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CoPS Projects Complexity: The 5P Model (Purpose, Product, Process, People, Peripheral)

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KEYWORDS

Complexity
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Factors of complexity
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ABSTRACT

The concept of "complexity" is familiar to many of project's managers; however, it is not comprehended by all in the same way. Researches conducted on this field have shown that the authors have difference understanding of "complexity" and their understanding mainly depends on their points of view. In fact, many identified aspects of the complexity in the literature are related to the aims of the research. This paper is an attempt to describe the complexity of project using three approaches; research literature (manufacturing and project complexity), interviews (deep interview with 20 experts) and questionnaire. The research was conducted on the Complex product and system (CoPS) projects. In addition, WH question technique was used. In conclusion, a 5p model (Purpose, Product, Process, People, and Peripheral) was introduced.

1. Introduction

Complexity plays an important role in all scientific and technological areas. Although mankind has perpetually struggled with this great problem from the past till the present, nowadays the pace of emergence of complexities is so high and their dimensions are so numerous that many scholars call the new century as the complexity century. Facing complex phenomena has not been confined to certain times and mankind's involvement in studying and mathematic modeling of them has created a long and unfinished chapter in the significant book of man's science and knowledge. If we accept numbers as the primary simple models of mathematics, then creation of algebra and use of the variables for computations can be considered as the steps taken for the first time to model science and management of the complexity.

1-1. Definition Of The Complexity

Many managers are familiar with the concept of complexity; however, the concept is perceived differently by different people. The term itself has a degree of ambiguity. The difficulty involving the concept points to the different interpretations developed by individuals of different education levels. The word complex is from Latin word "complexus" for a number of pieces piled on one another. Complex may refer to entities consisting of at least two or more sections, pieces, parameters, etc. This can be interpreted as follows: to have a set you need two or more members which may not be

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separated easily. Similarly, Oxford dictionary defines what is complex as "made of many different things or parts that are connected together closely".

It is quite useful to distinguish between the terms "complex" and "complicated" [39]. If one system despites the fact that it is comprised of many components including a full description of their comprising components viewpoint, such as a system, it is literally complicated. For instance, jumbo jets and computers are complicated. "In a complex system, the interaction happens between the system components, and also between the systems. The environment of a system has such a nature that the system as a whole cannot be completely understood only by analyzing its relevant components. This could result in exquisite features, which are often referred to as emergent properties. For instance, brain and a native language are complex systems." [5]

1-2. Manufacturing and production complexity

Increasing complexity continues to be one of the biggest challenges facing manufacturing today. It is manifested in products and manufacturing processes as well as company structures [8]. Manufacturing is facing unprecedented challenges due to the increasing variety of markets and distribution of global production. These systems operate in an environment of changes and uncertainty. Complexity has been defined differently in different fields of science based on different purposes and applications. "Manufacturing complexity is defined as a systematic characteristic, which integrates several key dimensions of the manufacturing environment, which include size, variety, information, uncertainty, control, cost and value." [21] Manufacturing complexity is classified into structural (static) and operational (dynamic) complexities. [11]

A complex system as an open system, in the thermodynamics concept, includes entropy principles and non-linear interactions between the subsystems that can represent, under particular circumstances, the degree of chaotic behavior.

"Most efforts done to say something about complexity in the automotive industry use product variety as the main complexity driver. In the context of production complexity, the product is only one of many factors causing complexity. In addition, other factors seem to increase its importance as production is becoming more automated, effective, flexible, and products are becoming more advanced. Naturally, these interacting factors may be grouped in many ways"[13]. Figure 1 illustrates the drivers for manufacturing complexity. [8]

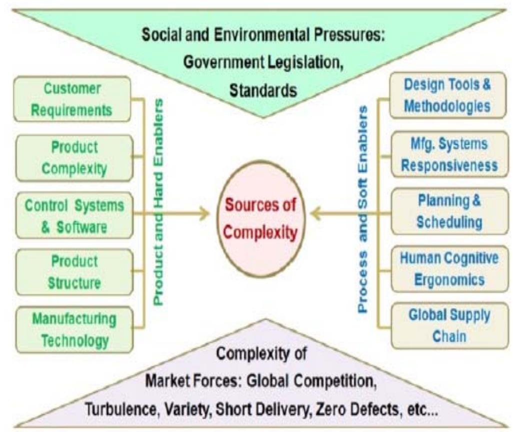


Fig.1. Drivers of manufacturing complexity. [8]

Many researches have been done in the field of manufacturing complexity. Shannon, introduced the complexity of the data, by using the word "entropy" that measures the uncertainty of a random variable in the system. Many have used entropy modeling approach. Frizelle and Woodcock [11] presented the static complexity and dynamic complexity based on Shannon's information theory.

The following table summarizes the research conducted in the field of manufacturing complexity is presented.

Tab. 1. **Summary of research works on definitions and dimensions of project complexity**

Row	Developed by	Year	Model name	Description
1	Frizelle and Woodcock [11]	1995	Entropy	presented the static complexity and dynamic complexity based on Shannon's information theory
2	ElMaraghy and Urbanic [9,10]	2003, 2004	Diversity, content and quality of information	They developed a complexity model based on three elements: (i) total quantity of information, (ii) diversity of information and (iii) the information content which corresponds to the effort to produce a feature within a product.
3	Meyer and Foley Curley [28]	1993	MFC	Complexity science and technology based on questionnaire
4	Papakostas et al. [29]	2009	Nonlinear Dynamics	They investigated the complexity and the stability of manufacturing systems, introducing concepts based on discrete event simulation and nonlinear dynamics theory.
5	Kuzgunkaya and ElMaraghy	2006	structural complexity	They introduced a metric to measure the structural complexity of manufacturing systems based on the complexity inherent in the structure of its components: machines, buffers, and Material Handling Systems (MHS). [8]
6	Samy and ElMaraghy	2010	Assembly complexity	they defined product complexity as the degree to which the individual parts/sub-assemblies have physical attributes that cause difficulties during the handling and insertion processes in manual or automatic assembly. [8]
7	Hu S et al	2008	manufacturing complexity in assembly and supply chains	They defined a complexity model based on product variety including station, system and supply chain complexity. It can be used to ensure robust performance of assembly systems and supply chains by reducing their complexity. [8]
8	Summers JD, Shah JJ	2010	Design process	described the design process as an iterative problem solving process in which the designers typically externalize the design problem, process, and product. [8]
9	Jenab K, Liu D	2010	design structural matrix (DSM)	Reduce product design complexity by providing a design structure matrix (DSM). [8]
10	1- Chryssolouris G, Guillot M 2- Dornfeld DA 3- Monostori L, Csa´ ji BC, Ka´da´ r B	1-1998 2-1990 3-2004	artificial intelligence, artificial neural networks	Using artificial intelligence, artificial neural networks and machine learning techniques to manage complexity and uncertainty in the production process. [8]
11	1- Baldwin CY, Clark KB 2- Parker, D.B	1-2006 2-2010	Modularity	They investigated the relationship between modular product and reduce complexity. [8]
12	Espinoza	2012	Structural Complexity of Manufacturing Systems Layouts	They introduced 6 layout complexity index as a graph. [8]
13	Huang	2003	Material handling pattern	Reduce the production complexity based on the complexities layout (flow and reduce bottlenecks) [8]
14	Kamrani et al [21]	2011	measuring complexity	They presented simulation-based methodologies for measuring complexity and analyze manufacturing complexity due product variety.

1-3. Project Complexity

By definition, project is a temporary attempt to develop a product or service with a unique result. Examples of diverse projects are: developing a new product or service-influencing on changes of a structure, employees, or an organizational style- developing or utilizing a new informational system- construction project- executing a new business process- , etc..

Project managers often utilize the term "complex project". In fact, the concept of complexity is rather familiar to many managers; albeit they do not conceive it in the same way. Nonetheless, there does exist a general agreement on what is simply more than a "big project". The executive managers use words such as "simple" or "complex" when they discuss managing the issues, and in fact, they hinge their managing style on one of these states (a range from simple to complex). Therefore, identifying these factors is of great importance, which entails determining something other than the project "size". Some projects may be big in size but not complex, or in contrary, they might be small in size but complex in nature.

Before dealing with the complexity category, it is better to define COPS. In fact, expensive and complex products and systems which are usually fabricated during a project and at a limited scale are called COPS. Airway traffic control systems, bridges, dams, space crafts and refineries are examples of COPS. Properties such as high technology, high price, customized equipment and parts, available risks, the required industrial agreements between the suppliers and several contractors and level of innovation make COPS distinguishable from other system products. [20]

Why the project complexity is important? [3]

The importance of project complexity has been admitted generally because:

- It can help to meet the requirements of planning, conformity and control.
- It may prevent recognizing main goals of the project clearly.
- It is an important measure to select and organize the project properly.
- It is an important measure to select providing network of the project.
- It can be effective on project goals including time, cost and quality.
- It can help to select and organize appropriate team of project.

1-4. Manufacturing Complexity and Project Complexity

Manufacturing complexity and project complexity are complementary and complexity is one of the most important characteristics of the system. "HilP states that the most important role of a production manager is management of complexity. Furthermore, the production of products or services of large scale or complexity is typically undertaken on project basis. Consequently, project-based management is frequently associated with the management of complexity." [3].

1-5. Research Question

In order to understand project complexity, the research question in this article is: what are the factors of project complexity from literature and the specialists' point of view in the field of COPS projects.

1-6. Research Approach

Inductive approach was chosen to answer the research question. In order to recognize project complexity from technical aspect, related literature was reviewed. However, there is no general definition of complexity in the literature as each research work has addressed the matter from its own viewpoint, It should be considered that complexity by itself is multidimensional subject.

The next step was to use specialists' point of view. To do so, profound and semi-structured interviews were done. The interviews were done to examine and recognize complexity factors from practical specialists' view point in the field of COPS. To do so, the specialists who had experiences from 10 to 33 years were chosen (20 people have been interviewed). These individuals were members of project team or top manager of projects.

The third step was to use a questionnaire, which was developed regarding literature and comparing real projects of CoPS. The specialists were asked to choose and prioritize the items. In the followings each one of the items are further explained.

2.Literature Review

There are different definitions about project and project complexity. a project is a temporary endeavor undertaken to create a unique product, service, or result [53]. Managers frequently use "complex projects" whereas there is no clear definition of what they mean. There seems, however, to be a consensus that it might be more than a merely "Big project". Baccarini [3] developed a good definition about project complexity and suggested that there may be a number of various kinds of related sections which can be operated through differentiation and interdependency. He defined dimensions of complexity as organizational and technological on the basis of his definition, so that these two dimensions are also studied from two aspects of differentiation and interdependency. For example, Dimension of organizational complexity from differentiation point of view can be divided into two categories: Vertical separation and Horizontal separation.

Vertical separation: pertaining to depth of hierarchical structure of the organization and the number of levels

Horizontal separation: can be defined in two ways; the number of organizational units and task structure (Division of labor and Personal specialization)

Another feature of organizational complexity in a project is a degree of operational dependences and interaction between the organizational factors of the project. Thompson recognized three types of dependency between the organizational units including pooled, sequential and reciprocal dependency.

Terry Williams [40] considered all dimensions suggested by Baccarini as structural dimension and suggested another dimension named uncertainty on the basis of studies conducted by Turner and Cochrane[36] and Tatikonda and Rosenthal [35]. He started from Baccarini's definition of structural complexity and continued with other structural dimensions, which increase complexity as follows:

1. Increasing the number of objectives, completing the project within time deadline cost limitations. Defining the project with multiple objectives and sometimes conflicted ones (i.e. specified time and minimum costs) may add to the (structural) complexity.
2. Different stakeholders rather than a specific customer; that is, most projects have complexity within their stakeholders. Most projects have lots of stakeholders, customers- each with unclear goals (managers , team members, owners, champions, people, the public- and etc. This category, like multiple objectives, can add to the (structural) complexity.

Another suggested dimension was uncertainty. Some scholars believe that uncertainty may increase the complexity of the project. Thus it can be considered as the dimensions composing the project complexity. There are some other theories suggesting that uncertainty and complexity are distinctive concepts, whereas both of them generally can create "problem" and "ambiguity" in a project which is called project complexity. The idea of uncertainty in project was well-known in Turner and Cochrane. They classified projects using two parameters: how well the goals are defined and how well the methods are defined.

According to the descriptions mentioned above, there are two main factors (Structural complexity, uncertainty); at the first level each of which are extended to two other factors (Size: number of elements and interdependence of elements, uncertainty in goals and uncertainty in methods).

Hass [19] interpreted uncertainty as lack of awareness of incidents and causality, inability to pre-evaluation and inability to know what will happen. In fact, they all deal with indicating the evidences of uncertainty.

Geraldi et al. [14] developed the concept of complexity patterns; the following is three dimensions of suggested pattern: complexity of faith, complexity of fact and complexity of interaction.

Complexity of faith and uncertainty look alike. The complexity emerges with high uncertainty when something is created, new problems are solved, or a transaction is taking place. In these conditions, no one knows what the result of the project will be, but they believe in it or at least pretend to do so, i.e. developing a new medicine in which the result and processes are indefinite, especially in conceptual phase.

Complexity of fact is similar to that of structure. Its challenge is to have a comprehensive approach to the problem rather than quantities of factual details. Building a refinery is a project influenced by the complexity of the kind; there are many restrictions and many people are involved, however, these are not indefinite (uncertainty) but facts/realities.

Complexity of interaction: it usually emerges pertaining to the points (places, people) and can be described by clarity, frequency of reference, and empathy. Organizational change may occur by this kind of complexity in which the interests of the groups are often ambiguous and contradictory. Communication between the members and empathy can play an important role in this regard

Shenhar and Dvir [7] developed a diamond model to compare the projects on the basis of the fact that all the projects of an organization cannot be in the same form. Four dimensions of technology, novelty, complexity and pace were defined in this model:

- Technology, in terms of how much new technology is used. Technology has the following levels: Low-tech, Medium-tech, High-tech, Super High-tech
- Novelty, in terms of how novel the product is in market and for consumer. Novelty is divided into the following types: Derivative, Platform, New-to-the-Market, New-to-the-World
- Complexity, in terms of how complex the product and/or the organization of the project is. It has the following levels: Material/Component, Assembly/Subsystem, System, Array/System of Systems
- Pace, in terms of how critical your time frame is. Pace represents the urgency to complete the project. It has the following levels: Regular, Fast/Competitive, Time-Critical, Blitz

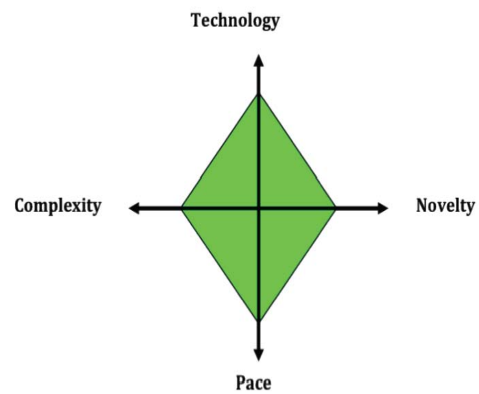


Fig. 2.Diamond model of Shenhar and Dvir (1998) [7]

As seen in figure2, the complexity is one of the axes of the model, whereas each axis is one dimension of the project complexity.

Hass et al [19] presented a project complexity model. They developed a framework of identifying the elements of complexity (which was considered in specified project) so that the project team can make decisions proper to complexity management. Spider diagrams are used to illustrate the complexity of the project and three levels of independent complexity, moderate complexity and high complexity. Some dimensions of project complexity of this model are time and project value, size and composition of team, required schedule of project, cost and range of flexibility, clarity of problem and solution, required stability, strategic importance, stakeholders' influence, level of organizational and business change, external constraints and dependencies, political sensitivity and unproven technologies.

Remington and Zolin [31] have presented a definition for a complex project based on which they defined the complexity of project. They defined the complex project as something indicative of the number of its features or intensity level causing the prediction of project results, and project controlling or managing difficult. These features include a high level of connection, non-linearity, inconformity, and emergence. The complexity model of the project was focused on the intensity factors (the factors which could worsen the complexity) and the dimension factors (the factors which are indicative of the nature of complexity or a combination of both).

Another definition for the project complexity was proposed by Vidal et al [37,38]. Based on their definition, "the project complexity is a project property, which makes the comprehension, prediction, and controlling its whole behavior to be difficult through giving the logical complete information about the system. The drivers of project complexity are project size, project variety, project interdependence, elements of context."

Zhang Xian and Wang Xue-qing [46] developed a construction system complexity concept model (CSCCM) for construction projects. The dimensions of this model are as follows:

- Definition dimension: there are two levels of definition of complex systems, namely difference and interdependency.
- Character dimension: autonomous elements, undefined and nonlinear values.
- Perspective dimension: description of different views of construction system, i.e. engineering perspective of technology, organizing the structure from the stockholders' perspective, task perspective, engineering information perspective, project goals perspective, and project environment perspective.

Fitsilis [50,51] introduced a model of complexity for software projects. This model suggests utilizing the whole knowledge of project management and modeling on the basis of Geraldian typology of complexity, i.e. complexity of faith, fact and interaction.

Rekveldt et al [4] suggested TOE (technical, organizational, environmental) model on the basis of large engineering projects. They used 18 interviews and 6 real projects to develop this model. This model introduces the factors of complexity from both theoretical and practical points of view. The question of the research was "what elements of complexity are participated concerning the project complexity and how these might be embedded in a pattern so that the project complexity can be described in large engineering projects". To answer the question they used deduction approach, interviews and some practical projects. Extracting complexity factors from literature as well as interviewing with 18 experts and examining 6 large real engineering projects they introduced three factors of complexity, namely technical, organizational and environmental (TOE). Afterward, they organized 50 factors of complexity obtained from the literature, the interviews and projects into these three categories.

Azim et al [34] highlighted the effective elements of complexity to understand project complexity using qualitative method and semi-structured interviews with the experts involving real projects concentrated on aerospace industry. The participants were selected from different projects with different levels of complexity. Their analysis indicated "People" as the most important level and they emphasized the importance of software skills of management of complex projects. Their results showed the triangle of project complexity –People, product and process- as three main settings of project complexity.

John Owens et al. [48] observed that management of complex projects need to be changed fundamentally and traditional tools (cost, schedule and design) do not work anymore. They presented a model with 5 dimensions including context, finance, schedule, cost and technique on the basis of comprehensive studies on complex transportation projects. They studied literature of these 5 fields and then gathered all factors addressed on these fields. At the next step, they introduced their final model through case studies (5 projects) and interviews with the managers of the projects. Afterward, they showed the complexity of the projects by using radar diagram. To do this, they asked the experts (the managers of the projects) to score(10-100) to each project involving any of these fields while no project can receive zero score. Given this the following figure

(figure 3) was designed for 5 projects.

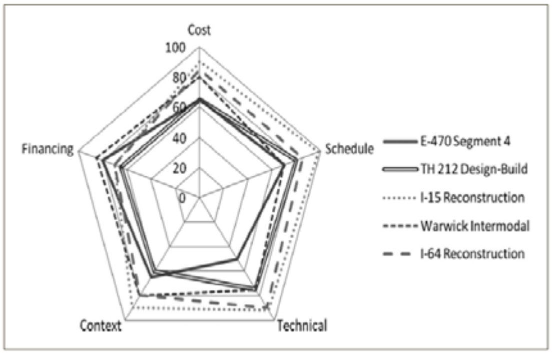
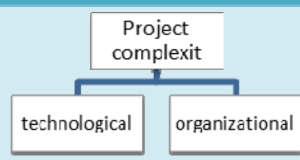
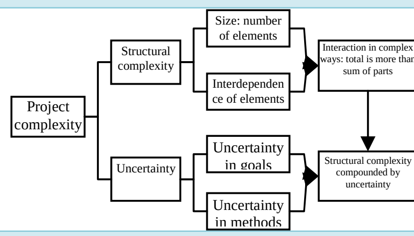
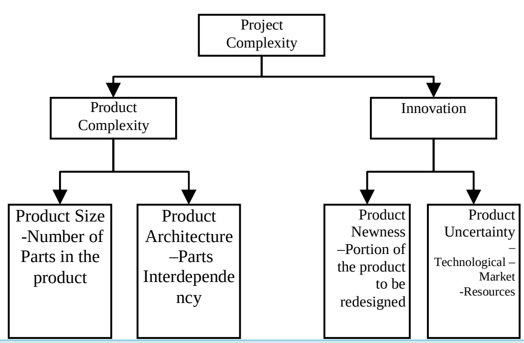
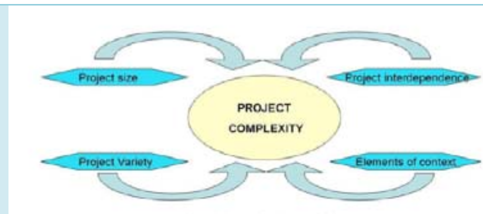
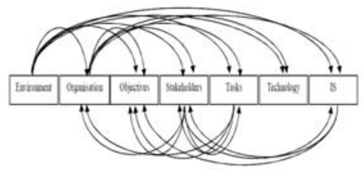
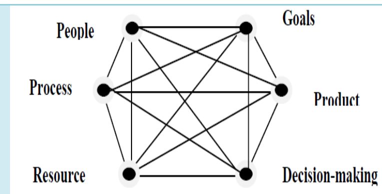
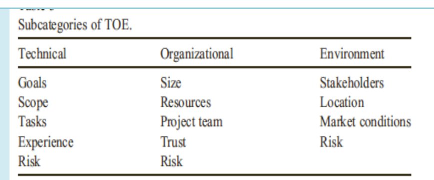
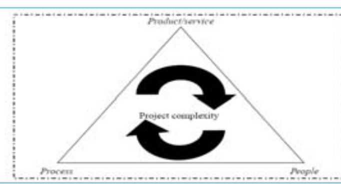


Fig. 3.Diagram of complexity radar suggested by John Owens et al [48]

The following table is a summary of discussed research works above as well as other studies conducted on the subject.

Tab. 2. Summary of Research on Definitions and Dimensions of Project Complexity

Row	Developed by	Year	Defined dimensions	Description
1	Baccarini	1996		The first categorization and definition which interpreted in two aspects of distinguishing and dependency [3]
2	Terry Williams	1999		Emphasis on uncertainty [40]
3	Xia and Lee	2004	dynamic complexity	Studying dynamic complexity in the projects of informational systems to identify dimensions of complexity. The methodology was questionnaire [43]
4	Lebcir	2006		Emphasis on innovation in NPD projects [24,25]
5	Geraldi et al	2007	complexity of faith, complexity of fact, complexity of interaction	Concepts and patterns of complexity [16]
6	Maylor et al	2008		Defining factors with emphasis on managerial aspects of project complexity [26]

Row	Developed by	Year	Defined dimensions	Description
7	Remington and Pollack	2008	structural, technological, directional and temporal	Adding two dimensions of directional and temporal complexity [30]
8	Saleem Gul and Shahnawaz Khan	2011	structural, uncertainty, humanity uncertainty	Human factor was emphasized [32]
9	Vidal et al	2011		Defining of indices including size, variety, dependency, concept (objectives and values) to use AHP technique [37,38]
10	Ali Sedaghat-Seresht	2012		Factors were presented by using Delphi technique and their effects on each other were examined by DEMATEL method [33]
11	Hagan	2011		Factors such as goals, product, decision making, people, process, and resource were introduced on the basis of multi projects environment [18]
12	Hass	2009		Presented complexity model (Independent complexity, Middle complexity and high complexity) [19]
13	Marian Bosch Rekveldt et al	2011	 Subcategories of TOE. Technical: Goals, Scope, Tasks, Experience, Risk Organizational: Size, Resources, Project team, Trust, Risk Environment: Stakeholders, Location, Market conditions, Risk	They developed the TOE framework (Technical, Organizational, and Environmental) [4]
14	Syed Azim et al	2012		They proposed project complexity triangle - "People, Product and Process" as the three major areas of project complexity [34]
15	Kouroush Jenab et al	2012	They used a fuzzy complexity model for educational projects, which has two primary aspects (technical aspects and transparency aspects). [52]	
16	Albrecht and Spang	2014	They proposed facts of project complexity in their case could be : □ Size of project team, □ Common working history of project team □ Geographical dispersion of project team, □ Overall company's size □ Number of company-internal departments/ units involved in project □ Number of company-external stakeholders involved □ Geographical distance to project's client □ Common working history of company and/or project manager with project's client □ (Change in) technological uncertainty [1,2]	
17	Dunovic et al	2014	They completed researches of Baccarini and Williams, and presented new model with 3 major factors : structural complexity, uncertainty and Constraints (environment, resources and objectives) [6]	
18	Xiang Ding et al	2014	They proposed project complexity factors :Project scale, technical difficulty, project target, uncertainty of environment [44]	

Literature review showed that most of the expressed problems in complexity area have their roots in researchers' viewpoint and there is no consensus about definition of complexity. Actually, most of recognized aspects of complexity in the literature are related to the objectives of the research.

However, the primary categorization of the recognized factors can be as follows:

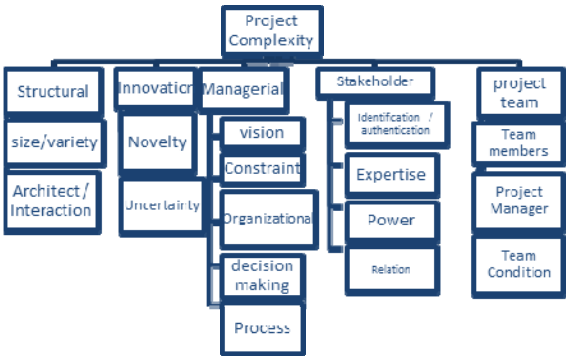


Fig.4. Initial categorization of complexity factors from literature review

Literature review showed that most of the reported cases within the complexity area referred to the purpose and viewpoint of the researcher.

3. Factors Identified Through Interview

The method for identifying project complexity factors through interview was inspired by the method of critical success factors (CSF), which forms a foundation for planning and strategic managing. This same approach is grounded theory. In the case of grounded theory, sampling begins as a "commonsense" process of talking to those informants who are most likely to provide early information, which is known as theoretical sampling. This information is then analyzed through the application of open coding techniques, or line-by-line analysis (looking for words and sentences in the text that have meaning), which can help to identify provisional explanatory concepts and direct the researcher to further "theoretically" identified samples, locations, and forms of data [49], and in this method the opinions and experiences regarding the complexity factors are identified through a series of interviews with the elites. This method is beneficial since the interviewed people are usually selected among the project managers who possess lots of experiences and such experiences cannot be attained through reviewing the research literature. Therefore, by using this interview with a specific goal and purposeful questions, an attempt is made to identify their thoughts and behaviors on the subject of project complexity. The major principle in recognizing the factors is the Pareto principle, which is described as follows.

Pareto principle: More than 80% of failures depend on only 20% of the factors. The critical success factors are lower than those 20% factors on which more than 80% of failures or successes of an organization is depended. Therefore, studying them and developing specific plans to surmount them are of great importance. Such principles are also valid for the complexity factors; in other words, there exist 20% of the factors which create 80% of the project complexities.

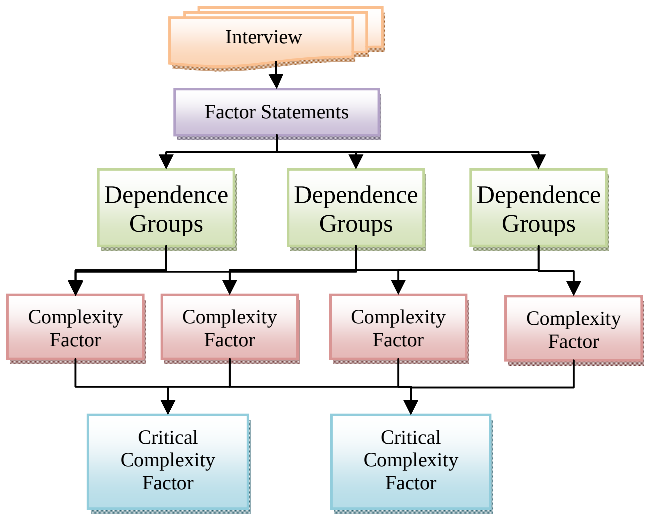


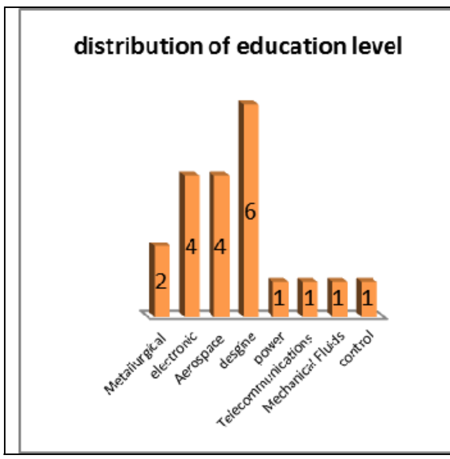
Fig. 5. Model of Project Complexity Factors

As illustrated in Figure 5, the first step in recognizing the project complexity factors is to interview with the elites (experienced in projects and project management) who have possessed the strategic and key roles in different projects. Then, on the basis of the expressed factors as well as based on the obtained abundance from these factors; a general list of complexity was developed. Finally, those with the highest abundance were selected as important factors in the project complexity.

3-1. Statistical Analysis Of The Interviewees:

As mentioned, the interviewees were selected among the experts with experience in the research on complexity product systems.

The distribution of education levels of the people is as follows:



Number	Grade
8	Ph.D.
6	MSc.
6	BSc.
20	Total

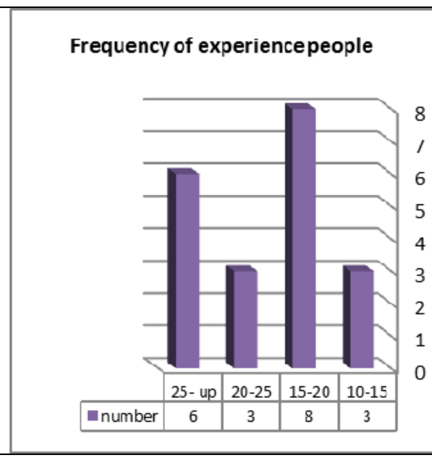


Fig. 6- Distribution of Education Level and Experience of The Subjects

The average of work experience was 20.4 years.

Some interview notes are briefly presented:

- The new requirements which were not applied in the previous projects and are necessary in the current project.
- Ambiguities concerning the project mission and objective, assignment and problems could increase the level of complexity to be increased.
- In the course of project, new issues are introduced by examining the project definition. For instance, an isolation

subject was not discussed in the previous project while it was introduced in the current one. Therefore, new requirements might bring about new technological problems.

- The type and level of technology in the project could lead to increase of the complexity of the project.
- Moving towards the future products caused a jump in the level technologies. Prior to this, the low level technology was used, and then, novel discussions resulted in new and unknown discussions.
- The new objectives require personnel with new skills. With respect to the hardware state which needed a specific specialty, new experts are needed. As a result, their management would be more complex compared with the previous cases.
- Several groups of experts should be formed for mechanical, electronic, chemical projects. The interaction between the groups and different specialties in line with teaching the properties and specifications of the project to different people could increase the complexity of the projects.
- Difficulty and perplexity do not have similar meaning. Traveling on a mountain pass is difficult but there are occasions one is not sure to select the route. In this case, it is perplexity that can increase complexity. The project volume increases its difficulty, cost, and time. Sometimes there is no knowledge about a smart beginning in a project. In this case, it is possible to make a mistake because these factors can be understood relatively, which could be easy for one and very complex for the other. The ambiguity and mysteriousness could lead to increase the level of complexity.

In the next step, the factor statements were derived. For example, factor statements of interview 1 were clarity of the assignment, general goals of the project, new issues of job, novelty levels, and new technology to be used.

3-2. Forming Dependence Groups And Supporting Themes:

According to the success factor statements, after forming the factor statements, they must be put into different dependence categories regarding the conceptual dependence, from which the complexity factors are derived eventually. It should be noted that the important factors of complexity would be categorized regarding their repeating abundance and percent in the statements of different managers.

Prior to the supporting themes derivation, the interviewees could be categorized in 8 main groups as shown in table 3:

Tab. 2- Categories of Dependence Groups

Group	Description	Interview	Sample
1	the subjects and statements are presented mainly on the project assignment and its clarity	1	Clarity of the assignment, general goals of the project. New requirement which were not applicable in the previous projects.
		5	High precision is expected which makes this project more complex than the previous ones.
		...	...
2	most of the subjects and statements are on the project product	3	The presence of systems and subsystems which are entangled and have complex relations. Combination of software and hardware problems
		4	Diversity of the structure and project components The number of special boxes in the project
		...	...
3	most of the subjects and statements are on the technology and the project technologies	7	Complexity due to technology and design knowledge Limited access to the technology makes you to explore unknown and new routes.
		9	The required technology for those projects should be up to date. The more up to date the project, the more complexity it

Group	Description	Interview	Sample
			brings about. The level of used technology in that project affects the level of complexity.
		...	...
4	most of the subjects and statements are on the implementation method and the design knowledge of the project	5	The complexity induced by knowledge based problems
		8	The design knowledge The tests which should be done for the project.
		12	Lack of knowledge and methods causes trial and error method to be used.
		...	...
5	most of the subjects and statements are on the manpower of the project	2	The absence of cooperation among the team members.
		3	The specialized manpower proper for the level of technology and the project complexity.
		4	One important problem is the Employer itself. Proper output can be made with a capable employer.
		4	The requirement statement could affect all the project activities.
		4	The relationship between the employer and employee.
		...	...
6	the majority of the subjects and statements are on the customer/employer	4	The requirement statement could affect all the project activities.
		7	The outside organizations could cause complexities.
		11	The conformity between the requirements and reality
		...	...
7	most of the subjects and statements are on the environment and substructure of the project	12	Some of the complexities are not naturally related to the project, rather some national conditions could cause those complexities. There are no proper foundations in any areas.
		16	The outside problems such as culture, technology. Cultural and environmental issues caused a higher level of complexity.
		...	...
8	most of the subjects and statements are on the project management processes	4	Decisions should be on-line. The type of decisions (on-time) may affect the project complexity. Decision making processes
		8	The designing step could also lead to more complexity in the project. The project management method and programming and controlling are influential in the complexity of the project.
		...	...

3-3. Extraction of Complexity Factors

To derive the complexity factors of supporting themes in each one of the dependence groups, we should focus on issues that have been more emphasized by interviewees. Therefore, on the basis of statements made by interviewees, frequency graph is presented as follows (Fig.7):

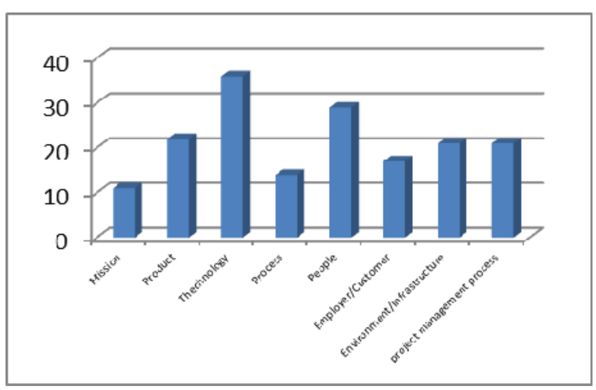


Fig. 7- Frequency Graph of Dependence Groups

The most important factor based on interviews is shown in Table 4.

Tab. 3- Most important factor based on interviews

Factor	frequency	Percent
The nature of mission and the new Cryptic issues	11	13%
Socio-political situation (sanctions and threats)	11	13%
The number of components and sub	9	11%
Achieving and acquisition Technology	9	11%
Technology issues and the multiplicity of Technology	9	11%
Novelty and the technological level of project / product	8	9%
Uncertainty and lack of knowledge of procedure	8	9%
Capabilities and expertise of the manager and the project team	8	9%
Managerial and organizational project team issues	6	7%
Requirements and needs of the clients	6	7%

4. Factors Identified Through Questionnaire

Another method for identifying the complex factors is questionnaire. To this end and according to the literature review, most of the factors mentioned by the researchers in this field, were listed and categorized (Figure 4). Afterwards, a certain number of experts were asked to score the defined algorithm according the factors identified.

4-1. The Questionnaire Statistical Population

For the questionnaire as well as interview, the experts from COPS projects were used. To this end, 16 experts were employed. For further details on the selected experts see figure 8.

Number	Grade
5	Ph.D.
3	Ph.D. St
4	MSc.
4	BSc.
16	Total

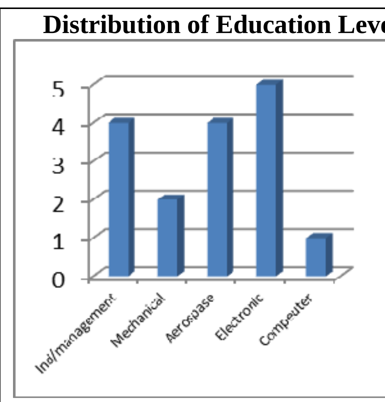


Fig. 8- Distribution of Education Level of The Peoples

Based on the field and literature review, the influential factors on the complexity of the project were extracted from initial categorization of all factors in the scales of zero and one. (Fig. 4)

For evaluation and factor preferences and selection of the most important factors, the following algorithm was utilized:

1- At first, choose the most important factor at the zero level and put it on top of the list. (Remove this factor from the list in the next step comparison).

2- From the remaining list, reselect the most important factor and put it on top of the remaining list and in the bottom of the previous one.
3- Repeat that step 1 and 2 until the remaining list is complete.
4- If the most important factor is scored10, what will be the score of the next factor (in the scale from 1 to 10). (Specify the score in front of the factor).
5- Repeat this scoring until the last factor (it is notable that the factors may score similar points).
6- Use this algorithm for scoring all the factors in all levels until all the factors are scored.

Before presenting the results of questionnaire, its validity was investigated.

4-2. Research tools

To collect information, a questionnaire consisting 90 questions was used and the interviewees were asked to score each item from 0 (no impact) to 10 (the greatest impact).

4-3. Validity of the questionnaire

To ascertain the validity of questionnaire "content validity" method was used. This method assures that the tool has enough questions to measure the questioned concepts. The more extended the elements of the scale, the wider area of the concept is covered, and higher and higher the validity of the questionnaire. In other words, the validity of content shows how accurate the dimensions of the questionnaire are. In this research questions were designed based on the theories of each variable. The questionnaire was provided to authors, specialists, and experts in the field; afterward, the irrelevant questions were eliminated or modified, and new questions were added if needed.

4-4-4. Reliability of the questionnaire

Reliability is a measure of the quality and accuracy of a questionnaire. In other words, reliability refers to the accuracy, trust, stability, reproducibility of the results of a questionnaire at the same conditions.

To calculate the reliability two methods were used: Cronbach's alpha and Split-Half. (Table 5)

Tab. 4- Results of SPSS to calculate reliability

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.938	.922	90

Reliability Statistics			
Cronbach's Alpha	Part 1	Value	0.873
		N of Items	45
	Part 2	Value	0.890
		N of Items	45
	Total N of Items		90
Correlation Between Forms			0.890
Spearman-Brown Coefficient	Equal Length		0.942
	Unequal Length		0.942
Guttman Split-Half Coefficient			0.941

The closer the Alpha to 1, the higher the reliability of the questionnaire. On the other hand, when the value of Alpha is more than 0.7, reliability of the tool is at acceptable level, reliability between 0.5 and 0.7 is at average level, and reliability less than 0.5 is not acceptable. Since, Cronbach's Alpha of for total questionnaire is equals 0.938 and split-half Alpha is about 0.873 and 0.890 for both groups, the reliability of the questionnaire is at acceptable level. Moreover, attained coefficient by Split-Half (0.941) indicates good quality of the questionnaire.

The most important factors, as indicated by the results, are listed in Table 6. It is notable “uncertainty in methods and knowledge of design” (score 749)and “existence of ownership view” (score 198) are the highest and the lowest factors, respectively. Table 6 lists 35 factors with scores more than 450 and 34 factors with scores less than 450. The less important factors are omitted from the final list.

Tab. 5- The Most Important Factors Based on Questionnaires

Factors	Score	Factors	Score
Uncertainty of Method - Uncertainty of Designing	749.33	Mismatch between the project and the organizational structure	510.5
Newness of Technology	682.2	Size of project funding	508.06
Uncertainty of purpose - defined as projects with multiple conflicting objectives or goals	680.53	Motivation among team members	507.31
Diversity of Project (multiplicity of professions required to accomplish the project)	655.13	Lack of adequate human resources allocated to the project	502.94
Multiplicity of components, the number of elements of the project, the number of phases of the project	651.56	Lack of control and choice concerning project manager on resources	502.13
Dependencies between elements of the project (phases, project network, etc.)	606.13	Clarity of vision and mission of the project (how clear it is Classified)	497.75
Sources of uncertainty (uncertainty in the quantity, quality and capacity resources)	595.07	Customer and market uncertainty or ambiguity -changing customer requirements	494.53
Product Design (level of modularity)	582.81	Effective relationships and influence of project manager on teams	493.56
Novelty of the product (innovative projects)	569.33	Time limits (how critical time frame considered)	492.00
Multiplicity of organizations involved	565.88	The relevance of project manager's authority with project level	491.75
There is a useful reference for decision-making on project	556.56	Dependence on Key Experts	480.19
Miss organizes and Manpower Allocation	546.94	Lack of Human Interaction	469.81
Lack of Key Experts	541.44	Changes in Managerial Project Team	466.38
Inability of Project Manager at Team	538.00	knowledge and experience of the team involving technical, business and project management	465.31
Uncertainty in project team	528.93	Information flow and reporting	459.31
Uncertainty in project scope	526.40	The complexity of the project environment (changes in technology, market, customer, competitor, geographic, etc.)	458.13
Supply Chain of Uncertainty	519.2	Decisions regarding changes to Project management / organizational (decisions and new decisions)	452.19
Multiple levels of Effective Managerial decision-making	515.56		

5. The complexity Definition and Conceptual Model of Project Complexity

Before evaluating the complexity factors, a conclusion was made from the complexity definition. Based on the literature review and the interviews the project complexity is defined as follows:

The project complexity is resulted from a set of different, changing, interacting, and ambiguous elements, which lead to difficulties in predicting the results and controlling or managing the projects.

After defining the project complexity for identifying the project complexity factors, it was evaluated from three viewpoints. This step was completed through literature review, interviews, and questionnaires data. Eventually, based on these three approaches, we achieved a general categorization for the main complexity factors. For attaining the categorization and considering the conducted steps so far, WH question technique was utilized.

The WH method is well-organized idea generating tool, which attempts to surmount the problem using a set of specific questions. This tool enables the problem-solving team to analyze the problem or opportunity from different viewpoints.

The WH applications are as follows:

- Evaluating and analyzing a process or a product in order to achieve improvement of ideas.
- Identifying potential problems or advanced opportunity.
- Helping to create novel ideas.
- Exploring problems or the ignored reasons.

By using this method as a pattern and based on answers to questions such as why, what, how, who and where, the major criteria of project complexity were derived.

Question 1- a set of factors, which refer to the reasons of project (why). This set is named purpose.

Question 2- a set of factors, which refer to the fact of the project (what). In fact, it is related to the output and product of the project and it is indicative of a product or service. This set is named product.

Question 3- a set of factors, which refer to how the project is done (how). The implementation method is divided into two technical (technologies and technical methods) and management methods (project management approaches and processes). This set is named process.

Question 4- a set of factors, which refer to the people involved in the project (who). These people are divided into two categories of internal (project team) and external groups (employer, customer, superior authorities). This set is named people.

Question 5- a set of factors, which refer to where the project is conducted (where). This set is also divided into two main categories of substrate, infrastructure and required sources and the environment where the project is located culturally, politically and socially. This set is named perimeter/peripheral.

The figure below (figure 9) illustrates the classification criteria.

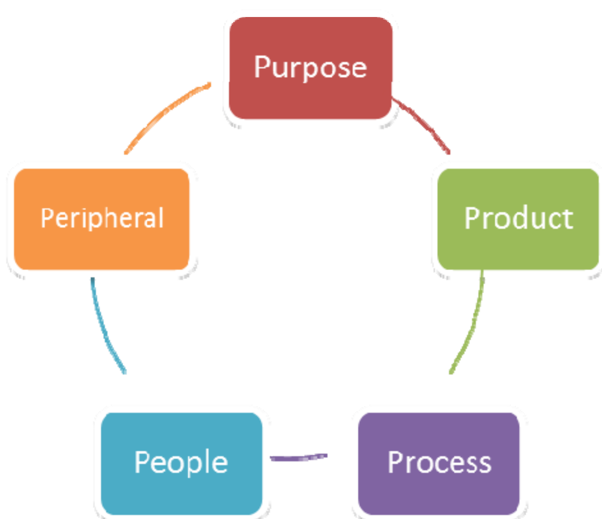


Fig. 9- Five derivers (factors) of project complexity (5P)

According to the definition of project complexity and factors, project complexity matrix is defined as follows (Table 7):

Tab. 6- project complexity matrix

Deriver			Process		People		Peripheral	
Concept	Purpose	Product	Technical	Managerial	Internal	External	infrastructure	Environment
Multiplicity								
Variety								
Variable								
Interaction								
Ambiguity								

Finally, on the basis of the method used in this research (literature review, interviews and questionnaires) the conceptual model was extracted. Outline of the model are shown figure9. The model has two levels; the first ring (level) consists of main factors or primary drivers, and the second-level offers sub-factors that were considered based on definition and complexity matrix in the context of COPS projects. This model covers all aspects of the complexity issues discussed here (major and minor criteria).

Fig. 10-Conceptual model of project complexity (5P)

6. Findings

The project complexity was identified using three different methods, namely, literature review, interviews and questionnaires. This was completed in the context of the COPS projects and WH questions technique. All aspects of complexity of the project were taken into account and a definition of project complexity was offered, which included the concepts of complexity. In addition, a complex matrix was attained by the definition and identified drivers of complexity (i.e. key factors). The definition indicated that each key factor can be found in each one of the concept. For instance, the human factor in terms of the multiplicity, variety, flexibility, interaction and ambiguity of roles and responsibilities can cause project complexity. This result can be true for other factors as well. Accordingly, a two-level conceptual model of project complexity was attained. The first level consists of main factors or primary drivers, and the second level offers sub-factors that were determined based on the definition and complexity matrix in the context of COPS projects.

7. Conclusion

As mentioned before, complexity is one of the most important features of multidisciplinary projects. It was found that most of the mentioned cases in the complexity filed are based on the viewpoint of the researcher. In fact, most of the complexity aspects identified in literature are related to the research's purposes highly extensive. In this paper, an attempt was made to completely describe the project with the aim of conceiving complexity through three approaches. To this end, the project complexity factors and parameters were identified based on literature review, interviews and questionnaire. In conclusion, using WH questions technique, which analyzes the project complexity from all aspects, a 5p model (Purpose, Product, Process, People, and Peripheral) was introduced.

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