of technological dependencies	13	27	**5**	
	Variety of the technologies used during the project	12	24	**6**	
	Variety of technological skills needed	16	33	**3**	
	Multiple participating countries/location	13	27	**5**	
	Geographic location of the stakeholders	12	24	**6**	
	Variety of information systems to be combined	11	22	**7**	
	Variety of the product components	10	20	**8**	
	Client transparency, empathy (the personal and intangible matter that improves cooperation)	12	24	**6**	
	Multiple suppliers, contractors, vendors, etc.	8	16	**10**	
Size	Number of decisions to be made	10	20	**12**	(Vidal et al. 2011a; Vidal et al. 2007; Vidal & Marle 2008; Vidal et al. 2011b; Azim 2010; Qureshi & Kang 2014; Geraldi & Adlbrecht 2007; Müller & Turner 2007; Thomas & Mengel 2008; Bosch-Rekveldt et al. 2011; Baccarini 1996; S. Cicmil & Marshall 2005; Hussein 2012; HE et al. 2012; Xia & Chan 2012; Akintoye 2000; Camci & Kotnour 2006; Ramasesh & Browning 2014; Williams 1999; Gidado 1996; Green 2004; Frame 2002; Maylor et al. 2008; Sinha et al. 2006; Santana 1990; Remington et al. 2009; Yugue & Maximiano 2012; Castejón-Limas et al. 2010; Xia & Lee 2004; Wood & Gidado 2008; Lessard et al. 2014; Nassar & Hegab 2006; Leung Wing Tak 2007; Shenhar et al. 1995; Shenhar 2001a; Doyle & Hughes 2000; Crawford 2005)
	Duration of the project	18	37	**4**	
	Number of deliverables/disciplines	17	35	**5**	
	Number and quantity of resources	12	24	**10**	
	Number of activities	15	31	**7**	
	Largeness of capital investment	11	22	**11**	
	Number of the project management methods and tools applied	18	37	**4**	
	Number of different occupational specialisations	5	10	**15**	
	Number of inputs and/or outputs	9	18	**13**	
	Largeness of scope (number of components etc.)	18	37	**4**	
	Size in CAPEX (Capital expenditures)	7	14	**14**	
	Number of stakeholders	23	47	**2**	
	Number of companies/projects sharing their resources	16	33	**6**	
	Number of formal units & departments involved	22	45	**3**	
	Number of objectives	14	29	**8**	
	Number of investors	12	24	**10**	
	Staff quantity	10	20	**12**	
	Number of structures/groups/teams to be coordinated	25	51	**1**	
	Number of hierarchical levels	14	29	**8**	
	Number of information systems	13	27	**9**	

Continued table 5-10. Project complexity factors based on SoS view (source: authors)

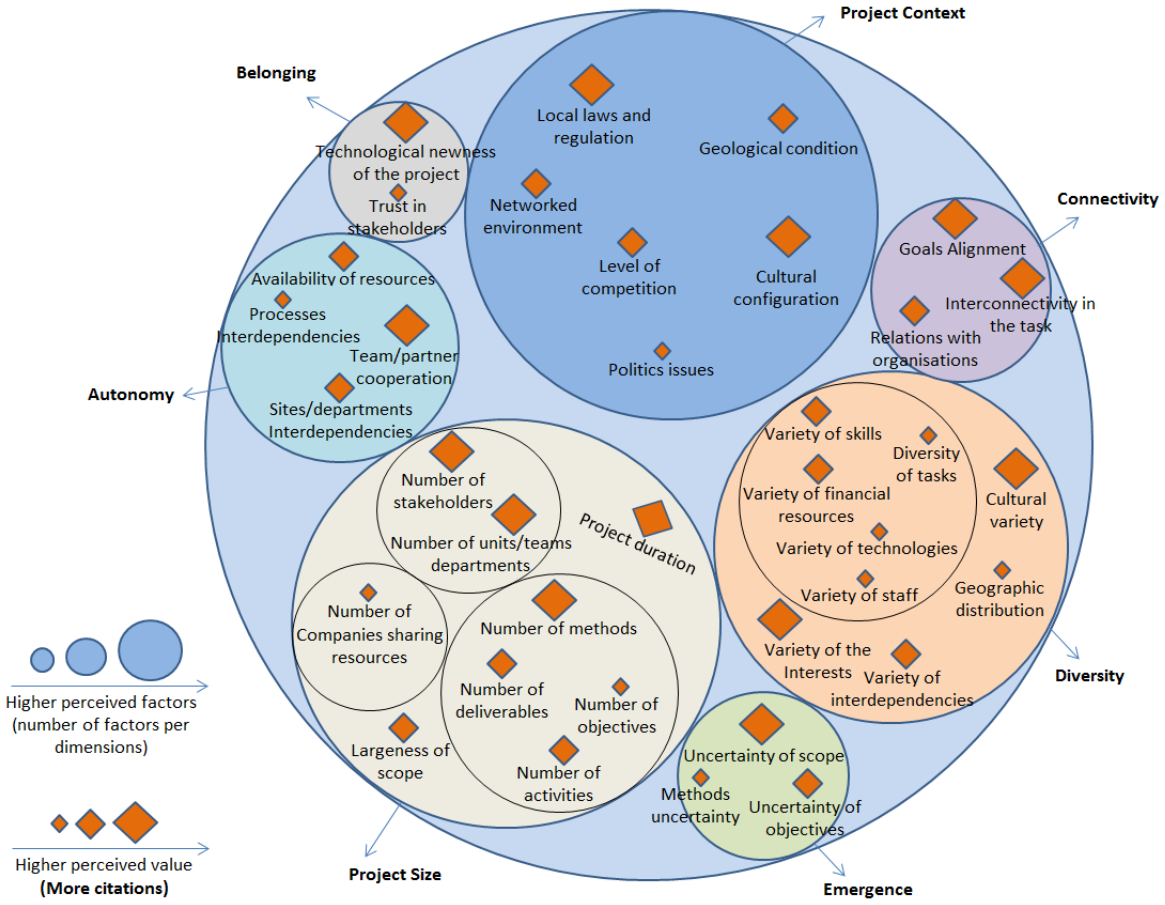


Figure 5-6. Project complexity factors according to number of citations represented by published view

5.3. Selected Major Project complexity factors

In this section, I use an innovative decision making algorithm to select major project complexity factors according to three criteria; top authors, peer reviewed journals and number of citations. This research takes the Fuzzy Simple Additive Weighting (SAW) method along with Shannon entropy to evaluate complexity factors according to the mentioned criteria with the following steps (Chen 2012; Soleimani-damaneh & Zarepisheh 2009; Wu et al. 2011).

Step 1. Identifying specific criteria: as mentioned above, this study use three criteria including top authors, peer reviewed journals and number of citations. These criteria could be very useful to characterize the scientific result of researchers (Hirsch 2005).

Step 2. Fuzzy criteria weight: in this stage, I take advantage of triangular fuzzy numbers (TFNs) to show the importance of each criteria as shown in table number 5.11. Fuzzy set introduced by Zadeh (1965) to address linguistic variables and fuzzy phenomena. It is very useful in human reasoning and uncertainty situations as well (Zadeh, 1997). "In a universe of discourse *X*, a fuzzy subset $\widetilde{A}$ of *X* is defined with a membership function $\mu_{\widetilde{A}}(x)$ that maps each element *x* in *X* to a real number in the interval [0, 1]. The function value of $\mu_{\widetilde{A}}(x)$ signifies the grade of membership of *x* in $\widetilde{A}$. When $\mu_{\widetilde{A}}(x)$ is large, its grade of membership of *x* in $\widetilde{A}$ is strong" (Chou et al. 2008, p. 134).

Linguistic variables	(TFNs)
Very low important	(0,1,3)
Low important	(1,3,5)
Medium	(3,5,7)
Important	(5,7,9)
Very important	(7,9,10)

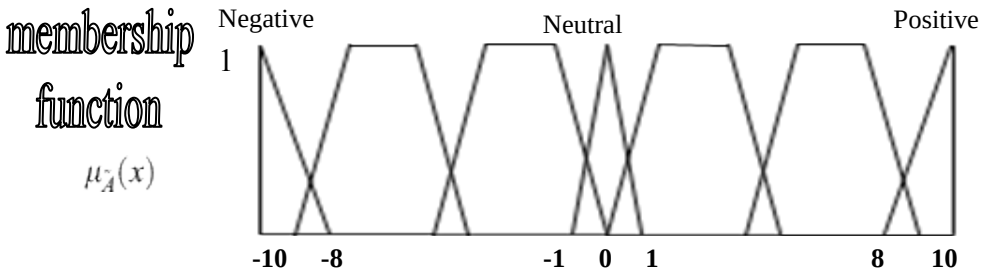
Table 5-11. Importance weight of criteria according to TFN adapted from Lin, Liao, & Chang (2010)

Step 3. Construct the aggregated fuzzy rating matrix: for considering the score of each project complexity factor with regard to the mentioned criteria, I use a scoring system which is shown in table 5.12.

TFN / Criteria	(-8,-9,-10)	(-1,0,1)	(8,9,10)
Top authors	Less than 5 related publications	Between 10 to 30 related publications	More than 30 related publications
Citations	Less than 10 citations	i10-index	h-index
Peer review journals	Not included to the ERA 2010	C and B rank	A rank

Table 5-12. Complexity factor scoring system (source: authors)

The h-index and i10-index are "author-level metric that attempts to measure both the productivity and citation impact of the publications of a scientist or scholar" (Hirsch 2005, p. 16569).



Step 4. Construct the decision making matrix based on FSAW: after indicating scoring system, we should build up decision matrix and compute the value of each project complexity factors according to the following formula.

$$U_i = \sum_{j=1}^{n} w_j \cdot n_{ij}$$

Equation (1)

$$w_j = weight\ of\ criteria\ j; j = 1,2,3$$

$$n_{ij} = \{(X_{ij}, \mu(x_{ij}))\};\ \forall i,j$$

Step 5. Defuzzification phase: I use below defuzzification equation to obtain crisp value of each project complexity factors and finally rank them (Chou et al. 2008).

$$X = m + (\frac{\beta - \alpha}{4})$$

Equation (2)

Fuzzy Aggregated ratings (m, α, β)	**Defuzzified values of factors (Rating)** $X = m + (\frac{\beta - \alpha}{4})$	**Rank**
(2.63, 3.51, 4.39)	$X = 2.63 + \left(\frac{4.39 - 3.51}{4}\right) = 2.85$	**3**
(6.41, 7.29, 8.17)	$X = 6.41 + \left(\frac{8.17 - 7.29}{4}\right) = 6.63$	**1**
(2.83, 3.69, 4.55)	$X = 2.83 + \left(\frac{4.55 - 3.69}{4}\right) = 3.04$	**2**

Table 5-13. Example of defuzzification phase

One example according to the top authors' criteria has been presented in appendix I. this process operates for three times to achieve a classification of project complexity factors (figure number 5.7).

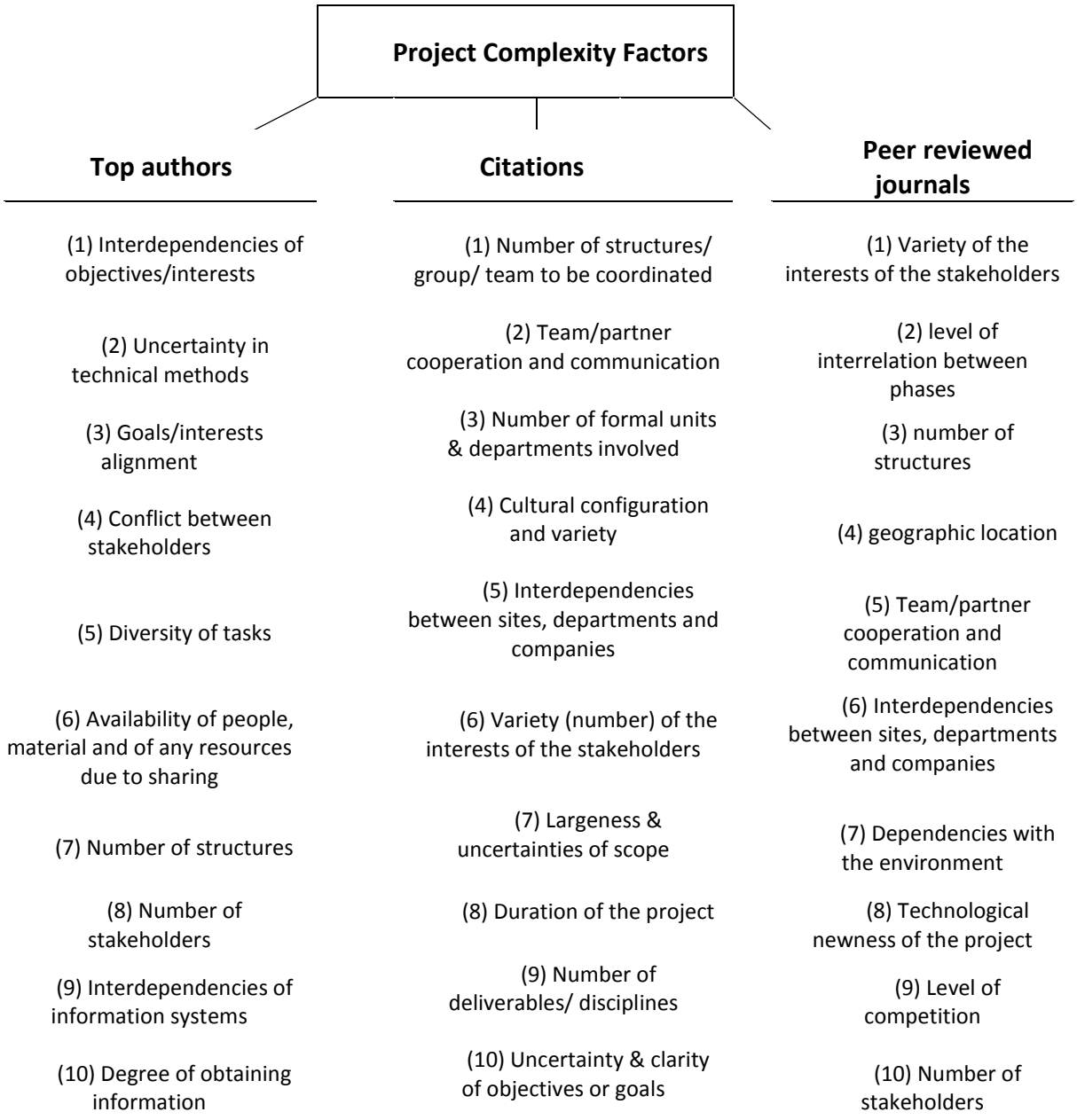


Figure 5-7. Top ten project complexity factors according to the different criteria (source: authors)

5.4. Conclusion

More than 125 project complexity factors have been provided by an in-depth literature review. It is worth mentioning that the analysis is not organised or differentiated by the different types of projects (e.g., engineering & construction, IT, industrial and business, defence, etc.). This level of analysis could be an interesting topic for future research. More attention needs to be paid to system thinking approach and how the relationship within complexity factors is. This study enables both practitioners and academics to understand attributes and characteristics of complex projects. The main contribution will correspond to insights embedded in the framework that can assist in decision-making processes in complex projects.

Chapter 6 -

Conclusion; a proposal for PhD

This thesis reviews the existing perspectives of project complexity in order to understand its concepts and investigates the differences between schools of thought. The research explores the historical development of project complexities. Moreover, more than 125 project complexity factors have been provided by an in-depth literature review. It is worth mentioning that the analysis is not organised or differentiated by the different types of projects (e.g., engineering & construction, IT, industrial and business, defence, etc.). This level of analysis could be an interesting topic for future research. More attention needs to be paid to the system thinking approach and the relationship within complexity factors. How these characteristics operate in various types of projects require more exploration. Most attention needs to be paid to characteristics such as Paretian and power laws distributions, operating at the edge of chaos, chaotic behaviour, scale laws, fractals, fitness landscape, adaptive cycles etc. (Ireland 2015). It is worth noting that some project complexity factors which have been collected in the literature cannot be part of complexity as mentioned in previous sections. For instance, technological newness of the project and specific requirements can be seen as lack of knowledge and familiarity of parts which is related to the complicated problems. This study enables both practitioners and academics to understand attributes and characteristics of complex projects. The main contribution will correspond to insights embedded in the framework that can assist in decision-making processes in complex projects.

6.1. Complex Projects Governance: developing a social networking approach with trust building and cultural aspects

Successful projects play critical role in productivity and organizational value. Effective project governance structure can be one of the dominant factors of project's success (Zwikael & Smyrk, 2015). "Governance is a tool to monitor the behaviour of the system and ensure it stays within the bounds of the system objectives. Governance is probably about monitoring outcomes regularly and bringing the system back onto course before it diverges too far" (Ireland, 2016, p. 5). As my research clearly shows that complex project governance is decentralised and autonomous teams exist. Thus, the nessesity of a project governance model according to the degree of complexity is unavoidable.

Projects are becoming more complex due to unexpected emergent behavior and characteristics. Complex projects can be seen as autonomous and independent systems which are often defined as self-organizing, unpredictable, uncontrollable and flexible. Complexity is one of the most important variables contributing to projects' failure and it has become the main concerns of project management field (Ireland et al. 2012). Regarding the complexity level, according to a series of hierarchical projects, it can be divided into simple, complicated, complex and chaotic. Indeed, it can be said that traditional projects (simple) and complex projects have significant differences which can be determined by different criteria such as environment effect, project goal, project control and management style (Shenhar et al. 2004). It is worth mentioning that many projects lie across the spectrum rather than being only on one side. On the other hand, a project can be defined as a system. This metaphor is used to better understand the nature of complex projects and manage them efficiently (Ireland, Rapaport, & Omarova, 2012; Vidal, Marle, & Bocquet, 2011).

Based on this concepts it is specified that other techniques and tools for management of traditional projects cannot be easily used as a complex projects. This principle is not because of the difficulty in understanding issues within the projects or unfamiliarity with different phenomena (complicated Projects) but also because of the autonomy and non-linear relationship between the components, capacity to adapt as conditions change and also

unpredictable behaviors or emergency (Ireland et al. 2012; Geraldi et al. 2011; Glouberman & Zimmerman 2002).

So, the key question is what factors contribute to complex projects. In other words, what factors make or increase complexity of projects. Although there is extensive research in this area, however, there is still a lack of understanding on project complexities. In 2013, Project Management Institute published an in-depth report called "Navigating Complexity". The report shows that multiple stakeholders and ambiguity are two key characteristics of project complexity. This report highlighted the role of leadership skills as the most important skills to managing successfully complex projects (PMI, 2013B).

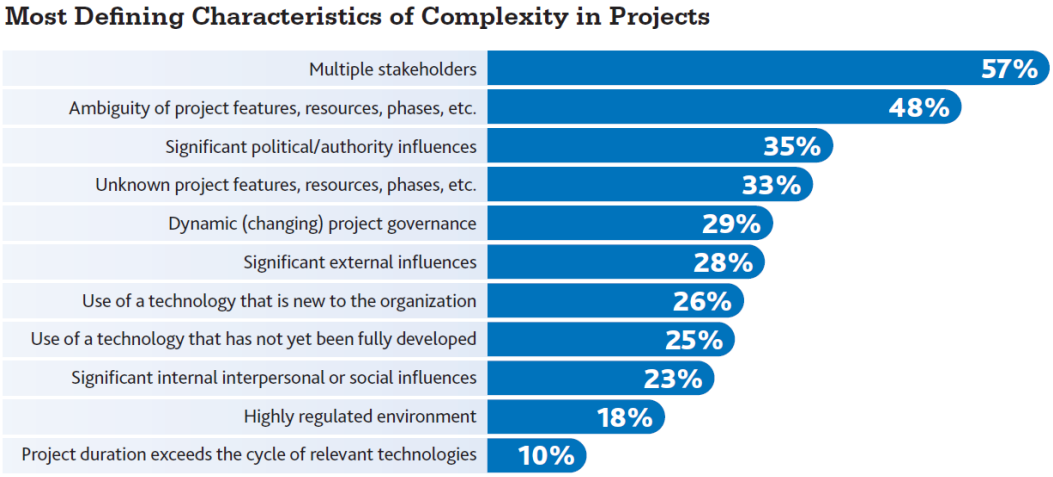


Figure 6-1. Most project complexity factors adapted from PMI's Pulse of the Profession™ In-Depth Report (PMI, 2013B)

Meanwhile stakeholders play a vital role in projects; lack of clarity in purposes besides conflicts among them can increase the project complexities and affect the possibility of success for a project. It is clear that stakeholders have different and various needs and purposes all of which must be taken into account mentioning that these are likely to change during progressing a project, otherwise it can follow some aftermath such as unsolvable conflicts and the worst of all terminations of a project. How to consider these conflicts effectively is the main challenge among stakeholders' interaction on projects. Conflict is a completely natural and unavoidable phenomenon in project management which is caused by many reasons in different forms. Having different stakeholders with various traits in personalities, needs, beliefs, values, expectations, and understandings has brought about the

inevitable conflicts in projects. Furthermore, the present structures of projects and lack of flexible-changing systems affected by environment have made them vulnerable to tension, conflict and incompatibility. It can be realized in different forms like competition, discussion, argument and challenge among people and groups. Although many scholars realize conflict, contrast and lack of agreement as negative, exact management and intelligent monitoring can change it into a positive and constructive phenomenon (Hempel et al., 2009; Rapaport & Ireland, 2012).

Generally speaking, conflict is a process by which a part feels that the other is doing some activities to ban them reaching their purposes and favorites (Greenberg and Baron, 1997). Conrad and Scott believe that conflict is the social interaction of individuals who are dependent on each other and feel that their favorites are contradictory, incompatible and conflicting (Conrad and Scott, 2002). Researches have shown that almost 20% of managers' time is allocated to coping with conflicts. Moreover, researchers have come up with this conclusion that conflict management among stakeholders and senior manager level is as or even more important than planning, organizing, communicating, motivation and decision-making. In other research, the conflict management has been known as the most effective factor among the other 25 factors for success among managers (Salami., 2010).

As it is clear from above, the most important reason for having a conflict in complex projects can be found in not having methods that are capable of designing common strategies and purposes on the basis of complexity and uncertainty of the environment which is definitely the concern of this study. In other words, although the present methods design purposes regarding to past and present data, there is a need to estimate the future needs considering the complexity of these systems. To meet this purpose, this research will intend to develop a model for effective planning of strategies and purposes regarding the future condition of stakeholders and conflict-resolutions via combining Robust Intelligent Scenario Planning and Strategic assumptions surface testing.

As it is clear from the definition, the role of social interaction and actors' cooperation cannot be ignored in projects' nature. That's why networking can play an undeniable part in advertising and publicizing the cluster. Social networks are a fast route for increasing the

social capital level and has a key role in sustaining cooperation experience (Bell et al., 2010; Felzensztein and Gimmon, 2008). Research have shown that social networks have a significant impact on systems to be successful or failed. Generally speaking, networks are a set of various relationships among cluster actors that cooperate with each other in facing with common challenges and opportunities (Mackinnon et al., 2004). Social networks can be divided into different types such as vertical, horizontal, soft and hard networks and so forth based on relationship type, trust level and the scope of the purpose.

As it also went on above, there is a high correlation between social networks' condition and complex project performance. Upon this, the efficiency of networks is of high importance that can have a vital role in projects performance to be whether effective or not. On the other hand, the review of literature shows that the social network failure rate is high. Many reasons have been mentioned in this regard such as cultural structure, environmental uncertainty, actors' trust level and knowledge heterogeneity. According to the investigations, there has been proved that a significant gap exists regarding practical peculiarities of social networks on the basis of project environmental and structural criteria which is the main concern in this research. To face with such challenges, this research will develop a networking approach benefitted from culture, social capital and inter-clustral trust level investigating the networking and trust building aspects. Besides, to cope with social-cultural and technical challenges, best practices will be benchmarked in this regard. In this contribution, we will take the challenge of investigating the flaws of traditional approaches; thereafter we will develop a system thinking approach as a new vision of networking towards a new approach of associated with notions of "flexible specialisation" and the "new competition".

Future studies will be looking to answer the following questions:

1) How is the relationship between networking and stakeholders trust level and how it must be shaped to increase social network efficiency?
2) Which tools or methods can measure the social network actors' trust level?

3) What characteristics can be regarded for networking systematic approach regarding elements such as culture, social capital and trust level?

These concepts will be tested within six complex projects including:

- Ebola or another pandemic deaseases
- a traditional construction project
- a defence project
- improving a company
- addressing indigenous disadvantage in Australia
- outbreak of terrorist groups

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Appendix I

Decision matrix based on Fuzzy SAW

	0.5 (0,1,3)	0.5 (0,1,3)	7.25 (7,9,10)			
Complexity factor	**Peer review Journals**	**Citations**	**Top Authors**	**Fuzzy Aggregated ratings**	**Ratings**	**Rank**
Unusual type of design process	(2,3,4)	(-5,-6,-7)	(1,2,3)	(5.75,13,20.3)	7.56	36
Demand of creativity	(1,2,3)	(-1,0,1)	(1,2,3)	(7.25,15.5,23.8)	9.31	34
Scope for development	(1,2,3)	(-8,-9,-10)	(1,2,3)	(3.75,11,18.3)	5.56	38
Institutional configuration	(3,4,5)	(-1,0,1)	(1,2,3)	(8.25,16.5,24.8)	10.31	32
Significant on public agenda	(1,2,3)	(-8,-9,-10)	(1,2,3)	(3.75,11,18.3)	5.56	38
Degree of project flexibility (in scope, process, organisation…)	(3,4,5)	(-1,0,1)	(3,4,5)	(22.7,31,39.3)	24.81	21
HSSE issues	(-1,0,1)	(-8,-9,10)	(1,2,3)	(2.7,10,17.3)	4.56	39
Decision making process challenges	(-1,0,1)	(-1,0,1)	(2,3,4)	(13.5,21.8,30)	15.56	28
Repetition of similar type of projects	(-1,0,1)	(-1,0,1)	(-1,0,1)	(-8.2,0,8.2)	-6.19	41
Internal politics Issue (ambiguity, hidden information)	(1,2,3)	(1,2,3)	(1,2,3)	(8.25,16.5,24.8)	10.31	32
Environment complexity (networked environment)	(1,2,3)	(-1,0,1)	(1,2,3)	(7.25,15.5,23.8)	9.31	34
Cultural configuration	(2,3,4)	(2,3,4)	(4,5,6)	(31,39.3,47.5)	33.06	15
Form of contract	(-1,0,1)	(-1,0,1)	(-1,0,1)	(-8.2,0,8.2)	-6.19	41
Overlapping office hours	(-1,0,1)	(-1,0,1)	(-1,0,1)	(-8.2,0,8.2)	-6.19	41
Stability project environment	(-1,0,1)	(-8,-9,10)	(1,2,3)	(2.7,10,17.3)	4.56	39
Experience with parties involved	(-1,0,1)	(-8,-9,10)	(1,2,3)	(2.7,10,17.3)	4.56	39
Project drive	(-1,0,1)	(-1,0,1)	(-1,0,1)	(-8.2,0,8.2)	-6.19	41
Commercial newness of the project (new partners, teams etc.)	(-1,0,1)	(-8,-9,10)	(1,2,3)	(2.7,10,17.3)	4.56	39
Conflict between stakeholders	(3,4,5)	(5,6,7)	(8,9,10)	(62,70.3,78.5)	64.0	4
Level of competition between stakeholders	(4,5,6)	(2,3,4)	(2,3,4)	(17.5,25.8,34)	19.56	25
Lack of support (top management, users, staff members etc.)	(1,2,3)	(-8,-9,-10)	(1,2,3)	(3.75,11,18.3)	5.56	38
Organisational degree of innovation	(1,2,3)	(-8,-9,-10)	(1,2,3)	(3.75,11,18.3)	5.56	38
New laws and regulations	(1,2,3)	(3,4,5)	(1,2,3)	(9.25,17.5,25.8)	11.31	30
Local laws and regulations	(1,2,3)	(3,4,5)	(1,2,3)	(9.25,17.5,25.8)	11.31	30
Level of competition	(5,6,7)	(-1,0,1)	(2,3,4)	(16.5,24.8,33)	18.56	26

Table I. FSAW decision matrix according to the top authors criteria (source: authors)

	0.5 (0,1,3)	0.5 (0,1,3)	7.25 (7,9,10)			
Complexity factor	**Peer review Journals**	**Citations**	**Top Authors**	**Fuzzy Aggregated ratings**	**Ratings**	**Rank**
Environment of changing technology, economy and nature	(2,3,4)	(-1,0,1)	(1,2,3)	(7.75,16,24.3)	9.81	33
Functional role	(-8,-9,-10)	(-8,-9,-10)	(-5,-6,-7)	(-44.2,-53,-61)	-46.3	45
Degree of obtaining information	(3,4,5)	(2,3,4)	(7,8,9)	(53.2,61.5,69.8)	55.31	10
Interaction between the technology system and external environment	(-8,-9,-10)	(-8,-9,-10)	(-5,-6,-7)	(-44.2,-53,-61)	-46.3	45
Organisational risks	(2,3,4)	(-1,0,1)	(1,2,3)	(7.75,16,24.3)	9.81	33
Neighbouring environment (including the site access/location)	(-1,0,1)	(-1,0,1)	(1,2,3)	(6.25,14.5,22.8)	8.31	35
Geological condition/difficulty of location	(-1,0,1)	(-1,0,1)	(5,6,7)	(35.2,43.5,51.8)	37.3	14
External politics issue	(2,3,4)	(1,2,3)	(1,2,3)	(8.7,17,25.3)	10.8	31
Union power	(2,3,4)	(-1,0,1)	(1,2,3)	(7.75,16,24.3)	9.81	33
Quality requirements	(-8,-9,-10)	(-8,-9,-10)	(-5,-6,-7)	(-44.2,-53,-61)	-46.3	45
Cost restraints (cost and financing)	(-1,0,1)	(-1,0,1)	(1,2,3)	(6.25,14.5,22.8)	8.31	35
Specific requirements/standards	(-8,-9,-10)	(-8,-9,-10)	(-5,-6,-7)	(-44.2,-53,-61)	-46.3	45
Capability (knowledge, experience, education, training etc.)	(-1,0,1)	(-1,0,1)	(1,2,3)	(6.25,14.5,22.8)	8.31	35
Technical capability of team	(-1,0,1)	(-1,0,1)	(1,2,3)	(6.25,14.5,22.8)	8.31	35
Unknown/poorly defined requirements	(-1,0,1)	(-1,0,1)	(1,2,3)	(6.25,14.5,22.8)	8.31	35
Bespoke software or hardware	(-8,-9,-10)	(-8,-9,-10)	(-5,-6,-7)	(-44.2,-53,-61)	-46.3	45
Trust in stakeholders	(-1,0,1)	(-1,0,1)	(2,3,4)	(13.5,21.8,30)	15.5	28
Team transparency, empathy (the personal and intangible matter that improves cooperation)	(-1,0,1)	(-1,0,1)	(2,3,4)	(13.5,21.8,30)	15.5	28
Project Manager competencies	(-8,-9,-10)	(-8,-9,-10)	(-5,-6,-7)	(-44.2,-53,-61)	-46.3	45
Technological degree of innovation	(-1,0,1)	(-1,0,1)	(-5,-6,-7)	(-37.2,-44,-50)	-38.8	43
Risk of highly difficult technology	(-1,0,1)	(-1,0,1)	(-5,-6,-7)	(-37.2,-44,-50)	-38.8	43
Technological newness of the project	(4,5,6)	(4,5,6)	(2,3,4)	(18.5,26.8,35)	20.5	23
Highly customised products	(-8,-9,-10)	(-8,-9,-10)	(-8,-9,-10)	(-66,-74,-83)	-68.1	46
Responsibility & Accountability	(-8,-9,-10)	(-8,-9,-10)	(-5,-6,-7)	(-44.2,-53,-61)	-46.3	45
Requirements capture	(-8,-9,-10)	(-8,-9,-10)	(-5,-6,-7)	(-44.2,-53,-61)	-46.3	45

Continued table I. FSAW decision matrix according to the top authors criteria (source: authors)

	0.5 (0,1,3)	0.5 (0,1,3)	7.25 (7,9,10)			
Complexity factor	**Peer review Journals**	**Citations**	**Top Authors**	**Fuzzy Aggregated ratings**	**Ratings**	**Rank**
Availability of people, material and of any resources due to sharing	(6,7,8)	(8,9,10)	(7,8,9)	(57.7,66,74.3)	59.8	6
Level of interrelation of between phases	(8,9,10)	(4,5,6)	(3,4,5)	(27.7,36,44.3)	29.8	16
Team/partner cooperation and communication	(7,8,9)	(8,9,10)	(4,5,6)	(36.5,44.8,53)	38.5	13
Levels of management are involved in project decision-making	(-1,0,1)	(-1,0,1)	(-1,0,1)	(-8.2,0,8.2)	-6.19	41
The amount of overlap and interactions	(-1,0,1)	(-1,0,1)	(1,2,3)	(6.25,14.5,22.8)	8.31	35
Dynamic and evolving team structure	(1,2,3)	(1,2,3)	(1,2,3)	(8.25,16.5,24.8)	10.31	32
Dependencies with the environment	(5,6,7)	(2,3,4)	(2,3,4)	(18,26.3,34.5)	20.1	24
Interdependencies between sites, departments and companies	(8,9,10)	(4,5,6)	(3,4,5)	(27.7,36,44.3)	29.8	16
Interdependencies of objectives/interests	(5,6,7)	(6,7,8)	(8,9,10)	(63.5,71.8,80)	65.5	1
Process interdependence	(2,3,4)	(1,2,3)	(2,3,4)	(16,24.3,32.5)	18.1	26
Stakeholders interrelation/interdependencies	(2,3,4)	(1,2,3)	(2,3,4)	(16,24.3,32.5)	18.1	26
Interdependencies between actors	(2,3,4)	(1,2,3)	(2,3,4)	(16,24.3,32.5)	18.1	26
Specifications interdependence	(-1,0,1)	(-1,0,1)	(1,2,3)	(6.25,14.5,22.8)	8.31	35
Interdependence between components of the product	(-1,0,1)	(-5,-6,-7)	(-5,-6,-7)	(-39.2,-47,-54)	-41.1	44
Technological process dependencies	(2,3,4)	(1,2,3)	(2,3,4)	(16,24.3,32.5)	18.1	26
Resource and raw material interdependence	(-1,0,1)	(-5,-6,-7)	(-5,-6,-7)	(-39.2,-47,-54)	-41.1	44
Dependencies between schedules	(-1,0,1)	(-1,0,1)	(1,2,3)	(6.2,14.5,22.8)	8.31	35
Interdependencies of information systems	(6,7,8)	(4,5,6)	(7,8,9)	(55.7,64,72.3)	57.8	9
Number of governmental people who involved in projects	(2,3,4)	(-1,0,1)	(1,2,3)	(7.7,16,24.3)	9.8	33
Combined transportation	(-8,-9,-10)	(-8,-9,-10)	(-5,-6,-7)	(-44.2,-53,-61)	-46.3	45
Interconnectivity and feedback loops in the task and project	(-1,0,1)	(-1,0,1)	(1,2,3)	(6.25,14.5,22.8)	8.31	35
Face to face relationship between project team members	(1,2,3)	(-5,-6,-7)	(1,2,3)	(5.2,12.5,19.8)	7.1	37
Number of interfaces in the project organisation	(1,2,3)	(-5,-6,-7)	(1,2,3)	(5.2,12.5,19.8)	7.1	37
Relations with permanent organisations	(-8,-9,-10)	(-8,-9,-10)	(-5,-6,-7)	(-44.2,-53,-61)	-46.3	45
Capacity of transferring information	(-1,0,1)	(-1,0,1)	(1,2,3)	(6.25,14.5,22.8)	8.31	35

Continued table I. FSAW decision matrix according to the top authors criteria (source: authors)

	0.5 (0,1,3)	0.5 (0,1,3)	7.25 (7,9,10)			
Complexity factor	**Peer review Journals**	**Citations**	**Top Authors**	**Fuzzy Aggregated ratings**	**Ratings**	**Rank**
Level of processing information	(-1,0,1)	(-1,0,1)	(1,2,3)	(6.25,14.5,22.8)	8.31	35
Goals/interests alignment	(3,4,5)	(5,6,7)	(8,9,10)	(62,70.3,78.5)	64.1	3
Dynamics of the task activities	(2,3,4)	(-1,0,1)	(1,2,3)	(7.7,16,24.3)	9.8	33
Uncertainties of scope	(5,6,7)	(5,6,7)	(3,4,5)	(26.7,35,43.3)	28.8	18
Uncertainty & clarity of objectives or goals	(5,6,7)	(4,5,6)	(3,4,5)	(26.2,34.5,42.8)	28.3	19
Uncertainty in technical methods	(5,6,7)	(5,6,7)	(8,9,10)	(63,71.3,79.5)	65.1	2
Information uncertainty	(2,3,4)	(2,3,4)	(2,3,4)	(16.5,24.8,33)	18.5	26
Clients with unrealistic goals	(-8,-9,-10)	(-8,-9,-10)	(-5,-6,-7)	(-44.2,-53,-61)	-46.3	45
Market uncertainty	(2,3,4)	(1,2,3)	(1,2,3)	(8.7,17,25.3)	10.8	31
Variety of financial resources	(-1,0,1)	(-1,0,1)	(-1,0,1)	(-8.2,0,8.2)	-6.1	41
Variety of organisational skills needed	(1,2,3)	(-5,-6,-7)	(1,2,3)	(5.2,12.5,19.8)	7.0	37
Variety of the project management methods and tools applied	(2,3,4)	(2,3,4)	(2,3,4)	(16.5,24.8,33)	18.5	26
Variety of resources to be manipulated	(-1,0,1)	(-1,0,1)	(-1,0,1)	(-8.2,0,8.2)	-6.1	41
Diversity of tasks	(3,4,5)	(3,4,5)	(8,9,10)	(61,69.3,77.5)	63.06	5
Diversity of inputs and/or outputs	(3,4,5)	(4,5,6)	(5,6,7)	(39.7,48,56.3)	41.8	12
Variety of the interests of the stakeholders	(8,9,10)	(7,8,9)	(4,5,6)	(36.5,44.8,53)	38.5	13
Diversity of staff (experience, social span ...)	(2,3,4)	(2,3,4)	(2,3,4)	(16.5,24.8,33)	18.5	26
Variety of the stakeholders status	(2,3,4)	(-1,0,1)	(2,3,4)	(15,23.3,31.5)	17.0	27
Cultural variety	(6,7,8)	(7,8,9)	(6,7,8)	(50,58.3,66.5)	52.0	11
Number of different languages	(-8,-9,-10)	(-8,-9,-10)	(-1,0,1)	(-15.2,-9,-2.8)	-13.7	42
Multiple time zones	(-1,0,1)	(-8,-9,-10)	(0,1,2)	(-4.5,2.7,10)	-2.6	40
Variety of hierarchical levels within the organisation	(-8,-9,-10)	(-8,-9,-10)	(-1,0,1)	(-15.2,-9,-2.8)	-13.7	42
Variety of organisational interdependencies	(6,7,8)	(7,8,9)	(6,7,8)	(50,58.3,66.5)	52.0	11
Variety of technological dependencies	(1,2,3)	(-1,0,1)	(1,2,3)	(7.2,15.5,23.8)	9.3	34
Variety of the technologies used during the project	(1,2,3)	(-1,0,1)	(1,2,3)	(7.2,15.5,23.8)	9.3	34
Variety of technological skills needed	(1,2,3)	(-1,0,1)	(1,2,3)	(7.2,15.5,23.8)	9.3	34

Continued table I. FSAW decision matrix according to the top authors criteria (source: authors)

	0.5 (0,1,3)	0.5 (0,1,3)	7.25 (7,9,10)			
Complexity factor	**Peer review Journals**	**Citations**	**Top Authors**	**Fuzzy Aggregated ratings**	**Ratings**	**Rank**
Multiple participating countries/location	(-1,0,1)	(-8,-9,10)	(0,1,2)	(-4.5,2.7,10)	-2.6	40
Geographic location of the stakeholders	(6,7,8)	(3,4,5)	(3,4,5)	(26.2,34.5,42.8)	28.3	19
Variety of information systems to be combined	(1,2,3)	(-1,0,1)	(1,2,3)	(7.2,15.5,23.8)	9.3	34
Variety of the product components	(-8,-9,10)	(-8,-9,10)	(-1,0,1)	(-15.2,-9,-2.8)	-13.7	42
Client transparency, empathy (the personal and intangible matter that improves cooperation)	(1,2,3)	(-8,-9,-10)	(1,2,3)	(3.7,11,18.3)	5.56	38
Multiple suppliers, contractors, vendors, etc.	(-1,0,1)	(-8,-9,-10)	(0,1,2)	(-4.5,2.7,10)	-2.6	40
Number of decisions to be made	(1,2,3)	(-8,-9,-10)	(1,2,3)	(3.7,11,18.3)	5.56	38
Duration of the project	(5,6,7)	(6,7,8)	(2,3,4)	(20,28.3,36.5)	22.0	22
Number of deliverables/disciplines	(4,5,6)	(5,6,7)	(1,2,3)	(11.7,20,28.3)	13.8	29
Number and quantity of resources	(-8,-9,10)	(-8,-9,10)	(-1,0,1)	(-15.2,-9,-2.8)	-13.7	42
Number of activities	(5,6,7)	(6,7,8)	(2,3,4)	(20,28.3,36.5)	22.0	22
Largeness of capital investment	(-8,-9,10)	(-8,-9,10)	(-1,0,1)	(-15.2,-9,-2.8)	-13.7	42
Number of the project management methods and tools applied	(1,2,3)	(-1,0,1)	(1,2,3)	(7.2,15.5,23.8)	9.31	34
Number of different occupational specialisations	(-8,-9,10)	(-8,-9,10)	(-1,0,1)	(-15.2,-9,-2.8)	-13.7	42
Number of inputs and/or outputs	(1,2,3)	(-8,-9,10)	(1,2,3)	(3.7,11,18.3)	5.56	38
Largeness of scope (number of components etc.)	(3,4,5)	(5,6,7)	(3,4,5)	(25.7,34,42.3)	27.8	20
Size in CAPEX (Capital expenditures)	(-8,-9,10)	(-8,-9,10)	(-1,0,1)	(-15.2,-9,-2.8)	-13.7	42
Number of stakeholders	(7,8,9)	(5,6,7)	(7,8,9)	(56.7,65,73.3)	58.8	8
Number of companies/projects sharing their resources	(1,2,3)	(1,2,3)	(1,2,3)	(8.2,16.5,24.8)	10.3	32
Number of formal units & departments involved	(4,5,6)	(7,8,9)	(3,4,5)	(27.2,35.5,43.8)	29.3	17
Number of objectives	(1,2,3)	(-1,0,1)	(1,2,3)	(7.2,15.5,23.8)	9.31	34
Number of investors	(-8,-9,10)	(-8,-9,10)	(-1,0,1)	(-15.2,-9,-2.8)	-13.7	42
Staff quantity	(1,2,3)	(-8,-9,10)	(1,2,3)	(3.7,11,18.3)	5.56	38
Number of structures/groups/teams to be coordinated	(5,6,7)	(8,9,10)	(7,8,9)	(57.25,65.5,73.8)	59.3	7
Number of hierarchical levels	(1,2,3)	(-1,0,1)	(1,2,3)	(7.2,15.5,23.8)	9.31	34
Number of information systems	(1,2,3)	(-1,0,1)	(1,2,3)	(7.2,15.5,23.8)	9.31	34

Continued table I. FSAW decision matrix according to the top authors criteria (source: authors)

Appendix II

list of the most relevant academic (peer reviewed) and industry journals on Project Management presented by Australiain Institute of Project Management

Title	Type	Format	Publisher	Country	Editorial Description	Frequency
International Journal of Project Management	Academic Journal	Print/ Online	Pergamon	United Kingdom	Provides a focus for worldwide expertise in the required techniques, practices and areas of research; presents a forum for its readers to share common experiences across the full range of industries and technologies in which project management is used; covers all areas of project management from systems to human aspects.	8 times a year
Project Manager	Trade Magazine	Print/Online	Banksia Media Group	Australia	Covers Australia project management and people.	Bi-monthly
Project Management Journal	Academic Journal	Print/Online	John Wiley & Sons, Inc.	United States	Features articles devoted to theory and practice in the field of project management.	Quarterly
International Journal of Project Organisation and Management	Academic Journal	Print/Online	Inderscience Publishers	United Kingdom	Fosters active dialogue about successful practice and theoretical research concerned with project management.	4 times a year
PM Network	Trade Magazine	Print/Online	Project Management Institute	United States	Professional magazine covering industry applications and practical issues in managing projects. Its mission is to keep the project management decision-maker abreast of the latest news of techniques and best practices.	Monthly
International Journal of Managing Projects in Business	Academic Journal	Print/ Online	Emerald Group Publishing Ltd.	United Kingdom	Provides broad coverage of all aspects of project management, from strategy to planning and implementation.	Quarterly
International Journal of Information Technology Project Management	Academic Journal	Print	I G I Global	United States		Quarterly

Table II. Most relevant academic (peer reviewed) and industry journals on Project Management adapted by AIPM

Title	Type	Format	Publisher	Country	Editorial Description	Frequency
Project Manager Today	Trade Magazine	Print/Online	Larchdrift Projects Ltd.	United Kingdom	Provides case studies, articles, and software reviews for project managers.	Monthly
International Journal of Construction Project Management	Academic Journal	Print/Online	Nova Science Publishers, Inc.	United States	Provides research on project management issues relevant to the built environments of developed and developing countries.	Quarterly
Journal of Project, Program & Portfolio Management	Academic Journal	Print/Online	U T S ePress	Australia	Publishes scholarly articles, case studies and research reports.	Semi-annually
Built Environment Project and Asset Management	Academic Journal	Print/Online	Emerald Group Publishing Ltd.	United Kingdom	Provides a forum for research on project management and asset management of building and civil engineering infrastructure.	Semi-annually
The Project Manager	Trade Magazine	Print	Cape Media Corporation	South Africa	Provides a vehicle for direct communication within the project management community in the fields of construction, architecture, computer networking, telecommunications, software development, design, production, service and other industries.	Quarterly

Continued table II. Most relevant academic (peer reviewed) and industry journals on Project Management adapted by AIPM

Appendix III

publications of the thesis

Statement of Authorship

Title of Paper	
Publication Status	☐ Published ☑ Accepted for Publication ☐ Submitted for Publication ☐ Unpublished and Unsubmitted w ork w ritten in manuscript style
Publication Details	Bakhshi, J , Ireland, V , Gorod, A. (2016), "What Is Project Complexity? Past, Present and Future", International Journal of Project Management, Accepted and forthcoming

Principal Author

Name of Principal Author (Candidate)	Javad Bakhshi
Contribution to the Paper	Performed systematic literature review, interpreted data, wrote manuscript and acted as corresponding author
Overall percentage (%)	85%
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.
Signature	Date 01/03/2016

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);
ii. permission is granted for the candidate in include the publication in the thesis; and
iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of Co-Author	Professor Vernon Ireland
Contribution to the Paper	Supervised development of work, helped in data interpretation and manuscript evaluation
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Available online at www.sciencedirect.com
ScienceDirect
International Journal of Project Management 34 (2016) 1199–1213
International Journal of Project Management
www.elsevier.com/locate/ijproman

Clarifying the project complexity construct: Past, present and future

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Received 6 October 2015; received in revised form 26 May 2016; accepted 2 June 2016

Abstract

The research explores the historical development of project complexity. Projects are becoming more complex due to unexpected emergent behaviour and characteristics. Complexity has become an inseparable aspect of systems and also one of the important factors in the failure of projects. While much has been written about project complexity, there is still a lack of understanding of what constitutes project complexity. This research includes a systematic literature review to demonstrate the current understanding of commonalities and differences in the existing research. This was achieved by examining more than 420 published research papers, drawn from an original group of approximately 10,000, based on citations during the period of 1990–2015. As a result of this exploration, an integrative systemic framework is presented to demonstrate understanding of project complexity.

It was found that there are three primary and distinctive models of project complexity, the Project Management Institute view, the System of Systems view and the view developed from the analysis of citations of research papers, which is called the Complexity Theories view. Further testing is required on a range of complex projects in order to attempt to reconcile these views.

Keywords: Project complexity; Complex projects; System of systems; Systematic review; Complexity theories; Histogram analysis

1. Introduction

Complexity is one of the most important and controversial topics in project management. It is controversial because some organisations, such as the Project management Institute (PMI), a leading body in the area, has a very different view of complexity by comparison with the System of Systems (SoS) view, which is employed on most major defence and health projects in the western world. Varying degrees of complexity exist in all types of projects. This is evident in the early definition of complexity as an entity consisting of many varied interrelated parts and elements such as tasks, components, and interdependence (Hornby and Wehmeier, 1995). Thus, every project contains a degree of complexity. However, there is no universally accepted definition of complexity (Ireland, 2013). At the same time, Stephen Hawking (2000) observed about the 21st century, it "will be the century of complexity". Similarly, Project Management Institute (PMI) noted that "complexity is not going away and will only increase. However, based on PMI's version of complexity, they state that ultimately, how organisations anticipate, comprehend and navigate complexity determines their successes and failures" (PMI, 2013, p. 5). Complex systems display a variety of behaviours, including self-organisation, emergent properties and non-linear behaviour, and are often counter-intuitive. As a consequence, opportunities for external or top-down control are very limited (Helbing, 2013). Given that numerous interactions are undertaken and project components do not follow simple causal relationships, complexity can be viewed as "the inability to predict the behaviour of a system due to large numbers of

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http://dx.doi.org/10.1016/j.ijproman.2016.06.002
0263-7863/00.

constituent parts within the system and dense relationships among them" (Sheard and Adviser-Mostashari, 2012, p. 11).

Although extensive research on project complexity exists, there is no conceptual definition agreed upon among researchers. In addition, insufficient research is available so far about the examination of the diverse perspectives on the subject in the project management literature, including SoS view, among others. The purpose of this paper is to clarify the understanding of project complexity and the implication of this definition for management of complex projects. The research seeks to answer the following questions:

Q1. What characteristics comprise project complexity and how they have been developed?
Q2. What factors contribute to project complexity considering the different schools of thought?

To answer the research questions, a systematic literature review has been conducted to define complexity in the context of project management. The analysis period is from 1990 to 2015 and covers key developments in project complexity (see Fig. 1). In addition, selected publications have been examined and are discussed in the paper. Finally, a project complexity framework is proposed, integrating three dominant perspectives, including the PMI view, the SoS view and the complexity theories view, developed from the large group of research papers examined.

As illustrated in Fig. 1, uncertainty and complexity concepts were introduced to project management literature around the year 1990. Analysis of selected publications in this paper covers 1990–2015. During 1990 to 1995 most studies were focused on the role of uncertainty and project structure in contributing to complexity in projects. The development of project management concepts was subsequently influenced by the advances in the domain of SoS between 1995 and 2000 and a new perspective of complexity was initiated by Maier in 1996, introducing four types of SoS, these being directed, acknowledged, collaborative and virtual (Maier, 1996). Furthermore, the most notable research milestone between 2000 and 2005 was achieved by Snowden as he drew clear distinctions between simple, complicated, complex systems and chaotic systems (Snowden, 2002).

Studies demonstrate that the number of publications on complexity soared in years between 2005 and 2013, and a wide spectrum of views of project complexity emerged in this period. These views are further discussed in Section 3.2.

2. Defining complexity in the context of project management

Before examining project complexity, it is useful to look at projects as a hierarchy of simple, complicated, complex, and chaotic. According to the available literature, we can define simple projects as limited activities undertaken to create products or services with clear cause-and-effect relationships. This implies that each participant in a project can appropriately respond to different situations by accessing the necessary information, which in the realm of project management can be qualified as belonging to the domain of "known knowns," where all operations are self-evident, predictable and repeatable. Preparing food and manufacturing simple house appliances or many constructions projects are usually good examples of simple projects. In complicated projects, there are cause-and-effect relationships between tasks and elements. Knowledge and expertise are essential for understanding complicated projects and eventually they require proper practices in order to overcome problems (Snowden and Boone, 2007). In other words, complicated projects contain subsets of simple projects but are not merely reducible to them. The nature of complicated projects is not always related to their scale, but to the issue of coordination or specialised expertise (Glouberman and Zimmerman, 2002). Sending a rocket to the moon, producing aircraft and most large construction projects are complicated and once completed a small

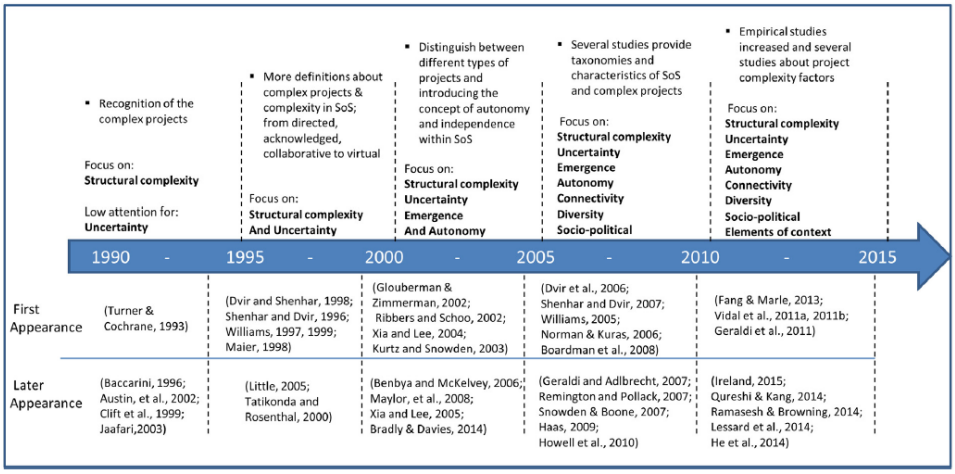

Fig. 1. Milestones of project complexity history (source: authors).

number times, they become complicated rather than complex, because the management of such is fairly predictable, and essentially linear, in terms of outputs such as cost, time and performance. By comparison complex projects consist of ambiguity and uncertainty, interdependency, non-linearity, unique local conditions, autonomy, emergent behaviours and unfixed boundaries. Most defence projects in the USA, UK and Australia, as well as the majority of health projects, communications satellites, and nuclear-powered submarines are good examples of complex projects. It should be noted that, based on the definitions above, factors caused by unfamiliarity and the lack of knowledge are not associated with project complexity (Bakhshi et al., 2015). It is true that managing complex projects is difficult but most project managers will succeed by understanding their past patterns of success and failure while focusing on project complexity factors. However, chaotic projects, such as most crises and disasters, cannot be immediately addressed (Snowden and Boone, 2007). It is further worth mentioning that many projects lie somewhere along the spectrum, rarely at one end or the other (see Fig. 2).

3. Research method

To achieve the research goals, related documents across multiple databases have been reviewed. In this regards, The Cochrane Handbook for Systematic Reviews (2008) and The Australian National Health and Medical Research Council guidelines (2000) were particularly pertinent. The research used systematic literature reviews to answer the research questions with an explicit, reproducible methodology (Geraldi et al., 2011; Tranfield et al., 2003). "A systematic review attempts to collate all empirical evidence that fits pre-specified eligibility criteria in order to answer a specific research question" (Higgins and Green, 2008, p. 6). According to the systematic review process shown in Fig. 3, number of discrete steps were conducted. As clearly illustrated in the Figure, a reasonable and explicit consensus has emerged as to its desirable methodological characteristics

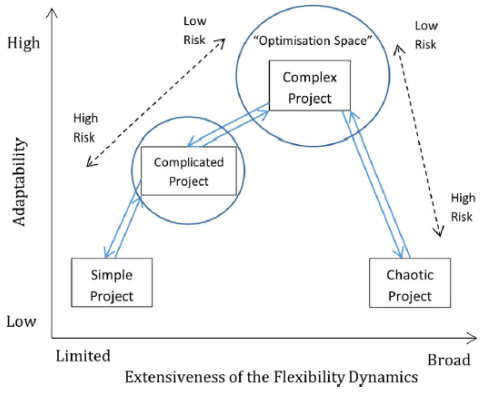

Fig. 2. A typology of projects adapted from Gorod et al. (2008).

(Ghapanchi and Aurum, 2011; Higgins and Green, 2008; Parris and Peachey, 2013).

3.1. Search terms

In order to construct a systematic search that attempts to identify all studies, the research questions were broken down into three keywords including complex, project, and system. In addition, most reputed keywords in the past studies have been considered. In the next step, the main "search string" was formulated as: (Complex* OR unknown OR "unk unks") AND (project OR "project management") AND (system OR theory).

To have more valid results, both automated and manual searching options were used for each single bibliographic database (Kitchenham et al., 2010). In addition, a preliminary investigation was taken to make sure all different perspectives and aspects of research domain had been identified.

3.2. Databases searched

After finding research terms, keywords were searched among the bibliographic and full text databases that included Scopus, Web of Science, Google scholar, Inspec, Business Source Premier, Business Source Complete, ProQuest Science journals, Springer Link, ACM Digital library, and IEEE Explore with consideration of Engineering, Business and Management, Decision Science and Construction Building Technology domains. All databases were selected with attention to coverage of the scientific literature and level of overlaps (Kousha and Thelwall, 2008; Spink et al., 2006).

3.3. Inclusion/exclusion criteria

Following the search for research keywords, five steps were completed to select related publications based on several criteria- Step 1. The publications had to be published from 1990 to April 2015 with a focus in one or more of the fields of Engineering, Business and Management, Decision Science and Construction Building Technology- Step 2. The publications had to be available full text in English- Step 3.1. The publications had to include all the articles from peer reviewed journals relevant to Project Management, including International Journal of Project Management (IJPM), Project Management Journal (PMJ), International Journal of Project Organisation and Management (IJPOM), International Journal of Managing Projects in Business (IJMPB), International Journal of Information Technology Project Management (IJITPM), Journal of Project Program & Portfolio Management (JPPPM), International Journal of Construction Project Management (IJCPM), and Built Environment Project and Asset Management Journal (BEPAM); Step 3.2. The publications had to be comprised of all articles that were written by top researchers (50 top researchers who have more than five publications related to the topic); Step 3.3. The publications had to include all the articles that had more than five citations or were published after 2013- Step 4. Abstracts, keywords and citation information were downloaded to Endnote software and duplicate publications were deleted- Step 5. Final filtering was undertaken and articles having most congruence with project complexity were selected.

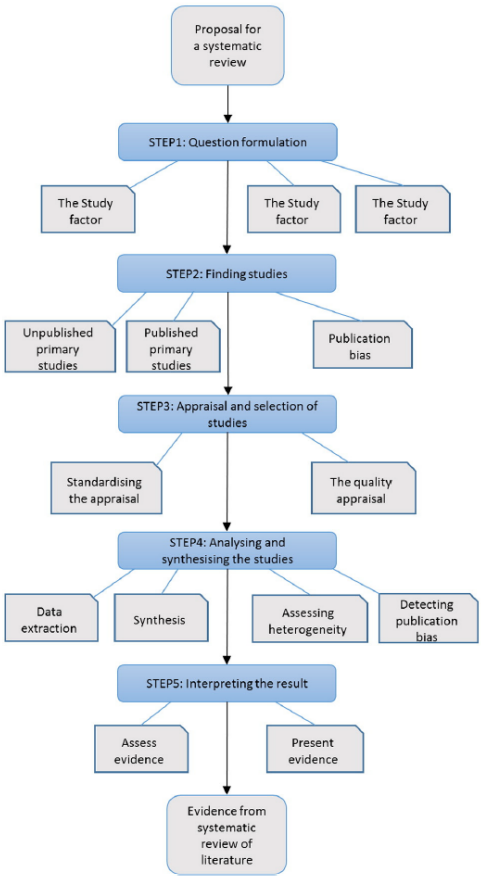

Fig. 3. Systematic review steps adapted by The Australian National Health and Medical Research Council guidelines.

Endnote software was used for storing and managing different publications. In addition, NVivo™ software was utilised for cataloguing, organising, analysing, and synthesising the set of data. This software was especially useful since it made it possible to conduct content analysis of a vast number of resources and was subsequently instrumental in identifying the connections among publications.

Initially, 783 papers were found as completely related to the complex projects. The papers' abstracts were carefully read and NVivo used to find "textual segments" within the all publications. Finally, 423 papers were selected that addressed project complexity (Fig. 4). Of these, 138 papers belong to the peer-reviewed project management journals as shown in Table 1.

4. Findings and discussion

This paper examined the historical development of project complexity as depicted in Fig. 1 based on the following criteria:

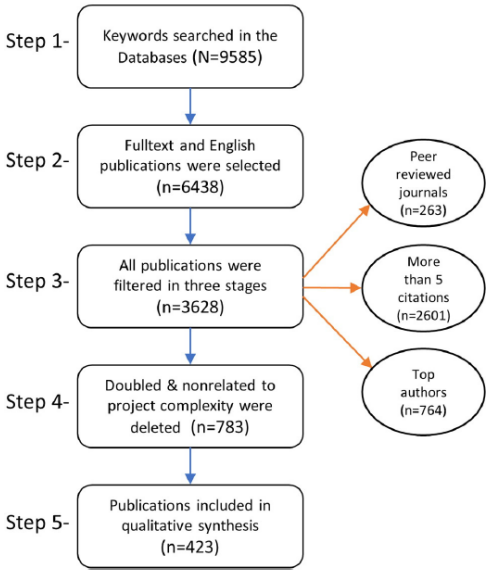

Fig. 4. Stages of the study selection process.

1. Definitions of project complexity
2. Characteristics of complex projects
3. Factors contributing to project complexity

It should be noted that research findings were not investigated according to various project domains (e.g., engineering and construction, IT, industrial, business, defence, etc.). While important, this level of analysis is beyond the scope of this research. However, the percentage of publications related to the different project types in the literature review is shown in Fig. 5. The frequency of papers per year is shown in Fig. 6.

The histogram analysis demonstrates that the highest frequency and cumulative value of papers on complexity increased from 2009 to 2013. These years can be considered a major leap in project complexity research. In addition, there are many valuable

Table 1
Number of articles identified from each database/journal.

Databases/Journal	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Scopus	3272	1493	3365	520	285
Web of Science	5097	4218			
Other databases	1216	727			
Int. J. Proj. Manag.			127	127	67
Proj. Manag. J.			54	54	32
Int. J. Proj. Org. Manag.			9	9	5
Int. J. Manag. Proj. Bus			39	39	18
Int. J. Info. Tech. Proj. Manag.			11	11	4
J. Proj. Prgm. Port. Manag.			0	0	0
Int. J. Cons. Proj. Manag.			8	8	3
Blt. Env. Proj. Ast. Manag.			15	15	9
Total	9585	6438	3628	783	423

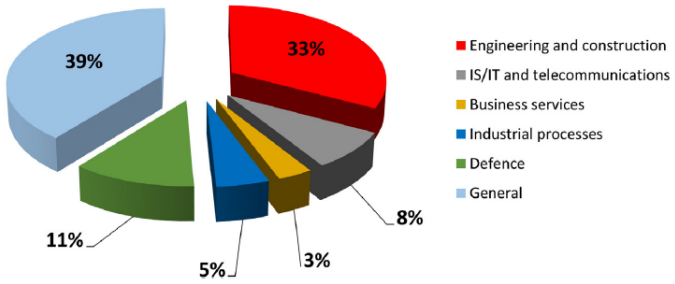

Fig. 5. Percentage of different projects considered by publications in the literature review.

publications that have had a vital role in the development of complex project concepts from 2001 to 2009, which can be viewed as an explorative phase in project complexity. In addition, as evident from the Fig. 6, this area of research is expanding and is anticipated to continue growing in the future.

4.1. Project complexity definition

There are several generally accepted definitions of project complexity listed in Table 2. However, it is challenging to present a truly accurate and comprehensive definition of complexity that encompasses and reflects its myriad of aspects and boundaries. Moreover, formal approaches share limited commonality. As a result, the understanding of this concept may be obscured for the non-specialist audience (Grisogono, 2006). Therefore, the most frequently mentioned key words were extracted via the analysis of the cross-citations and applied in defining complex projects as follows:

a) interdependence of the elements such as tasks, teams and inputs is present
b) causality is networked and simple cause-and-effect relationships between parts do not apply
c) dynamics emergence context exist
d) predictability and control is reduced
e) the project scope and boundaries are unclear
f) project governance is decentralised and autonomous teams exist
g) the number of plausible references is vast
h) the project is self-organised and adaptable
i) transparency is low including objectives, process, methods, etc.
j) diversity of resources is heterogeneous

After considering complexity theories as well as all features listed above, the authors agreed on defining project complexity as an intricate arrangement of the varied interrelated parts in which the elements can change and evolve constantly with an effect on the project objectives. This definition has been developed based on the most reputed definitions in the literature, which are shown Table 2.

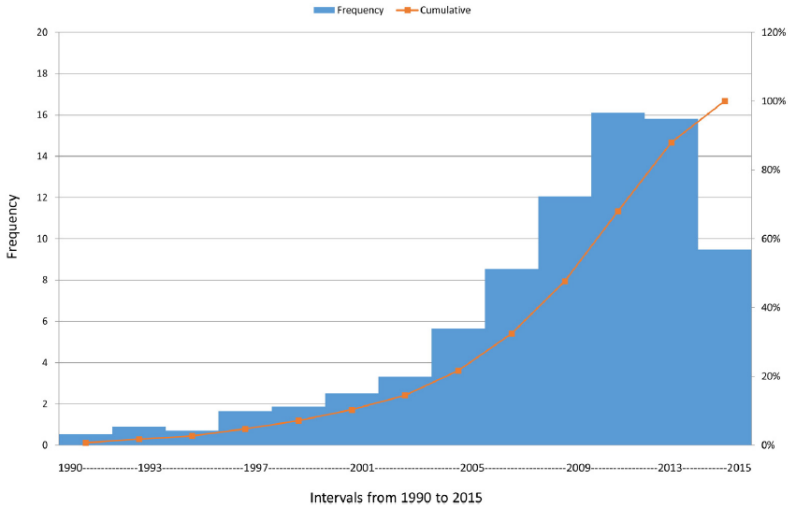

Fig. 6. Histogram analysis for project complexity development.

Table 2
Most cited different project complexity definition in the literature.

Study	Study type	Industry	Project complexity definition	Characteristics/keywords	Cited by [a]
Turner and Cochrane (1993)	Conceptual	Construction	Degree of whether the goals and methods of achieving them are well defined	Uncertainty of goals–uncertainty of methods	404
Baccarini (1996)	Review	General	Consisting of many varied interrelated parts and can be operationalised in terms of differentiation and interdependency	Operational interdependencies–multi-organisational structure–technological complexity	610
Cicmil and Marshall (2005)	Empirical study	Construction	Invokes ambiguity, paradox and the dimensions of time, space and power of the organising processes in project settings	Flux and change–radical unpredictability–conversational and power relating–ambiguity of process–social interaction	125
Hatch and Cunliffe (2012)	Conceptual	General	Consists of many different elements with multiple interactions and feedback loops between elements	Nonlinear–multiple components and interactions–change and evolve constantly–emergence	3564
Vidal et al. (2011a, 2011b)	Case study	Manufacturing	The property of a project which makes it difficult to understand, foresee and keep under control its overall behaviour, even when given reasonably complete information about the project system	Organisational complexity–technological complexity–interdependencies–property of project–project difficulty	61
Tatikonda and Rosenthal (2000)	Case study	Product development	The nature, quantity and magnitude of organisational subtasks and subtask interactions posed by the project	Technology interdependence–objectives novelty–project difficulty	377
Ribbers and Schoo (2002)	Case study	Information systems	Variety, variability and integration of system	Variety–variability–integration	123
Maier (1998)	Conceptual	General	Operational and managerial interdependence of the elements–evolutionary development–emergent behaviour–geographic distribution	Interdependence–evolutionary development–emergence–geographic distribution	1066
Jaafari (2003)	Conceptual	General	–	Open systems–chaos–interdependence–self-organisation	159
Benbya and McKelvey (2006)	Conceptual/ interviews	Information systems	–	Structural–organisational- dynamic	140
Remington et al. (2009) and Remington and Pollack (2007)	Conceptual/ interviews	General	A number of characteristics to a degree, or level of severity, that makes it extremely difficult to predict project outcomes, to control or manage project	Hierarchy–communication–addictiveness–fitness landscape–edge of chaos	159
Geraldi and Adlbrecht (2007)	Empirical study	Plant engineering	Complexity of fact, faith and interaction	Dynamics–uniqueness & customisation–immaturity interdependence–size–sources–transparency–reference–empathy	68
Grisogono (2006)	Report	Defence	The ratio of the number of ways of getting the wrong outcome to the number of ways of getting it right	Coherent behaviour–networked causality–vast options–unpredictable–unfixed rules	12
DeRosa et al. (2008)	Conceptual	Defence	The complexity of a problem situation stems from its openness, interdependence of contributing factors and multi-scalarity	Autonomous agents–adaptation–self organisation–phase changes	42

[a] Number of citations is taken from Google scholar on 15/08/2015.

4.2. Characteristics of complex projects

As a result of implementing an analysis of over 420 different publications, the authors found three dominant schools of thought within the construct of complex projects: the PMI perspective, the SoS perspective, and the complexity theories perspective (the group of papers analysed). These perspectives are adapted from the past research contributions including Geraldi et al. (2011) and Ireland et al. (2013). To better understand project complexity aspects and characteristics, it is essential to investigate all three views and these are delineated in the next section.

4.2.1. The Project Management Institute (PMI) view

One of the first attempts to systematically define project complexity is provided by Baccarini (1996). Using two approaches to define project complexity, the first emphasises differentiation and connectivity while the second introduces complexity as a subjective concept focusing on the difficulty of understanding the object (Baccarini, 1996). According to Baccarini (1996), structural complexity and project complexity can be inferred based on integrity of communication, coordination and control. In the research conducted by Turner and Cochrane (1993) the uncertainty of objectives and methods of achieving project outcomes are also considered as important factors contributing to a project's complexity. This paper contends that these two research streams are the foundations of PMI's further study and practice. Building upon the two previous definitions, Williams (1999) introduces a new description of project complexity which is based on the two factors of two structural uncertainties, such as numbers of activities and interdependencies of elements taken from the first definition, as well as the

uncertainty of objectives and methods based on the achievement of the second research (Williams, 1999). Following this, numerous studies focusing on structural complexity and uncertainty aspects can be included in the PMI perspective (Austin et al., 2002; Clift and Vandenbosch, 1999; Jaafari, 2003; Little and Graphics, 2005; Tatikonda and Rosenthal, 2000). In 2001, Shenhar came up with a new paradigm by introducing "One size does not fit all projects". His research focuses on two databases of 26 and 127 projects, respectively. The findings show that some projects such as those in construction have a lower degree of uncertainty while projects requiring innovation like IT and defence have a higher degree of uncertainty (Shenhar, 2001a).

Overall, most researchers who tend towards the PMI perspective emphasise structural complexity, uncertainty and socio-political elements rather than other complexity dimensions (Geraldi et al., 2011). The PMI published an in-depth report, "Navigating Complexity", which indicates multiple stakeholders and ambiguity as two key characteristics of project complexity (Project Management Institute, 2013). This approach has also been followed by a large number of researchers and other aspects of complexity have been disregarded in the PMI's view (see Fig. 7).

4.2.2. The System of Systems (SoS) view

Despite extensive general research, there were few studies that defined and distinguished complex projects from other types of projects until 2002. Snowden (2002) introduced a decision-making framework, which recognises that causal differences exist between system types. Snowden employed the theory of knowledge management to develop four categories of organisational system: simple, complicated, complex, and chaotic. Snowden and Boone (2007) use the Cynefin model as a leader's framework for decision-making with regard to different systems. In addition, they present new definitions for simple, complicated, complex, and chaotic systems as well as distinguishing their boundaries (Snowden and Boone, 2007).

The Snowden and Boone (2007) approach to complexity, further articulated in Kurtz and Snowden (2003), supports the System of Systems view of inclusion of autonomous and independent systems as well as the issue of the lack of control in managing autonomous and independent systems in the same way that control is exerted on projects in the Ashby's requisite variety space (Ashby and Goldstein, 2011; Ashby, 1958). Requisite variety is a system under control which is analogous to the complicated state proposed by Kurtz and Snowden. By comparison, an example of a SoS project is the Air Operations Center in the USA which has 80 autonomous and independent systems, in which the systems within the SoS, still fulfil their original function for the system for which they were originally designed, as well as their SoS function (Norman and Kuras, 2006).

Complex projects may be divided into three categories (Ireland et al., 2012):

1. Type A projects are traditional SoS projects that include or build on existing systems to achieve other goals in the new project. For example, the Air (and Space) Operations Centre

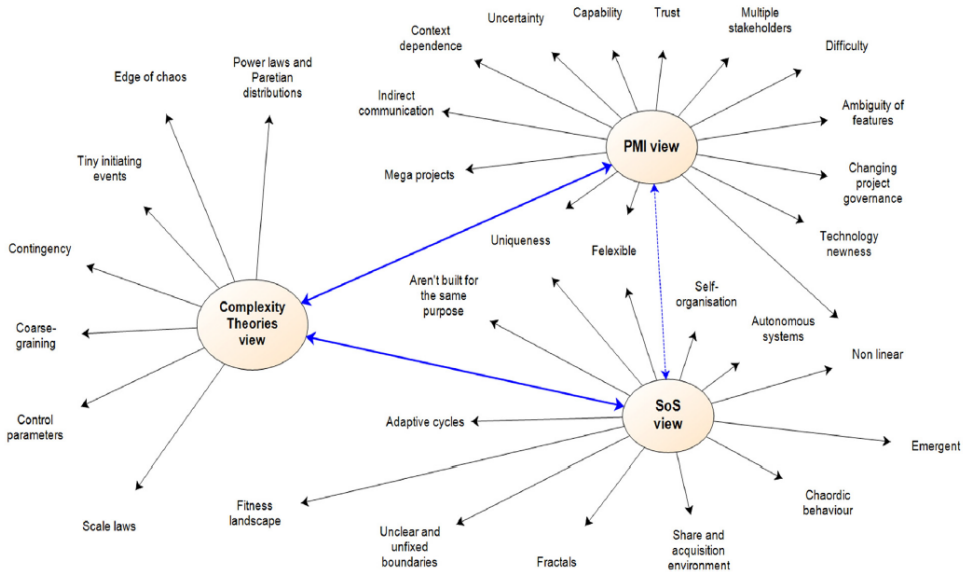

Fig. 7. Different characteristics of complex projects in three schools of thought in the literature. (Source: authors)

(AOC) in the USA prepares the tools for planning, carrying out tasks and monitoring operations in Iraq, and Afghanistan, especially DoD drones.
2. Type B projects, which primarily describes wicked problems, which concern different aspects of the systemic concept. The real issue is that the solution is difficult to determine. Checkland's soft system methodology and possibly system dynamics could be used to develop an appropriate solution.
3. Type C projects combine independent assets that arise within a large system. For example, Global Distribution Centres which are from lower levels of hierarchy and include many components, while independent, and are part of a larger supply chain.

Systems of Systems are "large-scale integrated systems that are heterogeneous and independently operable on their own, but are networked together for a common goal" (Jamshidi, 2008, p. 2). Furthermore, Maier (1998) attempts to explain complexity in SoS in terms of characteristics, such as operational and managerial interdependence of the elements, evolutionary development, emergent behaviour, and geographic distribution. In another study,the research results show that all of these autonomous independent systems serve various divergent purposes but also continue to satisfy the original purpose. In other words, they were not built for the same purpose or used within specific Air Operations Centre workflows (Norman and Kuras, 2006). Autonomy and independence, belonging, connectivity, diversity, and emergence are foundations and characteristics of the SoS that have been considered by many researchers (Braha et al., 2006; Ireland et al., 2015; Sauser et al., 2009).

Based on the SoS perspective, the agents in complex projects spontaneously organise themselves to cope with various internal and external perturbations and conflicts. This allows them to evolve and adapt. There are varieties of complexity aspects that deserve greater attention with regard to the project management context (Ireland, in press).

4.2.3. The complexity theories view

This group, composed of the research papers chosen, looks at projects through the lenses of various theories (Geraldi et al.,

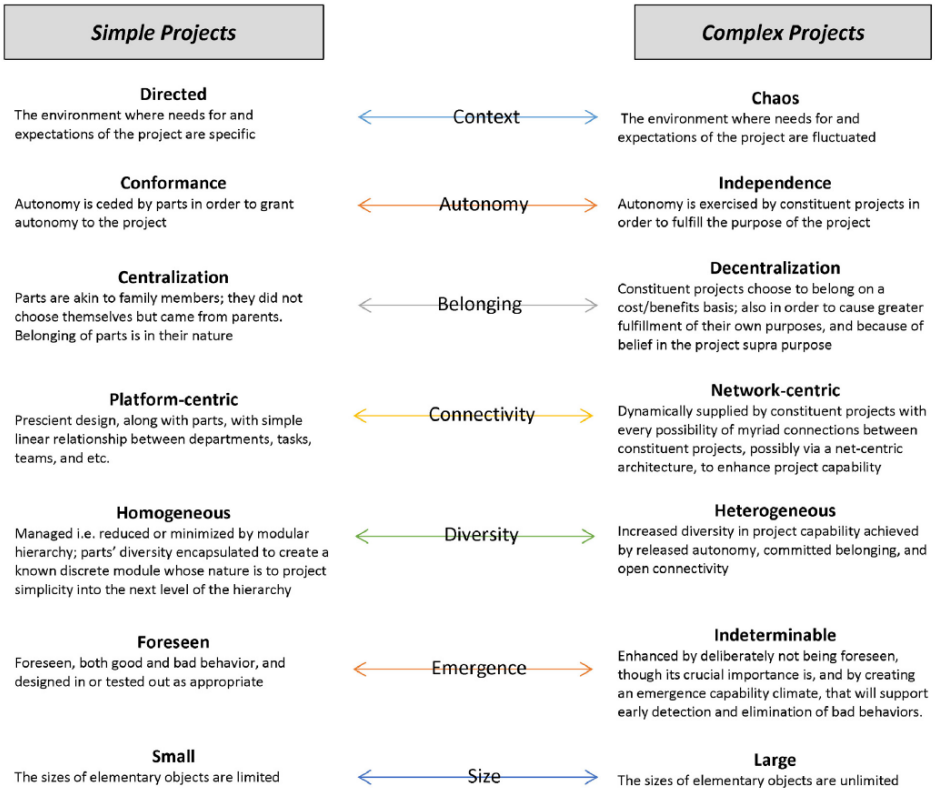

Fig. 8. Project complexity drivers and their paradox synthesised from Boardman and Sauser (2006), Cicmil (1997), and Vidal et al. (2011a).

2011). A multitude of publications consider project or systems complexities with regard to various theories such as complexity theory (Burnes, 2004; Cooke-Davies et al., 2007; Cilliers, 2000; Levy (2000); Manson, 2001; Pollack, 2007; Shenhar and Dvir, 1996; Whitty and Maylor, 2009), co-evolutionary theory (Benbya and McKelvey, 2006), organisational theory (Cicmil and Marshall, 2005; Anderson, 1999), contingency theory (Baccarini, 1996; Ireland, 1985; Keller, 1994; Levitt et al., 1999), theory of constraints (Rand, 2000), systems theory (Checkland, 1999), network theory (Pryke, 2005; Rowley, 1997), nonlinearity and chaos theory (Singh and Singh, 2002), and adaptive self-organisation theory (Aritua et al., 2009; DeRosa et al., 2008; Jaafari, 2003; Saynisch, 2010a). The results are shown in Fig. 7 with the remainder of the papers focused on the Complexity Theories view, which is based on the 420 papers analysed.

It is worth mentioning that most of this group has focused solely on a single functional aspect of the project (Shenhar and Dvir, 1996). In addition, all the features and characteristics discussed in theories are time-dependent, observer-dependent and problem-dependent. How these characteristics operate in various types of projects requires exploration. Most attention needs to be paid to characteristics considered in this perspective, such as Paretian and power-law distributions, operating at the edge of chaos, chaotic behaviour, scale laws, fractals, fitness landscape, and adaptive cycles in the context of project management.

4.3. Project complexity factors

Following the examination of the three schools of thought, it is clear that there are distinctions between these perspectives. Although many characteristics are important to consider in the context of project management in different views, this paper proposes seven dominant elements integrating the three perspectives. In fact, this framework has been synthesised from the work of past studies including Boardman and Sauser (2006), Cicmil (1997), and Vidal et al. (2011a). Based on the research findings, it was found that differentiation between each project can be analysed by context, autonomy, belonging, connectivity, diversity, emergence, and size. From these descriptors, each complex project consists of autonomous

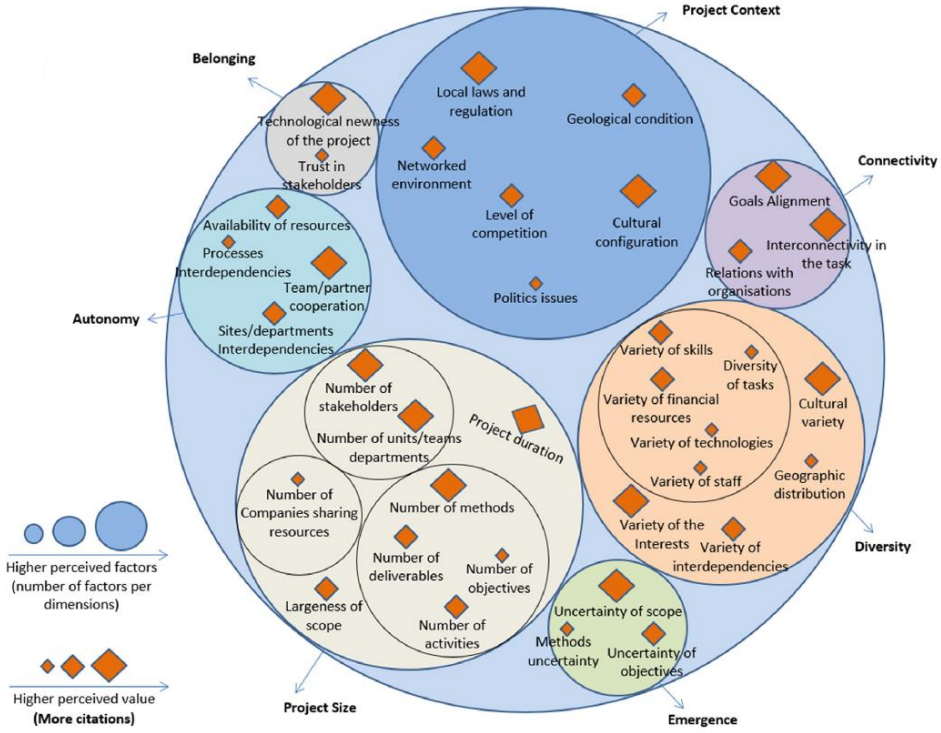

Fig. 9. Project complexity factors according to number of citations.
(Source: authors).

and independent parts and different structures that belong to the same project and are connected to the other parts and systems in the project. Furthermore, the collection of actors, tasks and systems in the project are diverse and can generate unexpected emergent properties (Ireland et al., 2015). However, these concepts require qualification. A project's context, including its environment and project organisation, is related to the nature, scope, and environment, where needs and expectations of the project are met (Cicmil, 1997; Snowden, 2002). Autonomy is exercised by constituent systems, teams or partners in order to fulfil the purpose of the project. Constituent departments and/or partners choose to be involved because they believe in the overall project while it also assists them with fulfilling their own independent objectives. The ability of agents in a system and/or group to link with other parts of the project is titled connectivity. Diversity can be defined as distinct element or quality in a group — the variation of social and cultural identities among people existing together in the project. The appearance of new properties or behaviours in the course of development or evolution is considered emergent (Boardman and Sauser, 2006; Ireland et al., 2015).

Nevertheless, there is a vast number of factors that affect these characteristics and change the degree of complexity. Over the last 25 years, project complexity factors have been collected and applied in a variety of academic and practical research. However, there is still a lack of universal agreement and subsequently, many ambiguous points to cope with.

More than 125 factors are identified through the literature review as shown in the Appendix 1. In order to make the research audience more cognizant with project complexity factors, a clear framework needs to be presented. All project complexity factors are classified under seven drivers of project complexity as shown in Fig. 8.

Through the analysis of published articles, project context, diversity, size, and autonomy dimensions have a large number of factors. Although project context is recognised as the most pronounced complexity driver in terms of the number of factors, only "cultural configuration" and "local laws and regulations" were cited by more than 30% by the scholars in this dimension. On the other hand, project diversity and size dimensions consist of many factors that had been cited by more than one-third of researchers. Complexity factors such as "cultural variety", "variety of methods", "stakeholders' interests", "organisational interdependencies", and "technological skills needed" are more reported factors in the project diversity section. Therefore, this reveals that increased diversity in project capability is achieved by releasing autonomy, committed belonging, and open connectivity (Gorod et al., 2008). As following by many authors in PMI perspective, the "number of structures, stakeholders, deliverables", "number of departments involved or method and tools applied", "largeness of scope", and "duration of project", are considered under the category of size. In addition, "team/partner cooperation and communication", "interdependencies between objective/interests, sites, departments, and companies" are the most popular complexity factors in the autonomy dimension. Autonomy and independent concepts are less considered by PMI's group than others (Bakhshi, 2016). "Goals/interests alignment" and "interconnectivity and feedback loops in the tasks" are part of connectivity driver which have been mentioned by researchers more than others. Finally, "uncertainty of scope, objectives and methods", "technological newness of the project", and "trust in stakeholders" are more cited in emergence and belonging dimensions (see Fig. 9).

5. Conclusion

This paper reviews existing perspectives on project complexity three different views of complexity and the differences between these three schools of thought, these being the PMI view, the SoS view, and the view developed from the research papers analysed, which has been titled the Complexity Theories view, in order to improve the overall scientific understanding of the concept. The research explores the historical development of project complexity. One hundred and twenty eight project complexity factors were identified as a result of the literature review over the period from 1990 to 2015, which can serve as a foundation for future research.

The main contribution of the paper is in the insights gained in the attempt to clarify the project complexity constructs while in parallel, also considering different aspects of complexity. In addition, the distinction between different types of projects such as simple, complicated, complex, and chaotic is demonstrated. The research results show that these concepts are not always used correctly and sometimes interchangeably. Also, some project complexity factors identified in the literature cannot be part of complexity as mentioned in previous sections. For instance, technological novelty of the project and specific requirements can be seen as the lack of knowledge and unfamiliarity factors related to complicated projects. Furthermore, as mentioned above, while the analysis is not organised or differentiated by the different types of projects (e.g., engineering, construction, IT, industrial, business, defence, etc.), this level of examination can serve as a potentially valuable topic for future research. In addition, more attention needs to be paid to the system thinking approach and the relationship between complexity factors. Developing a greater understanding of the behaviour of various types of projects requires further exploration. Moreover, it is critical to study the characteristics which have been considered in the complexity theories group, such as Paretian and power-law distributions, operating at the edge of chaos, chaotic behaviour, fractals, fitness landscape, and adaptive cycles, to name some.

Acknowledgments

We acknowledge the special support of Dr Barry Elsey who through many conversations kept us motivated and sustained on the learning journey. The authors would also like to thank the Reviewers for insightful comments and for significant contribution to the improvement of this article.

Appendix 1. Project complexity factors based on systematic literature review (source: authors)

Dimension	Project complexity factors (provenance of complexity)	Number of referred	%	Rank	Referred to by
Context	Unusual type of design process	9	18	7	Akintoye (2000), Austin et al. (2002), Azim (2010), Baccarini, 1996, Bosch-Rekveldt et al. (2011), Calinescu et al. (1998), Cicmil et al. (2006), Crawford (2005), Fang and Marle (2013), Favari (2012), Frame (2002), Geraldi and Adlbrecht (2007), Geraldi (2008), Gidado (1996), Hussein et al. (2013), Hussein (2012), Koivu et al. (2004), Lessard et al. (2014), Leung Wing Tak (2007), Little and Graphics (2005), Maylor et al. (2008), Müller et al. (2007), Qing-hua et al. (2012), Qureshi and Kang (2014), Remington et al. (2009), Saynisch (2010b), Senescu et al. (2013), Sinha et al. (2006), Vidal et al. (2011a), Vidal and Marle (2008), Wood and Gidado (2008), Xia and Chan (2012), Xia and Lee (2004)
	Demand of creativity	9	18	7	
	Scope for development	7	14	9	
	Institutional configuration	10	20	6	
	Significant on public agenda	9	18	7	
	Degree of project flexibility (in scope, process, organisation...)	9	18	7	
	HSSE issues	7	14	9	
	Decision making process challenges	8	16	8	
	Repetition of similar type of projects	7	14	9	
	Internal politics Issue (ambiguity, hidden information)	12	24	4	
	Environment complexity (networked environment)	13	27	3	
	Cultural configuration	19	39	1	
	Form of contract	10	20	6	
	Overlapping office hours	6	12	10	
	Stability project environment	4	8	12	
	Experience with parties involved	5	10	11	
	Project drive	7	14	9	
	Commercial newness of the project (new partners, teams etc.)	9	18	7	
	Conflict between stakeholders	7	14	9	
	Level of competition between stakeholders	12	24	4	
	Lack of support (top management, users, staff members etc.)	7	14	9	
	Organisational degree of innovation	10	20	6	
	New laws and regulations	11	22	5	
	Local laws and regulations	16	33	2	
	Level of competition	12	24	4	
	Environment of changing technology, economy and nature	11	22	5	
	Functional role	7	14	9	
	Degree of obtaining information	5	10	11	
	Interaction between the technology system and external environment	5	10	11	
	Organisational risks	7	14	9	
	Neighbouring environment (including the site access/location)	9	18	7	
	Geological condition/difficulty of location	13	27	3	
	External politics issue	9	18	7	
	Union power	7	14	9	
Belonging	Quality requirements	8	16	7	Alderman and Ivory (2007), Antoniadis et al. (2011), Azim (2010), Baccarini (1996), Bosch-Rekveldt et al. (2011), Camci and Kotnour (2006), Castejón-Limas et al. (2010), Cicmil and Marshall (2005), Fang and Marle (2013), Geraldi and Adlbrecht (2007), Gidado (1996), Hussein et al. (2013), Hobday (1998), Hussein (2012), Little and Graphics (2005), Maylor et al. (2008), Qureshi and Kang (2014), Ramasesh and Browning (2014), Remington et al. (2009), Shenhar et al. (2004); Tatikonda (1999), Vidal et al. (2007, 2011b), Vidal and Marle (2008), Xia and Chan (2012), Xia and Lee (2004), Yugue and Maximiano (2012)
	Cost restraints (cost and financing)	9	18	6	
	Specific requirements/standards	13	27	2	
	Capability (knowledge, experience, education, training etc.)	11	22	4	
	Technical capability of team	10	20	5	
	Unknown/poorly defined requirements	10	20	5	
	Bespoke software or hardware	1	2	10	
	Trust in stakeholders	13	27	2	
	Team transparency, empathy (the personal and intangible matter that improves cooperation)	8	16	7	
	Project Manager competencies	9	18	6	
	Technological degree of innovation	12	24	3	
	Risk of highly difficult technology	9	18	6	
	Technological newness of the project	17	35	1	
	Highly customised products	2	4	9	
	Responsibility & Accountability	8	16	7	
	Requirements capture	3	6	8	
Autonomy	Availability of people, material and of any resources due to sharing	16	33	3	Antoniadis et al. (2011), Azim (2010), Baccarini (1996), Bosch-Rekveldt et al. (2011), Browning (2014), Cicmil and Marshall (2005), Favari (2012), Geraldi and Adlbrecht (2007), Gidado (1996), Green (2004), Hussein et al. (2013), Kennedy et al. (2011), Lessard et al. (2014), Little and Graphics (2005), Lu et al. (2015), Maier (1996), Maylor et al. (2008), Pich et al. (2002), Qureshi and Kang (2014), Remington et al. (2009), Senescu et al. (2013), Sinha et al. (2006), Tatikonda and Rosenthal (2000), Thomas and Mengel (2008), Vidal et al. (2007, 2011a, 2011b), Vidal and Marle (2008), Williams (1999), Wood and Gidado (2008), Xia and Chan (2012), Yugue and Maximiano (2012)
	Level of interrelation of between phases	9	18	10	
	Team/partner cooperation and communication	22	45	1	
	Levels of management are involved in project decision-making	5	10	12	
	The amount of overlap and interactions	11	22	8	
	Dynamic and evolving team structure	12	24	7	
	Dependencies with the environment	12	24	7	
	Interdependencies between sites, departments and companies	19	39	2	
	Interdependencies of objectives/interests	16	33	3	
	Process interdependence	15	31	4	
	Stakeholders interrelation/interdependencies	12	24	7	
	Interdependencies between actors	13	27	6	

(continued on next page)

Appendix 1 (*continued*)

Dimension	Project complexity factors (provenance of complexity)	Number of referred	%	Rank	Referred to by
	Specifications interdependence	10	20	9	
	Interdependence between components of the product	5	10	12	
	Technological process dependencies	14	29	5	
	Resource and raw material interdependence	10	20	9	
	Dependencies between schedules	13	27	6	
	Interdependencies of information systems	11	22	8	
	Number of governmental people who involved in projects	7	14	11	
	Combined transportation	9	18	10	
Connectivity	Interconnectivity and feedback loops in the task and project networks	16	33	1	Bosch-Rekveldt et al. (2011) Favari (2012), Gidado (1996), Green (2004), Kennedy et al. (2011), Lessard et al. (2014), Lu et al. (2015), Qing-hua et al. (2012), Qureshi and Kang (2014), Ramasesh and Browning (2014), Vidal et al. (2011a), Vidal and Marle (2008), Williams (1999)
	Face to face relationship between project team members	4	8	6	
	Number of interfaces in the project organisation	9	18	3	
	Relations with permanent organisations	10	20	2	
	Capacity of transferring information	5	10	4	
	Level of processing information	5	10	5	
	Goals/interests alignment	16	33	1	
Emergence	Dynamics of the task activities	8	16	5	Akintoye (2000), Azim (2010), Ahern et al. (2014), Bosch-Rekveldt et al. (2011), Brady et al. (2012), Crawford (2005), Geraldi and Adlbrecht (2007), Geraldi et al. (2011), Jaafari (2001), McDaniel and Driebe (2001), Little and Graphics (2005), Maylor et al. (2008), Müller et al. (2007); Ramasesh and Browning, 2014; Senescu et al. (2013), Shenhar (2001b), Turner and Cochrane (1993), Vidal et al. (2011a), Vidal and Marle (2008), Wood and Gidado (2008), Yugue and Maximiano (2012)
	Uncertainties of scope	18	37	1	
	Uncertainty & clarity of objectives or goals	17	35	2	
	Uncertainty in technical methods	16	33	3	
	Information uncertainty	10	20	4	
	Clients with unrealistic goals	7	14	6	
	Market uncertainty	5	10	7	
Diversity	Variety of financial resources	14	29	4	Akintoye (2000), Azim (2010), Baccarini (1996), Bosch-Rekveldt et al. (2011), Brady and Davies (2014), Camci and Kotnour (2006), Castejón-Limas et al. (2010), Cicmil and Marshall (2005), Frame (2002), Geraldi and Adlbrecht (2007), Gidado (1996), Green (2004), Hobday (1998), Hussein (2012), Lessard et al. (2014), Maier (1996), Maylor et al. (2008), Müller and Turner (2007), Qing-hua et al. (2012), Qureshi and Kang (2014), Ramasesh and Browning (2014), Remington et al. (2009), Santana (1990), Sinha et al. (2006), Thomas and Mengel (2008), Vidal et al. (2007, 2011a, 2011b), Vidal and Marle (2008), Williams (1999), Wood and Gidado (2008), Xia and Chan (2012), Xia and Lee (2004), Yugue and Maximiano (2012)
	Variety of organisational skills needed	13	27	5	
	Variety of the project management methods and tools applied	18	37	2	
	Variety of resources to be manipulated	10	20	8	
	Diversity of tasks	11	22	7	
	Diversity of inputs and/or outputs	9	18	9	
	Variety of the interests of the stakeholders	18	37	2	
	Diversity of staff (experience, social span ...)	13	27	5	
	Variety of the stakeholders status	10	20	8	
	Cultural variety	19	39	1	
	Number of different languages	10	20	8	
	Multiple time zones	5	10	11	
	Variety of hierarchical levels within the organisation	11	22	7	
	Variety of organisational interdependencies	16	33	3	
	Variety of technological dependencies	13	27	5	
	Variety of the technologies used during the project	12	24	6	
	Variety of technological skills needed	16	33	3	
	Multiple participating countries/location	13	27	5	
	Geographic location of the stakeholders	12	24	6	
	Variety of information systems to be combined	11	22	7	
	Variety of the product components	10	20	8	
	Client transparency, empathy (the personal and intangible matter that improves cooperation)	12	24	6	
	Multiple suppliers, contractors, vendors, etc.	8	16	10	
Size	Number of decisions to be made	10	20	12	Akintoye (2000), Azim (2010), Baccarini (1996), Bosch-Rekveldt et al. (2011), Camci and Kotnour (2006), Castejón-Limas et al. (2010), Cicmil and Marshall (2005), Crawford (2005), Doyle and Hughes (2000), De Reyck and Herroelen (1996), Frame (2002), Geraldi and Adlbrecht (2007), Gidado (1996), Giezen (2012), Green (2004), Hussein (2012), Lessard et al. (2014), Leung Wing Tak (2007), Maylor et al. (2008), Müller and Turner (2007), Nassar and Hegab (2006), Qureshi and Kang (2014), Ramasesh and Browning (2014), Remington et al. (2009), Santana (1990), Shenhar et al. (1995), Shenhar (2001a), Sinha et al. (2006), Thomas and Mengel (2008), Vidal et al. (2007, 2011a, 2011b), Vidal and Marle (2008), Williams (1999), Wood and Gidado (2008), Xia and Chan (2012), Xia and Lee (2004), Yugue and Maximiano (2012)
	Duration of the project	18	37	4	
	Number of deliverables/disciplines	17	35	5	
	Number and quantity of resources	12	24	10	
	Number of activities	15	31	7	
	Largeness of capital investment	11	22	11	
	Number of the project management methods and tools applied	18	37	4	
	Number of different occupational specialisations	5	10	15	
	Number of inputs and/or outputs	9	18	13	
	Largeness of scope (number of components etc.)	18	37	4	
	Size in CAPEX (Capital expenditures)	7	14	14	
	Number of stakeholders	23	47	2	
	Number of companies/projects sharing their resources	16	33	6	
	Number of formal units & departments involved	22	45	3	
	Number of objectives	14	29	8	

Appendix 1 (*continued*)

Dimension	Project complexity factors (provenance of complexity)	Number of referred	%	Rank	Referred to by
	Number of investors	12	24	10	
	Staff quantity	10	20	12	
	Number of structures/groups/teams to be coordinated	25	51	1	
	Number of hierarchical levels	14	29	8	
	Number of information systems	13	27	9	

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Statement of Authorship

Title of Paper	
Publication Status	☑ Published ☐ Accepted for Publication ☐ Submitted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
Publication Details	Bakhshi, J., Ireland, V., DE Zubielqui, G C. (2015), "Exploring project complexities: a critical review of the literature", AIPM Conference, 11-14 October, Hobart, Australia

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Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.
Signature	Date 01/03/2016

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i the candidate's stated contribution to the publication is accurate (as detailed above);

ii permission is granted for the candidate in include the publication in the thesis; and

iii the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

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Signature	Date 02/03/2016

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Proceedings of the

Australian Institute of Project Management

2015 National Conference

ISBN: 978-0-646-93701-4

Australian Institute of Project Management

NATIONAL 2015 CONFERENCE

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Exploring project complexities: a critical review of the literature

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Abstract

This paper examines project complexity factors and what makes a complex project. A vast number of factors seem to be contributing to project complexity, but some of them are unknown. Projects are becoming more complex due to unexpected emergent behaviour and characteristics. Complex projects can be seen as autonomous and independent systems which are often defined as self-organising, unpredictable, network-centric and flexible. Complexity is one of the most important variables contributing to a project's failure and it has become the main concern of the project management field. Although there is extensive research in this area, there is still a lack of understanding on project complexities. Numerous authors have considered the lack of knowledge and unfamiliarity with the system as a fundamental aspect of complexity. This paper proposes that this is a misunderstanding of the issues at hand. Thus, this paper provides an overview of integrated collections of complexity factors that can support both researchers and practitioners to understand and manage complex projects. To do this, a systematic literature review has been conducted, which includes peer reviewed journal articles, theses, books and unpublished materials. More than 350 sources have been included in the analysis to explore the development of project complexity. Overall, this study provides a framework which includes 97 project complexity factors which are critical to understanding the complexity concept. Owing to the limitations of projects, project managers are able to consider only those factors which play a critical role in helping them to achieve their goals. Selected major complexity factors provide inputs to decision analyses and eventually ask for the right resources.

Keywords: Project Complexity, Complex projects, system of systems, epistemology, Autonomous and independent systems

1. Introduction

It is hard to imagine any simple projects in today's emergent behaviour world. There is a variable degree of complexity in all types of projects. This is evident in the basic definition of complexity, which is defined as an entity consisting of many varied interrelated parts and elements such as tasks, components, and interdependence. Thus, every practical project in the world contains a degree of complexity. Complexity is one of the most important and controversial topics in many disciplines, project management included. Interestingly, however, there is no satisfactory definition of complexity (Ireland, 2013). Although there is extensive research in this area, there is still a lack of understanding on what factors contribute to project complexity. Accordingly, the purpose of this paper is to clarify the epistemology of project complexity and the implication of this definition for complex project management, considering different schools of thought.

Complex systems display numerous different behaviours. Self-organisation and the emergent properties of them are often counter-intuitive. As a result, opportunities for external or top-down control are very limited (Helbing, 2013). This is because of their diverse components' properties and interactions without simple cause-

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effect relationships. Based on this, "complexity is the inability to predict the behaviour of a system due to large numbers of constituent parts within the system and dense relationships among them" (Sheard & Adviser-Mostashari, 2012). To clarify this definition further, we have conducted an in-depth systematic literature review to define complexity in the context of project management. The analysis period is from 1990 to 2015, and covers key developments in project complexity (see figure 1).

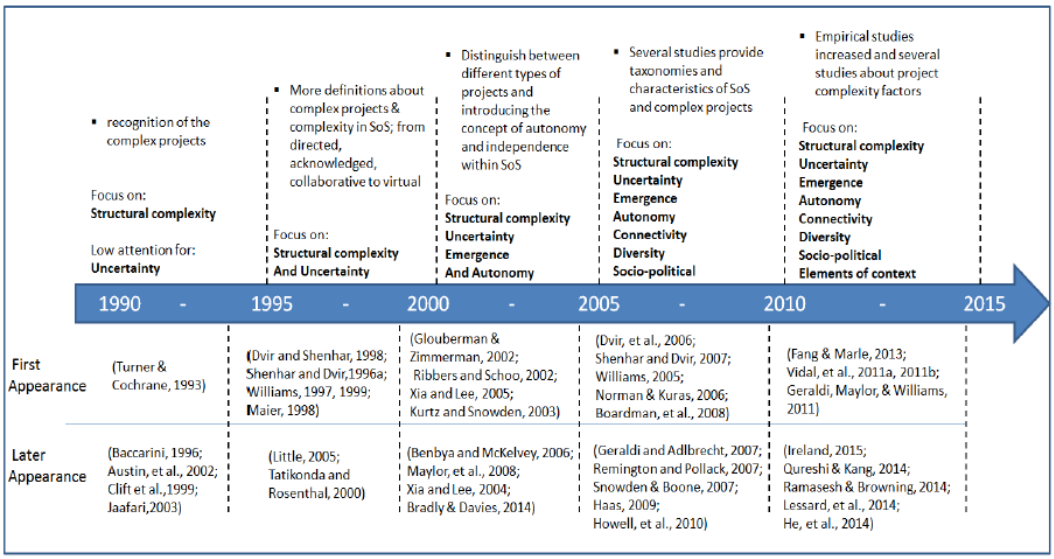

Fig1: Milestones of project complexity history (source: authors)

2. Defining Complexity in the Context of Project Management

There are several definitions of project complexity. However, it is difficult to find an appropriate definition which covers all aspects of complexity in projects. In general, we can define the project complexity as the "property of a project which makes it difficult to understand, foresee and keep under control its overall behaviour, even when given reasonably complete information about the project system" (Vidal, Marle, & Bocquet, 2011a). It could be useful to look at projects as a hierarchy of simple, complicated, complex, and chaotic. We can define simple projects as temporary activities undertaken to create products or services with clear cause-effect relationships. It means that everyone who participates in a project can appropriately respond to the different situations by accessing the necessary information. This is the domain of "known knowns" which is self-evident, predictable and repeatable. Making food, manufacturing simple house appliances and small constructions are often good examples of simple projects. In complicated projects, there are still cause-effect relationships between tasks and elements, however, they are disputed. Knowledge and expertise are essential for understanding complicated projects and eventually take good practices in order to overcome on their problems (Snowden & Boone, 2007). In other words, complicated projects contain subsets of simple projects but are not merely reducible to them. The nature of complicated projects is not always related to their scale, but to the issue of coordination or specialized expertise (Glouberman & Zimmerman, 2002). Sending a rocket to the moon, producing aircraft and most large construction projects are complicated. In some cases, we don't know what we don't know. This is the domain of "unknown unknowns". Unavoidably, complex projects consist of large elements of ambiguity and uncertainty, interdependency, non-linearity, unique local conditions, autonomy, emergent behaviours and unfixed boundaries. Most defence projects in the USA, UK and Australia as well as

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most health projects, communications satellites, and nuclear-powered submarines are very good examples of complex projects. It is worth mentioning that, based on the definitions above, unfamiliar environments and elements and lack of knowledge are not part of project complexity. It is true that managing complex projects is hard but most project managers will succeed by understanding their patterns by focusing on project complexity factors. However, chaotic projects are not manageable immediately such as most crisis throughout the world. Indeed, it can be said that simple projects and complex projects have significant differences which can be determined by different criteria such as project content or context, project organisation, environment effect, project goal and so on (Cicmil, 1997; Shenhar, Dvir, Morris, & Pinto, 2004). It is worth mentioning that many projects lay somewhere along the spectrum, rarely at one end or the other.

After analyzing over 350 different publications, we found out that there are three dominant schools of thought within the construct of complex projects: the Project Management Institute (PMI) perspective, the System of Systems (SoS) perspective, and the theoretical perspective. To better understand project complexity aspects it is essential to investigate all three views. These three perspectives are introduced in next section.

2.1. The Project Management Institute (PMI) view

One of the first attempts to systematically define project complexity is provided by Baccarini (1996). He uses two angles to define project complexity. The first emphasizes differentiation and connectivity, and the second introduces complexity as a subjective concept focusing on difficulty of understanding the object (Baccarini, 1996). According to Baccarini (1996), structural complexity and project complexity can be inferred based on integrity of communication, coordination and control. In another research, the uncertainty of objectives and methods of achieving project outcomes are also considered important factors contributing to a project's complexity (Turner & Cochrane, 1993). We argue that these two research streams are the foundations of PMI's further research and practice. Based on two previous definitions, Williams (1999) presents a new definition of project complexity. He defines the two factors of two structural uncertainty such as numbers and interdependencies of elements taken from the first definition and also the uncertainty of objectives and methods based on the achievement of the second research as complexity of projects (Williams, 1999). After this, numerous studies which have focused on structural complexity and uncertainty aspects can be included in the PMI perspective (Austin, Newton, Steele, & Waskett, 2002; Clift & Vandenbosch, 1999; Jaafari, 2003; Little & Graphics, 2005; Tatikonda & Rosenthal, 2000). In 2001, Shenhar came up with a new paradigm by introducing "One size does not fit all projects". His research focuses on two databases, the first consisting of 26 projects and the second 127 projects. The findings show that some projects, such as those in the construction industry, have a lower degree of uncertainty, while projects which represent innovation have a higher degree of uncertainty (Shenhar, 2001).

Despite extensive general research, until 2002 there were few studies which defined and distinguished complex projects from other types of projects. Snowden (2002) introduced a decision-making framework that recognises that causal differences exist between system types. He employed the theory of knowledge management to develop four categories of organizational context: simple, complicated, complex and chaotic. Snowden and Boone (2007) use the Cynefin (pronounced ku-nev-in) model as a leader's framework for decision-making with regard to different contexts (see figure 2). They also present new definitions for simple, complicated, complex and chaotic contexts and distinguish their boundaries (Snowden & Boone, 2007).

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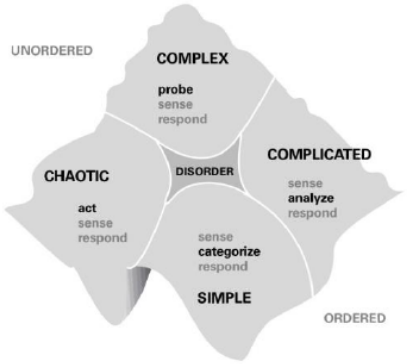

Fig 2: Different types of projects by Cynefin framework adopted from (Snowden & Boone, 2007)

Overall, most researchers who tend towards the PMI perspective concentrate on structural complexity, uncertainty and socio political rather than other complexity dimensions (J. Geraldi, Maylor, & Williams, 2011). The PMI published an in-depth report, "Navigating Complexity", which indicates multiple stakeholders and ambiguity as two key characteristics of project complexity (Project Management Institute, 2013). This approach has also been followed by a vast number of researchers and other aspects of complexity have been neglected in the PMI's perspective.

2.2. The System of Systems (SoS) view

The Snowden and Boone (2007) approach to complexity, more readily articulated in Kurtz and Snowden (2003), supports the System of Systems view of inclusion of autonomous and independent systems, and the issue of not being able to control autonomous and independent systems in the same way that control is exerted on projects in the Ashby's requisite variety space. An extreme example of a SoS is the Air Operations Centre in the USA which has 80 autonomous and independent systems (Norman & Kuras, 2006).

Based on the SoS perspective, we can divide complex projects into three categories (Ireland, Rapaport, & Omarova, 2012):

1. Type A projects are traditional SoS projects which include or build on existing projects for other goals in the new project. For example, the Air (and Space) Operations Centre (AOC) in the USA prepares the tools for planning, carrying out tasks and monitoring operations in Iraq and Afghanistan.
2. In the second category, Type B, which primarily describes wicked problems, the approach concerns different aspects of the systemic concept. The real issue is that the solution is difficult to determine. Checkland's soft system methodology and possibly system dynamics could be used to develop an appropriate solution.
3. The third category, Type C, is projects that combine independent assets arise within a large system, for example, we can point on Global Distribution Centres which come from under systems and many components while independent are part of a larger enterprise.

Systems of systems are "large-scale integrated systems that are heterogeneous and independently operable on their own, but are networked together for a common goal" (Jamshidi, 2008). Maier (1998) attempts to explain complexity in SoS in terms of characteristics such as operational and managerial interdependence of the

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elements, evolutionary development, emergent behaviour, and geographic distribution. Maier then introduces four types of SoS that include Directed, Acknowledged, Collaborative and Virtual. In another study, Norman and Kuras (2006) investigate independent systems integrated into a SoS. The research result shows that all of these autonomous independent systems serve various divergent purposes but also continue to satisfy the original purpose. In other words, they were not built for the same purpose, or used within specific AOC workflows. Autonomy, belonging, connectivity, diversity, and emergence are foundations and characteristics of the SoS that have been considered by many researchers (Braha, Minai, & Bar-yam, 2006; Ireland, White, Gandhi, Sauser, & Gorod, 2015; Sauser, Boardman, & Gorod, 2009).

Based on the SoS perspective, complex projects spontaneously organize themselves to cope with various internal and external perturbations and conflicts. This allows them to evolve and adapt. There are varieties of complexity aspects that deserve greater attention with regard to the project management context (for more information see (Ireland, 2015).

2.3. The Theoretical view

There are numerous publications that consider project or systems complexities with regard to various theories such as complexity theory (Cooke-Davies, Cicmil, Crawford, & Richardson, 2007; Pollack, 2007; Shenhar & Dvir, 1996; Whitty & Maylor, 2009), co-evolutionary theory (Benbya & McKelvey, 2006), organizational social theory (S. Cicmil & Marshall, 2005), contingency theory (Baccarini, 1996; Ireland, 1985; Keller, 1994; Levitt et al., 1999), theory of constraints (Rand, 2000), systems theory (Checkland, 1999), network theory (Pryke, 2005; Rowley, 1997), nonlinearity and chaos theory (Singh & Singh, 2002), and adaptive self-organisation theory (Aritua, Smith, & Bower, 2009; DeRosa, Grisogono, Ryan, & Norman, 2008; Jaafari, 2003).

It is worth noting that many theoretical studies on project management have focused on a single functional aspect of the project (Shenhar & Dvir, 1996). In addition, use all the features and characteristics discussed in theories are time-dependent, observer-dependent, and problem-dependent. How these characteristics operate in various types of projects require more exploration. Most attention needs to be paid to characteristics such as Paretian and power laws distributions, operating at the edge of chaos, chaotic behaviour, scale laws, fractals, fitness landscape, adaptive cycles and etc.

3. Findings and Discussion

After analyzing three schools of thought, distinctions between their perspectives are unavoidable. Although many characteristics are important to be considered in the context of project management in different views, we choose six dominant elements to compare them in the three positions. In our opinion, differentiation between each project can be analyzed by context, autonomy, belonging, connectivity, diversity and emergence. From these descriptors, each complex project consists of autonomous and independent parts and different structures that while are belonging to the same project and are connected to the other parts and departments of the project. Furthermore, the collection of actors, tasks and departments in the project is diverse in some sense and can generate unexpected emergent properties (Ireland et al., 2015). But these concepts require qualification. A project's context, content, and project organisation, is related to the nature, scope, managerial and organisational aspects of project (Cicmil, 1997). Autonomy is exercised by constituent departments, teams or partners in order to fulfil the purpose of the project. Constituent departments / partners choose to be involved because there is a cost benefit for them to do so, but also because they believe in the overall project and because it assists them with fulfilling their own independent objectives. The ability of a department/group to link with other parts of the project is connectivity. Diversity can be defined as distinct or unlike elements or qualities in a group – the

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variation of social and cultural identities among people existing together in the project. The appearance of new properties/behaviours in the course of development or evolution is considered emergent (Boardman & Sauser, 2006; Ireland et al., 2015).

Nevertheless, there are a vast number of factors that affect these characteristics. In other words, there are a variety of factors that change the degree of complexity. Over the last 25 years, project complexity factors have been collected and applied in numerous academic and practical researches. However, there is no international agreement on this and there are many ambiguous points to face with project complexity as a result. In the following, we have collected more than 150 factors that have been reported in different publications from a comprehensive literature review. However, we just selected 97 of them according to different issues that have been discussed in previous sections and number of citations (Table 1). In order to help the audience to increase awareness of factors when dealing with the project complexity, it is important to define clearly a framework for that. Based on this, we develop a new framework by using some past research (Figure 3) (Cicmil, 1997), (Vidal & Marle, 2008), (Vidal, Marle, & Bocquet, 2011b).

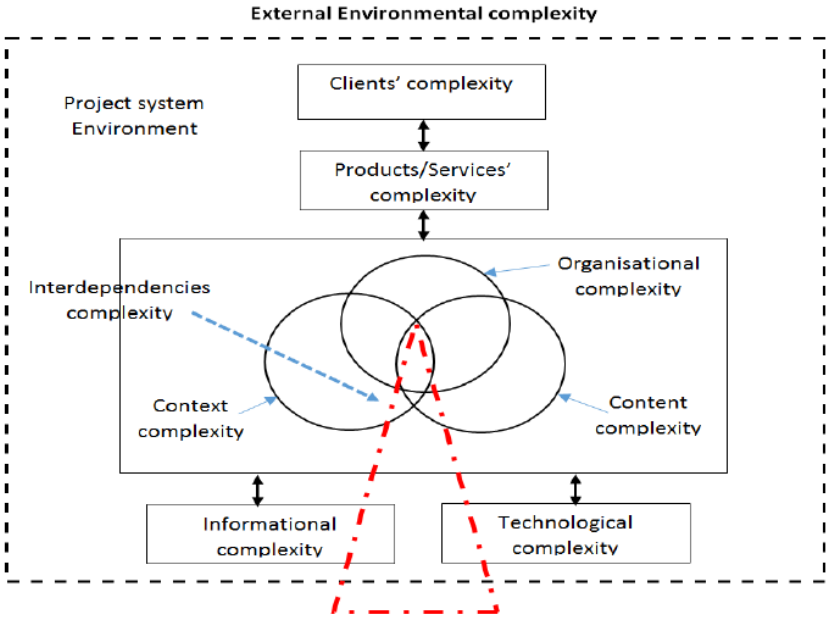

Fig3: Project complexity factors framework (source: authors)

4. Conclusion

This paper reviews the existing perspectives of project complexity in order to understand its concepts and investigates the differences between schools of thought. The research explores the historical development of project complexities. Moreover, more than 90 project complexity factors have been provided by an in-depth literature review. It is worth mentioning that the analysis is not organised or differentiated by the different types of projects (e.g., engineering & construction, IT, industrial and business, defence, etc.). This level of analysis could be an interesting topic for future research. More attention needs to be paid to system thinking approach and how the relationship within complexity factors is. This study enables both practitioners and academics to understand attributes and characteristics of complex projects. The main contribution will correspond to insights embedded in the framework that can assist in decision-making processes in complex projects.

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Dimension	Project complexity factors (provenance of complexity)	Referred to by
Project Content	Number of decisions to be made– Duration of the project– Unknown / poorly defined requirements– Number of activities– Variety of financial resources– Availability of people, material and of any resources due to sharing– Interconnectivity and feedback loops in the task and project networks– Level of interrelation of between phases– Demand of creativity– Scope for development– Institutional configuration– Significant public agenda– Team/partner cooperation and communication– Degree of project flexibility (in scope, process, organisation…)– Diversity of tasks– Dynamics of the task activities– Decision making process challenges– Repetition of similar type of projects– Cost restraints (cost and financing)– Number and diversity of inputs and/or outputs– Largeness & uncertainties of scope– Relationship between project team members– number of autonomous teams/partners	(Baccarini, 1996; J. G. Geraldi & Adlbrecht, 2007; Maylor, Vidgen, & Carver, 2008; Müller, Geraldi, & Turner, 2007; Norman & Kuras, 2006; Qureshi & Kang, 2014; Ramasesh & Browning, 2014; Shenhar, Shulman, & Dvir, 1995; L.-A. Vidal et al., 2011a; L.-A. Vidal & Marle, 2008; Williams, 1999; W. Xia & Lee, 2003)
Project Context	Geographic distribution– Stakeholders conflicts– Number of stakeholders– Number of companies/ projects sharing their resources– Number of formal units & departments involved– Internal politics Issue (ambiguity, hidden information) – Number of objectives– Number of investors– Staff quantity– Variety of the interests of the stakeholders– Diversity of staff (experience, social span ...)– Variety of the stakeholders status– Cultural configuration and variety– Networked environment– The amount of overlap and interactions– Trust in stakeholders– Stability project environment– Uncertainty & clarity of objectives or goals– Goals/interests alignment– Conflict between stakeholders– Level of competition between stakeholders (members, teams, etc.)	(Baccarini, 1996; Bosch-Rekveldt, Jongkind, Mooi, Bakker, & Verbraeck, 2011; S. Cicmil & Marshall, 2005; Crawford, 2005; Hussein, Silva, & Pigagaite, 2013; Lessard, Sakhrani, & Miller, 2014; Maylor et al., 2008; Remington, Zolin, & Turner, 2009; Santana, 1990; L.-A. Vidal et al., 2011a)
Project Organisation	Responsibility & Accountability– Number of structures/ group/ team to be coordinated– Number of hierarchical levels– Variety of hierarchical levels within the organization– Number of interfaces in the project organization– Dynamic and evolving team structure– Relations with permanent organisations– Organisational degree of innovation– Functional role– Team transparency, empathy (the personal and intangible matter that improves cooperation) – Levels of management are involved in project decision-making	(Azim, 2010; Baccarini, 1996; Camci & Kotnour, 2006; Doyle & Hughes, 2000; Frame, 2002; J. G. Geraldi & Adlbrecht, 2007; Green, 2004; HE, Luo, Wang, Li, & Zhao, 2012; Leung Wing Tak, 2007; Little & Graphics, 2005; Thomas & Mengel, 2008; L.-A. Vidal et al., 2011a)
Interdependency	Dependencies with the environment– Variety of organisational interdependencies– Variety of technological dependencies– Interdependencies between sites, departments and companies– Interdependencies of objectives/interests– Process interdependence– Stakeholders interrelation/interdependencies– Interdependencies between actors– Specifications interdependence– Interdependence between components of the product– Technological process dependencies– Resource and raw material interdependence– Dependencies between schedules– Interdependencies of information systems	(Baccarini, 1996; Gidado, 1996; Senescu, Aranda-mena, & Haymaker, 2013; M. V. Tatikonda & Rosenthal, 2000; L.-A. Vidal et al., 2011a; Williams, 1999; Wood & Gidado, 2008; B. Xia & Chan, 2012; Yugue & Maximiano, 2012)
Technology	Variety of the technologies used during the project– Variety of technological skills needed– Technological degree of innovation– Interaction between the technology system and external environment– Uncertainty in technical methods	(Antoniadis, Edum-Fotwe, & Thorpe, 2011; Castejón-Limas, Ordieres-Meré, González-Marcos, & González-Castro, 2010; J. G. Geraldi, 2009; M. V Tatikonda, 1999; Turner & Cochrane, 1993; Wood & Gidado, 2008)
Information	Variety of information systems to be combined– Number of information systems– Information uncertainty– Capacity of transferring information– Level of processing information– Degree of obtaining information	(Ahern, Leavy, & Byrne, 2013; Frame, 2002; HE et al., 2012; Remington et al., 2009; L.-A. Vidal et al., 2011a; W. Xia & Lee, 2003)
Products/ Services	Variety of the product components– Highly customized products	(Maylor et al., 2008; Ramasesh & Browning, 2014)
Clients	Client transparency, empathy (the personal and intangible matter that improves cooperation) Clients with unrealistic goals– Multiple suppliers, contractors and vendors	(Alderman & Ivory, 2007; Hussein, 2012; W. Xia & Lee, 2004)
External environment	New laws and regulations– Local laws and regulations– Level of competition– Environment of changing technology, economy and nature– Multiple participating countries/location– Neighboring environment (including the site access/location) – Geological condition/ difficulty of location– External politics Issue– Union power– Market uncertainty– Number of governmental people who involved in projects	(Azim, 2010; Lessard et al., 2014; Leung Wing Tak, 2007; Little & Graphics, 2005; Sinha, Kumar, & Thomson, 2006; L. Vidal, Marle, & Bocquet, 2007; L.-A. Vidal et al., 2011a)

Table1: Project complexity factors based on systematic literature review (source: authors)

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