



HAL
open science

Building up a project complexity framework using an international Delphi study

Ludovic-Alexandre Vidal, Franck Marle, Jean-Claude Bocquet

► **To cite this version:**

Ludovic-Alexandre Vidal, Franck Marle, Jean-Claude Bocquet. Building up a project complexity framework using an international Delphi study. *International Journal of Innovation and Technology Management*, 2013, 10.1504/IJTM.2013.055158 . hal-01219423

HAL Id: hal-01219423

<https://hal.science/hal-01219423v1>

Submitted on 27 Nov 2015

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

BUILDING UP A PROJECT COMPLEXITY FRAMEWORK USING AN INTERNATIONAL DELPHI STUDY

Ludovic-Alexandre VIDAL, Franck MARLE and Jean-Claude BOCQUET*

*Ecole Centrale Paris
Laboratoire Genie Industriel
Grande Voie des Vignes
92290 Chatenay-Malabry
FRANCE*

Abstract

Project management has spread around the world to become what it is today, that is to say a set of theories, principles, methodologies and practices. Past research works argue for a paradigm shift so that one could focus more on project complexity to manage projects more efficiently. However, there is a lack of consensus on what project complexity is, which makes it difficult to understand it good. As a consequence, this article reviews the literature in order to build a standardized project complexity framework. Then, it describes how a Delphi study was conducted over a panel of academic and industrial experts to refine it. Further on, it draws some conclusions regarding project complexity factors perception, functions of experts type (academic/industrial experts, gender study). Finally, after a correlation study based on the Spearman Rank, some perspectives are given to illustrate the applications of the project complexity framework which is built.

Keywords: project management, complexity, systems analysis, Delphi methodology, position, gender, expert systems, Spearman Rank, measure, Analytic Hierarchy Process.

Introduction

A project is “is a temporary endeavor undertaken to create a unique product or service” (PMI 2004). Project management has grown up to become what it is today, that is to say a set of theories, principles, methodologies and practices, sometimes included in standard body of knowledge as PMI (PMI 2004) and IPMA (IPMA 2006). The traditional vision tends to rely upon the notions of planning and control to propose models and prescriptions as ways to increase the ability of humans to control complex worlds (STACEY 2001; WOOD 2002). For all practical purposes, many studies have been done, based on statistical calculations or surveys. Their conclusion is that current methods have shown their limits, since they cannot face anymore the stakes of ever growing project complexity. Limits and lacks have been detected in research as well as in industry about the project predictability, since usual parameters (time, cost and quality) are clearly not sufficient to describe the complete situation at a given time (MEIJER 2002). Jaafari thus argued that “a paradigm shift in project management is essential for it to be relevant and effective in the complex society of this century” (JAAFARI 2003). On his side, Williams underlined that “it is clear that classical project management techniques are unsuitable for dealing with [complex] projects” (WILLIAMS 1999): he gave the example of structural complexity since decomposition models (such as Work Breakdown Structure) cannot account for the compounding effects when individual phenomena, evolutions and perturbations accumulate within the project. He concluded that “what are needed, then, are new ways of looking at modern, complex projects, new models and techniques for analyzing them, new methods for managing them –in fact, new paradigms to underline our approach to them.” This article thus aims at building up a standardized project complexity framework in order to understand better the concept of project complexity, by understanding better its complex structure. This work thus addresses the issue of project structural complexity. This research issue is addressed regarding a project manager oriented view and mainly addresses engineering design and product or service development projects.

Dealing with project complexity

Preliminary discussion on project complexity

Complexity is everywhere and is continuously growing. Research works on the concept of complexity have been conducted for years and have produced some interesting results and notions. There are historically two main scientific approaches of complexity (SCHLINDWEIN AND ISON, 2005). The first one, usually known as the field of descriptive complexity, considers complexity as an intrinsic property of a system, a vision which incited researchers to try to quantify or measure complexity.

An example of this vision is the work of Baccarini (BACCARINI, 1996). He considers project complexity through the concepts of technological complexity and organisational complexity. He regards them as the core components of project complexity which he tries to describe exhaustively. The other one, usually known as the field of perceived complexity, considers complexity as subjective, since the complexity of a system is improperly understood through the perception of an observer. Both approaches can apply to project complexity and project management complexity. Knowing that one tries to cope with perceived complexity, this research work aims at bridging the gap between perceived complexity and real complexity by defining, describing and modelling better real project complexity. The definition and identification of a list of project complexity factors which could be used as a check-list for instance may then permit to complement one's perception and intuition when analysing the complexity of a given project. This new frame of reference would then enable anyone who shares this representation to talk about project complexity with less ambiguity (due to their own perception).

The difficulty is that there is actually a lack of consensus on what project complexity really is. As Sinha et al. (SINHA ET AL., 2001) underline it, "there is no single concept of complexity that can adequately capture our intuitive notion of what the word ought to mean". Complexity can be understood in different ways, not only in different fields but has also different connotations within the same field (MOREL AND RAMANUJAM, 1999). However, Edmonds (EDMONDS, 1999) proposes an overview of the concept of complexity within different fields and finally tries to give a generic definition of what complexity is: "Complexity is that property of a model which makes it difficult to formulate its overall behaviour in a given language, even when given reasonably complete information about its atomic components and their inter-relations". This definition, which is quite appropriate to encompass all the aspects of project complexity, emphasises that complexity is generally related to the way the project system is modelled. To some extent, the model is the first layer of project perception, the second layer being the perception when understanding the project model.

Problem setting and methodology

Whatever the vision, understanding project complexity to improve project management (and therefore project success rate) has thus become an even more strategic issue for organisations. Still, some work has to be done to clarify the notion of project complexity in order to cope with it more efficiently (VIDAL ET AL., 2007). This paper thus aims at addressing the notion of project complexity in terms of its characteristics and factors in order to build a standardized project complexity framework that could be a reference for any project. Our research methodology is based upon six successive steps.

- Reviewing the literature to build up a first version of the project complexity.
- Writing the Delphi survey using the first version of the project complexity framework.
- Selecting the experts panel for the Delphi survey.
- Conducting the Delphi survey according to the Delphi methodology.
- Analyzing and discussing the results of the Delphi survey.
- Refining the project complexity framework using the results of the Delphi survey.

Elaborating the first version of a project complexity framework

Understanding projects as systems

Referring to the field of systems analysis (LE MOIGNE 1990; PENALVA 1997), a system is an object, which, in a given environment, aims at reaching some objectives (teleological aspect) by doing an activity (functional aspect) while its internal structure (ontological aspect) evolves through time (genetic aspect) without losing its own identity. According to this definition, a project can be considered as a system (VIDAL AND MARLE, 2008). Indeed, it possesses the four aspects listed above. A project exists within a specific environment and aims at reaching objectives given this context (teleological aspect). A project has to accomplish a set of activities using some methods and methodologies (functional aspect). A project has an internal structure composed of resources, deliverables, tools, workers, etc... (ontological aspect). Finally, a project evolves through time, via resource consumption, product delivery, members' changes and gain of experience, without losing its own identity (genetic aspect).

Identifying project complexity factors : methodology

First, a literature review on project management and project complexity factors was carried out. The ambition of this literature review is to be relevant, and illustrative of what project structural complexity is in fieldwork (as the final framework is to encompass all the aspects of project complexity). However, it must be underlined that some factors may be absent from this version of the framework, and that this one is likely to be evolving. This literature review was performed, keeping in mind the definition of Edmonds which underlines complexity as the property which makes it difficult to formulate the behaviour of the project system (both in terms of diagnostic and prediction). We chose this initial definition and approach in order to draw the literature review by the consequences of project complexity, so that implications on project management processes are more direct.

As a consequence, an important point we need to underline is that project ambiguities and uncertainties are to be considered as manifestations of the difficulty to formulate the project behaviour, given its complex structure. This means they are considered here as a consequence (and as crucial stakes) of project complexity. Therefore, uncertainty or ambiguity-related factors are not present in the framework, although sometimes cited as project complexity sources in the literature. In fact, in the literature, there are traditionally two kinds of ways to look at complexity, one including uncertainty factors into complexity factors (BACCARINI, 1996), and the other kind of approaches excluding them to consider them only as consequences or coexisting factors which lead to the existence of risks (AVEN, 2007), (HELLSTRÖM, 2007). Our works belong to the second kind of approaches.

This issue being stated, the methodology which was followed to identify these factors was the following:

- Step 1 – Constitution of a first list of factors using a literature review based on:
 - Some project management academic standards (PMI, 2004), (IPMA, 2006)
 - Some project management industrial standards (ISO, 2003), (AFNOR, 2004), (AFNOR, 2007)
 - Some publications focusing on complexity and project complexity aspects (BACCARINI, 1996), (CALINESCU ET AL., 1998), (EDMONDS, 1999), (WILLIAMS, 1999), (LAURIKKALA ET AL., 2001), (SINHA ET AL., 2001), (BELLUT, 2002), (CORBETT ET AL., 2002), (JAAFARI, 2003), (KOIVU ET AL., 2004), (SHERWOOD JONES AND ANDERSON, 2005)
- Step 2 – Gathering of some complexity factors under a same common denomination and obtaining as a consequence a refined list of factors.
- Step 3 – Gathering of factors into several groups through the analysis of the factors list and the identification done during Step 1.
- Step 4 – Final construction of the first version framework

Steps 1 to 3 – Constituting a first list of factors using a systems thinking-based approach and common denominations

In order to identify factors, a literature review was conducted using the four aspects of systems thinking, which need to be encompassed in a project complexity framework. Some insights about the identification of factors and discussions about them are given at the end of the article in Appendix A.

Step 4 – Building up a first version of the framework using common denominations

The point is that speaking in terms of teleological, genetic, functional and ontological aspects of project complexity is not the easiest manner to communicate about complexity in real projects and see what are the concrete phenomena behind these notions. We thus claim for a gathering of these factors into four more intuitive groups (see Figure 1), which were cited in several of the references which permitted to list factors. The first group gathers the factors that are relative to the size of the project system. The second one gathers those that are relative to the variety of the project system. These two first groups globally correspond to the ontological aspect of the project system. The third one gathers those that are relative to the interdependencies and interrelations within the project system, which corresponds to some extent to the functional pole of the project system. Finally, the fourth one deals with the context-dependence of project complexity, which mainly corresponds to the teleological and genetic poles of the project system.

Please insert Figure 1

The gathering of the identified project complexity factors into these four distinct groups makes more meaning both for direct industrial use (as these denominations make more sense for fieldwork) and for academic establishment (since these denominations have widely been used in research articles for instance). Indeed:

- Project size is to be defined as a whole as the sizes of elementary objects which exist within the project system. These sizes are likely to be assessed using appropriate quantitative measure (for instance time

scale, cardinal scale, etc...). This aspect of project size (which is somewhat close to the ontological aspect of project complexity in terms of number of identified elements) then seems to be a necessary condition for project complexity which makes sense. Indeed, recent papers notably state that any organisational system should be over a minimum critical size to be considered as a complex system (CORBETT ET AL., 2002).

- Project variety is to be defined as a whole as the diversity of elementary objects which exist within the project system. This aspect of project variety (which is somewhat close to the ontological aspect of project complexity in terms of diversity of identified elements) is indeed a group which makes sense. Indeed, as mentioned by Sherwood and Anderson (SHERWOOD JONES AND ANDERSON, 2005), “diversity relates closely to the number of emergent properties”. Moreover, as underlined by Corbett and al. (CORBETT ET AL., 2002), “the one thing that comes through loud and clear is that complexity is tied up with variety, be it in the world of biology, physics or manufacturing”.
- Project interdependence is to be defined as the existence of relationships between elementary objects within the project system. This aspect of project interdependence (which is somewhat close to the functional aspect of project complexity in terms of interactions between elements to execute the project) is indeed another category which makes sense. As underlined by several authors, interdependencies (and all the notions related with them such as interactions, interrelationships or interfaces) are even likely to be the greatest drivers of project complexity. Besides, Rodrigues and Bowers (RODRIGUES AND BOWERS, 1996) explain that “experience suggests that the interrelationships between the project’s components are more complex than is suggested by the traditional work breakdown structure of project network”, suggesting that traditional project management tools cannot be sufficient to catch the reality of interdependence. This seems all the more problematic since “there is a complete interdependence between the components of the complexity: each element will depend and influence on the others” (CALINESCU ET AL., 1998).
- Project context is defined here as what refers to the environment within which a project is undertaken. This aspect of project context-dependence (which is somewhat close to the teleological and genetic aspects of project complexity) is indeed another relevant category. First, Chu and al. (CHU ET AL., 2003) underline that contextuality is an essential feature of complexity, considering it as a common denominator of any complex system. The context-dependence of project complexity is also stressed by Koivu and al. (KOIVU ET AL., 2004) who notably insist on the fact that “the context and practices that apply to one project are not directly transferable to other projects with different institutional and cultural configurations, which have to be taken into account in the processes of project management and leadership”.

As a whole, this literature review and proposed classification permits to build a project complexity framework which aims at being a reference for any project manager to identify and characterize some aspects of its project complexity, so that he can understand more efficiently the stakes of its project complexity management. Once again, even though we had the ambition to be quite exhaustive, some others project complexity factors are likely to be added to this framework. Particular attention should be paid to the specificity of each project (and its context) when using this framework.

Please insert Table 1

Hereinbefore, in Table 1, the completed project complexity framework we have built using this research is exposed. It has to be noticed that approximately 70% of the identified complexity factors are related to organizational aspect, not technical. Principal sources of project complexity are thus likely to be organisational factors, as underlined by some former works on this issue (SHENHAR, 2007). Moreover, even though the factors belonging to the family of interdependencies within the project system are hardly more numerous than the others, this group appears in the literature as the most important for project complexity and day-to-day project management (MARLE, 2002). Interactions management is likely to be both one of the causes of greatest value creation during the project and one of the riskiest parts of the project.

First applications of this framework

Defining project complexity

This literature review being made, this framework being elaborated and the concepts being discussed, we now propose a refined definition of project complexity. We state that:

Definition :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. Its drivers are factors related to project size, project variety, project interdependence and project context.

This definition is an adaptation of Edmonds which was presented formerly (EDMONDS, 1999). The differences we introduce is first that there is no reference to any project model or language of modelling, and second, that its drivers are directly included in the definition to make the concept of “complexity” more easily comprehensible. Contrary to other definitions which were presented in our state of the art, this definition, through the inclusion of drivers, also permits to encompass every aspect of project systems, since those categories (and drivers) were identified using a systems thinking approach (the objective of which is to have an holistic approach to better understand project systems). Every aspect of systems thinking is thus part of the overall behaviour of the project system, which means that, according to this definition, project complexity is the property which makes it difficult to understand, foresee and keep under control any of these aspects. This definition we propose is finally different from other definitions of project complexity since it is:

- Oriented regarding the practical consequences of project complexity, which is to assist more easily complex project management,
- Based on four aspects which permit to describe with simple words crucial aspects of project structural complexity, which is to improve communication about it.

As a whole, as noticed by Ivan and Sandu (IVAN AND SANDU, 2008), there are three types of project complexity (as in the case of the majority of project characteristics): estimated, planned and actual. According to them, “Estimated complexity is based mostly on expertise gathered from of similar past projects. Planned complexity is a refinement of the estimated complexity, as some corrections are applied in order to adapt to the distinct project context. Actual complexity is finally measured after the project has been implemented.” This classification permits us to insist on three direct possible uses of the project complexity framework which is proposed here:

- **Predictive project complexity analysis.**

This application consists in the a priori project complexity evaluation. This finds direct implications in the management of the pre-project period and the project start processes. As underlined in (GAREIS, 2000) “the project start is the most important project management subprocess, because in it the bases for the other project management subprocesses, such as the project plans, the project communication structures, the relationships to relevant environments, are established”. As for them, (DVIR ET AL., 1998) also note that “pre-contract activities [...] are highly influential in all types of projects”. Predictive project complexity analysis is thus a crucial issue to achieve properly the pre-contract and project start phases. Using the project complexity framework as a checklist is to ensure a better identification of possible complexity sources within the project. It may also influence decisions which are directly made during these phases. For instance, project team constitution should be addressed in terms of possible complexity sources by focusing on the factors “staff quantity”, “diversity of staff (experience, social span,...)”, etc... By paying attention to such phenomena when making decisions during the pre-contract and start phases, one is to avoid some unnecessary or undesired complexity sources.

- **Diagnostic project complexity analysis.**

Diagnostic project complexity analysis is to be performed during the execution phase of the project. This analysis permits to assist project management processes during the execution phase, such as planning and re-planning, monitoring and control, decision-making, etc... The identification of existing project complexity sources during the project permits to stand back on some issues of the execution phase. We claim for the conjoint use of traditional project management tools as a basis and a more holistic approach which can permit to analyse more properly project complex situations. This approach is facilitated by the project complexity framework which is proposed here. Generally, people have a tendency to focus on some detail which appear to them as existing crucial problems in a project. But focusing on detail does not permit them to solve the problem, which causes some project failures (SHENHAR AND DVIR, 2007). Looking at these problems through the glass of complexity permits to have a holistic vision of the tackled issue and thus to make more influent decisions. Having a better vision of interdependencies for instance permits to understand better propagation phenomena and change implications on a whole project. In the case of design engineering for example, such understanding of change propagation is to avoid unnecessary and costly rework during the project (AUSTIN ET AL. 2002), (CLARKSON ET AL. 2004), (STEFFENS ET AL., 2007). Adaptive management practices should thus be employed when facing complex situations (SHENHAR, 2007), (LINDKVIST, 2008).

- **Retrospective project complexity analysis.**

Retrospective project complexity analysis using the project complexity framework is to assist project closure and return on experience processes. Indeed, the a posteriori identification of complexity sources which existed during the project permits to assess what happened and thus draw some lessons for the future. The overall processes of lessons identification and lessons learned future use is to give some precious experience to the firm. As underlined by Williams (WILLIAMS, 2003), “management’s role in facilitating and encouraging learning from projects is vital”, and particularly in the context of complex projects. Learning finally improves project maturity and future project complexity management within the firm. Indeed, building up databases on possible complexity sources of a firm’s projects for instance is to facilitate future predictive and diagnostic project complexity analysis.

Case study: Renault Multi-Purpose Vehicle (MPV) development projects

In order to illustrate this framework and show how it can be useful to identify possible complexity sources within a project, the case of several Renault Multi-Purpose Vehicle (MPV) development projects are explored. This case study corresponds to the third utilisation of the framework which was stated before, that is to say retrospective project complexity analysis. As an introduction, general description of MPVs is the following. The engine is mounted close to the front edge of the car, and its elements are generally grouped higher than in other cars, which minimizes front overhang length. Generally, seats are located higher than in lower cars, leaving more space for the legs. Larger minivans usually feature three seat rows, with two or three seats each. Smaller minivans tend to have two seat rows, with a traditional 2-3 configuration. Most current minivans are front-wheel drive. The main advantage is better traction than rear-wheel drive cars under slippery driving conditions. This configuration also permits to have more inner area along the floor, due to the absence of the driveshaft hump. Most modern MPVs feature unibody architecture (this is notably the case of the two projects which are to be studied), which offers better crashworthiness and a much more comfortable ride than a body-on-frame chassis. Two MPV development projects are the main basis of this study: the Renault Espace development project and the Renault Twingo development project. Some forewords about these two projects are given hereunder in order to appreciate the scope and context of these two projects. The framework was used in this case to perform a retrospective complexity analysis and learn lessons about these two projects regarding project complexity. Some factors were listed using the framework. For instance, we give three examples in this article:

- **Example of SIZE-ORG factors** : Number of stakeholders can affect project complexity. For instance, in the case of the Renault Espace development project, the coordination between the employees, cultures, processes, etc... of Renault and Matra due to the cooperation of these two firms implied greater managerial and organisational complexity.
- **Examples of INT-TECH factors** Interdependence of the components of the product appeared to be a critical complexity factor in the Renault Espace development project. The technological innovation due to the MPV format implied changes in the windscreen inclination. Even though they had not been predicted, because of the component interdependence, this implied changes in the front windscreen wipers and also in the engine position. As for the Renault Twingo development project, resource and raw material interdependence made the project more complex regarding the same components. Indeed, a new kind of glass was used to elaborate the windscreen. But it had not been seen that this new material which was used was not compatible with the glue which was formerly used to fix the windscreen wipers. This implied some changes and rework in the end.
- **Example of CONT-ORG factors** Local laws and regulations appeared to make these two projects more complex when trying to extend the commercialisation and production of these vehicles into different European countries. For instance, new local laws and norms appeared in the mid 1980s in Germany. These ones were not all compatible with the Renault Espace technical specifications and production processes, which implied major changes in order to keep the possibility for the Renault Espace to exist in Germany.

These were examples of project complexity factors which can be identified through the use of the project complexity framework. As a whole, a synthesis of identified project complexity factors in these two projects using this retrospective analysis is proposed in Table 2, where expert judgments attributed some importance (from negligible to 3) to possible project complexity factors. Still, if this list of factors permit to have a closer look on projects in terms of complexity, the factors are still very numerous and no a priori classification of these factors (in terms of the importance of their average contribution to project complexity) is proposed. That is why we carried out an international Delphi study to refine this framework.

Please insert Table 2

Conducting a Delphi study to refine the framework

The Delphi methodology

Refining our results by performing an international Delphi study is indeed to permit to have a more reliable definition and understanding of the project complexity framework we have built. The Delphi methodology (LINSTONE ET TUROFF., 2002), which was originally developed in the 1950's, is a systematic and interactive method which relies on a panel of independent experts. It is a very flexible tool which permits to reach a consensus, through the collection of experts' opinions on a given issue during successive stages of questionnaire and feedback. Direct confrontation of the experts, whose anonymity is kept at every stage of the study, is avoided (OKOLI AND PAWLOWSKI, 2004). As mentioned in (SKULMOSKI ET AL., 2007), "the Delphi method is well suited as a research instrument when there is incomplete knowledge about a problem or phenomenon". It has proven over the years to be a very popular tool for framework building, forecasting, issues prioritizing, decision-making, etc... It has been used for several studies in the field of industrial engineering and project management, which encouraged us in our research work. For instance, Schmidt and al. used the Delphi method in order to build up a list of common risk factors in software projects (SCHMIDT ET AL., 2001). Our research methodology is based on a two-round Delphi process (see Figure 2):

Please insert Figure 2

The Delphi survey was conducted using blind copy electronic mail sending to international academic and industrial experts in project management in order to save time and expenses for both the surveyor and the experts. The questionnaire was introduced by a page explaining, such as in (BRYANT AND ABKOWITZ, 2007), the overall purpose and structure of the survey as well as the experts anonymity conditions at each stage of the study. The questionnaire was divided into eight sections, following the structure of the first version of the project complexity framework: SIZE-ORG, SIZE-TECH, VAR-ORG, VAR-TECH, INT-ORG, INT-TECH, CONT-ORG, CONT-TECH. An excerpt of the questionnaire is given in Appendix B in a Table format (the excerpt consists of the answers and commentaries of a respondent for the INT-ORG tab of the questionnaire). The questions were formulated using a 5-level Likert scale, in order to express the importance of the contribution of a given factor to project complexity (from no contribution -1- to essential contribution -5-, leaving the possibility to answer "do not know" and "do not want to answer"). Furthermore, participants could leave commentaries and questions at any moment on any point of the Delphi questionnaire in order to generate some discussions about it or to suggest other potential project complexity factors. At each round, a little more than three weeks were left to the panelists to answer the survey.

Panel selection and survey scales definition

The Delphi survey group size can be very different in the literature. However, it is often recommended to have a group between 9 and 18 participants in order to draw some relevant conclusions and avoid at the same time difficulty to reach consensus among experts. We argue, such as in (Okoli and Pawlowski, 2004), that an experts categorization should be made properly before undertaking the Delphi survey in order to build up the most representative panel. As for them, Skulmoski and al. require different aspects for the participants to be selected in the Delphi survey panel (SKULMOSKI ET AL., 2007):

- Sufficient knowledge and experience about the survey issues,
- Capacity, willingness and time to participate,
- Good communication skills.

Our prospective panel was constituted of 38 experts, 19 of them being industrial practitioners and 19 being academics, and at the same time 19 being men, 19 being women. Of those 38 solicited experts, 18 actually participated to the study from the beginning to the end, 10 of them being academics and 8 being industrials, and at the same time 10 of them being women, and 8 being men. Academics were notably identified with their publications regarding project complexity in the Web of Science and specialized conferences or revues (International Journal of Project Management, PMI Research Conference, etc...). Industrial practitioners were identified through the browsing of some professional social networks (LinkedIn), the identification of some project managers of large firms websites, and the identification of project managers whose education was followed in some high standard schools, universities and institutions. We thus consider that the overall results are going to be relevant since the interrogation of 18 experts permits to trust them. In order to do comparisons and generate discussions during the next section, we also study separately men, women, academics and industrials. Even though the suggested minimum quota of 9 experts is not reached for men and industrials (8 for each category instead of 9), we will consider the results as relevant. We do insist here that the study was thus conducted with a project manager-oriented view.

Results and discussions

Global results and discussion

Our discussion starts with the overall analysis of the panelists' answers to our survey. The convergence of the experts was fast, even though they were of different origins and backgrounds. It must be noted that the factors which appear earlier in the Delphi questionnaire do not receive significantly higher or lower scores than the factors which appear at the end of it. This implies that there is no direct correlation between the order of the questions and the scores of the factors. This was notably observed when alternating the orders of the tabs in the Delphi questionnaire without observing a change in the average scores of each group of factors. A synthesis of their reached consensus can be seen after in Tables 3 and 4.

Please insert Table 3

Average scores and mean deviations were calculated to perform the analysis of this questionnaire. Mean standard deviation of the answers, as shown in Table 3, is 0.682, which makes it a satisfying consensus for (also notice that all standard deviations are less than 1). Table 4 shows the statistical results of the survey. Average values lie between 2.278 and 4.889.

Please insert Table 4

When having a closer look at the answer of the panel, some points are to be noticed about project complexity:

- First, of the first 18 identified project complexity drivers after the panelists' evaluation (the mean value of which is over 4.500), only 2 of them are of a technological type (11.1%), as shown in Table 3. Organizational complexity thus seems to be the greatest source of complexity for projects and project management today. Project managers should thus focus on organizational issues when tackling and dealing with complexity. This is also legitimate when discussing with industrials facing their project day-to-day life.
- Second, of these first 18 project complexity drivers, 11 of them belong to the family of project interdependencies (61.1%), making it the most contributive family of project complexity drivers, before context-dependence and variety (both 16,7%) and size (5.6%). Some bias might have been introduced because of the project manager view orientation of the study. Indeed, project managers traditionally have a transverse vision of projects, due to their responsibilities: this implies that they have a natural tendency to deal with organizational sources of complexity, notably at interfaces within and outside the project. Moreover, even technical issues, when addressed at a "project governance level", have organizational implications since they are often situated at interfaces between heterogeneous parameters (processes, technologies,...). In the end, this explains why our project complexity framework, which is to be used mostly by project managers or governance team members, has a majority of organizational factors (notably regarding interfaces and interdependencies). These results are consistent with former works of the academic literature (GENELOT, 2001) and with the industrials' feelings about complexity when discussing with us. This is also enlightened by the number of tools and works that have been developed to try to better catch project interactions and interdependencies, such as interactions model (MARLE, 2002), or Design Structure Matrices (STEWART, 1981)."

Position comparison

Results of the comparisons between academic and industrial experts can be seen hereinafter in Table 5. Two aspects are to be enlightened to compare those two populations:

Please insert Table 5

- First, mean standard deviations appear to be different between populations since academics mean standard deviation on the survey is 0.615 and industrials' one is 0.738. This difference can express the fact that, even though there are very conscious of and interested in the concept of project complexity, they might not all understand it the same proper way. This observation is also enlightened by some commentaries during the Delphi survey, since some industrials wanted to have some details on some criteria, not understanding them, or not seeing them first as complexity sources.
- Slight differences can be observed in the judgments of the two populations. First, SIZE-TECH complexity factors appear to be judged more important by academics than

industrials (4.350 VS 3.938). To some extent, this lower maturity around the conceptual vision of project complexity is to explicit the lower assessments of these factors by industrials. However, some work should be carried out to clarify those relative divergence zones, which remain quite isolated, the whole survey showing a relative common vision of project complexity between academics and industrials.

Gender study

One of the ambitions of this research work was also to compare two other populations, men and women, in order to see if their perception of project complexity, whether they are industrial practitioners or academics, was the same or not. Others works had indeed shown that no difference was observed between men and women when dealing with managerial tasks. The results synthesized in Table 6 give us a part of answer, since the results obtained for those two populations are impressively similar. Mean standard deviation is 0.699 for men and 0.734 for women. Mean evaluations of organizational and technological complexity appear to be the same (3.963 VS 3.990 and 4.045 VS 4.028). Gender does not thus seem to be a source of different project complexity perception.

Please insert Table 6

Deeper analysis of the results using a correlation study

In order to understand better the relationships between the identified project complexity factors, a correlation analysis has been performed with the realization of Spearman Rank correlation analysis (see Figure 3). This analysis is well-established in statistics and permits to identify some correlations. Our aim here is to underline the possible existing correlations between factors in the set of answers of the panelists.

Please insert Figure 3

We highlighted the correlations which were superior to the critical values of the Spearman Rank for the value of 19 pairs (for $p < 0.05$ in orange and $p < 0.01$ in red). The conclusion is that the project complexity factors tend to be positively correlated. It must be noticed that less than 7% of the values in the correlation matrix are negative. Moreover, this positive correlation is somewhat limited since the average value of r_s^2 is equal to 0.16. Finally, less than 5% of the values are above the critical value for $p < 0.05$ and less than 2% of them are above the critical value for $p < 0.01$, which means that strong correlations are very rare in this case. However, organizational factors seem to be more correlated than technical factors, with a mean square Spearman Rank reaching the value of 0.22 and a level of values over the critical value for $p < 0.01$ reaching 5%.

Furthermore, some strong correlations are to be highlighted and discussed. For instance, the highest value in the matrix ($r_s=0.92$) indicates that “numbers of team/structures/groups to be coordinated” and “number of departments involved” are strongly positively correlated factors regarding project complexity. So are “variety of organizational interdependencies” and “processes interdependence” ($r_s=0.91$) as well as “variety of organizational skills needed” and “variety of the interests of stakeholders” ($r_s=0.90$). Less intuitive correlations but very strong ones are for instance “combined transportation” and “organizational environment complexity” ($r_s = 0.88$) or “stakeholders interrelations” and “dependencies with the environment” ($r_s=0.83$).

Finally, in all these cases, Kruskal-Wallis tests were conducted (both over the gender and position of panelists). No distinction (with a sensitivity of $p < 0.05$) according to the panelists’ profile was observed for all of these correlations, underlining that the strong positive correlations are not due to similar responses within males/females or academics/industrials. This highlights that these strong correlations tend to be commonly shared by the panelists.

Refinement of the project complexity framework

In the end, after this deeper study of factors’ correlation, using the Delphi survey, we propose a refined project complexity framework with the 18 most important complexity drivers according to the panellists. Our choice was to keep only the factors which would appear as essential (a score of 5 in our questionnaire). To do so, the mean scores of each factor were rounded up/down to the nearest integer, and that is why factors with a mean score which was at least 4.5 were considered as essential (since their scores were rounded up to 5). This was all the more interesting that they represented 26% of the initial factors, which was fairly consistent with the traditional 20% cut of Pareto. The users should in the end consider this refined framework and feel free to incorporate factors which are not in the refined version but which were present in the first framework, or even other factors, depending on the context of their projects. Table 7 draws as a synthesis the refined project complexity framework.

Please insert Table 7

As seen before, the majority of complexity factors are organisational and interdependence-related.

Final applications

This Delphi study is one part of a global research work about project complexity, its stakes, influences, and its measure. Indeed, one of the general objectives of our research works is to assess project complexity, notably in multi-project environments. The main potential use of this refined project complexity framework is to assess project complexity according to the selected criteria through the use of a multi-criteria evaluation method. We are using the Analytic Hierarchic Process (DYER 1990; SAATY 1991; SAATY 1999) to assess project complexity on different project alternatives, given our project complexity framework. With the refined project complexity framework, an AHP hierarchical structure is to be built according to Figure 9.

Please insert Figure 4

We hope that this structure is going to be the basis for an effective industrial tool to assess and visualise project complexity. Moreover, given the ranking obtained with the AHP calculations on the set of alternatives, we do propose a relative measure of project complexity. Alternatives can be projects in a multi-project environment, or possible future scenarios in a mono-project environment, etc... Let α_i be the priority value of alternative A_i obtained with the AHP calculations ($0 \leq \alpha_i \leq 1$). We propose that the relative complexity of alternative A_i , given the specific context of the set of alternatives, can be expressed as:

$$C_i = \frac{\alpha_i}{\max(\alpha_i)} \rightarrow 0 \leq C_i \leq 1$$

A relative project complexity scale between 0 and 1 can thus be built using this method. It permits to give a relative indicator of project complexity given the multi or mono-project environment context. Indeed, this complexity measure can be used as an indicator to assist project selection in a portfolio, as an indicator to analyze the complexity of existing projects in a given portfolio, or an indicator to compare future possible project scenarios in the mono-project case. Another advantage of a multi-criteria methodology like the AHP is to permit an application in different industries, since it permits to change the weights of the criteria (complexity factors here), depending on the context of the industries.

The generic computing of it is notably still to be done, with the ambition to give to the user default values and this default hierarchical structure (the structure being the one of the framework, the values being initially calculated through the use of a Saaty scale and the results of the Delphi study). However, we will leave the user the opportunity to add the complexity criteria which were eliminated between the original and the refined version of the framework. We will also leave the possibility to add new criteria or new values which could better cling to the project context the user is working in. This tool is finally to be tested on case studies, notably one in the stage musicals production industry. More details about this global research project are given in (VIDAL ET AL., 2010).

In the future, we also aim at refining this approach with the use of the Analytic Network Process which would consider the criteria (complexity factors) as non-independent. This would permit to introduce correlation coefficients which could be obtained using the Spearman Rank correlation analysis. All of these points make the point of ongoing works and/or publications.

Conclusion

This paper reports on the use of the Delphi methodology to address some issues about project complexity and its drivers. One of the ambitions of the study was to build up a project complexity framework. A large literature review permitted us to build a first theoretical version of the framework. The Delphi study which was conducted enabled us to refine this framework, falling from 68 drivers to 18. The main conclusions of the study are the following. First, organizational complexity, compared to technological complexity, is the major source of project complexity (88.9% of the selected criteria). Second, project interdependencies, compared to variety, size and context-dependence, seem to generate the most project complexity drivers (61.1%). Comparisons between experts permitted us to highlight that industrials seem to show less consensus on their perception of project complexity than academic experts. They also give lower estimates than academics. It also appeared that gender had fairly no influence on complexity perception. At this stage, no comparison between oriental and occidental population was possible, but this is to be another perspective of work around this notion. Finally, a first

correlation analysis of the project complexity factors is proposed. As well as the results of this study, it should be extended through the interview of other experts. As a whole, the refined project complexity framework is to be the basis of an AHP hierarchical structure or an ANP complex structure, which enables us to define a relative project complexity measure. This measure is notably to assist project selection in the case of multi-project management or project scenario assessment in the case of mono-project management. Some work and case studies are still to be achieved to carry out this specific work.

Acknowledgements

We would like to thank the 18 anonymous experts for their time and effort in participating to our Delphi survey and providing their comments during the study. Special acknowledgements are addressed to Jean-Louis Giordano, who worked as a project manager at Renault for several years.

References

- AFNOR (2004). "Management de projet, recueil de normes". AFNOR, édition 2004
- AFNOR (2007). "Management de projet". AFNOR
- AUSTIN, S., A., NEWTON, J. STEELE and P. WASKETT (2002). "Modelling and managing project complexity". *International Journal of Project Management* Vol.20, pp.191-198
- AVEN, T. (2007) - A unified framework for risk and vulnerability analysis covering both safety and security - *Reliability engineering & systems safety* Vol. 92, No. 6, pp. 745-754
- BACCARINI, D. (1996). "The concept of project complexity – a review." *International Journal of Project Management* 14(4): 201-204.
- BACCARINI D. (1996) - The concept of project complexity, a review - *International Journal of Project Management*, Vol.14, Issue 4, pp.201-204
- BELLUT S. (2002). "Maîtriser les coûts d'un projet . Le management par la valeur". AFNOR.
- BRYANT, D. L. and M. D. ABKOWITZ (2007). "Estimation of terrestrial chemical spill risks factors using a modified Delphi approach." *Journal of Environmental Management* 85: 112-120.
- CALINESCU, A., J. EFSTATHIOU, J. SCHIRN and J. BERMEJO (1998). "Applying and assessing two methods for measuring complexity in manufacturing." *Journal of Operational Research Society* 49(7): 723-733.
- CHU, D., R. STRAND, and R. FJELLAND (2003). "Theories of complexity – Common denominators of complex systems." *Complexity* 8(3).
- CLARKSON, P.J., C., SIMONS and C.M. ECKERT (2004). "Predicting Change Propagation in Complex Design". *ASME Journal of Mechanical Design* 126(5): 765-797.
- CORBETT, L. M., J. BROCKELSBY, and C. CAMPBELL-HUNT (2002). "Tackling industrial complexity". Cambridge, Cambridge: Institute for Manufacturing.
- DVIR, D., S., LIPOVETSKY, A. SHENHAR and A. TISHLER (1998). "In search of project classification: a non-universal approach to project success factors". *Research Policy*, Volume 27, Number 9, pp. 915-935(21)
- DYER, J. S. (1990). "Remarks on the Analytic Hierarchy Process." *Management Science* 36(3).
- EDMONDS, B. (1999). "Syntactic measures of complexity. faculty of arts". Manchester, University of Manchester. PhD.
- GAREIS, R.(2000). "Managing the project start". *The Gower Handbook of Project Management*, JR Turner and SJ Simister (ed), Gower, Aldershot
- GENELOT, D. (2001). "Manager dans la complexité. Réflexions À L'usage Des Dirigeants" - Insep Consulting
- HELLSTÖM, T. (2007) - Critical infrastructure and systemic vulnerability :Towards a planning framework - *Safety science* vol. 45, no3, pp. 415-430
- IPMA (2006). "IPMA Competence Baseline (ICB)", Version 3.0, March 2006 International Project Management Association.
- ISO (2003). "ISO:10006 Quality management systems". *Guidelines for quality management in projects - ISO*
- IVAN, I. and A. SANDU (2008). "Projects Hierarchy Based on Duration and Complexity". 22nd IPMA World Conference, Roma, Italy.
- JAAFARI, A. (2003). "Project management in the age of complexity and change." *Project Management Journal* 34(4): 47-57.
- KOIVU, T., J. NUMMELIN, et al. (2004). Institutional complexity affecting the outcomes of global projects. VTT Working Papers, VTT. 14.
- LAURIKKALA, H., E. PUUSTINEN, S. TUKIAINEN, R. TAINIO and B. ATKIN (2001). "Reducing complexity of modelling in large delivery projects". 13th International Conference on Engineering Design, Glasgow, Scotland.

- LE MOIGNE, J.-L. (1990). "La théorie du système général. Théorie de la modélisation". Presses Universitaires de France.
- LINDKVIST, L. (2008). "Project management: exploring its adaptation properties". International Journal of Project Management, Vol. 26, No.1, pp.13-20
- LINSTONE, H. and M. TUROFF (2002). "The Delphi method: techniques and applications" Edited by Harold A. Linstone and Murray Turoff.
- MARLE, F. (2002). "Modèle d'informations et méthodes pour aider à la prise de décision en management de projets". Génie Industriel. Paris, Ecole Centrale Paris. PhD: 220.
- MEIJER, B. (2002). "Reducing complexity through organisational structuring in manufacturing and engineering". in *Tackling industrial complexity : the ideas that make a difference*. F. G. R. H. (Ed.). Cambridge, Cambridge: Institute for Manufacturing: 183-192.
- MOREL, B. and R. RAMANUJAM (1999). "Through the looking glass of complexity : the dynamics of organizations as adaptive and evolving systems." Organization science 10(3): 278-293.
- OKOLI, C. and S. D. PAWLOWSKI (2004). "The Delphi method as a research tool: an example, design considerations and application." Information & Management 42: 15-29.
- PENALVA, J.-M. (1997). "La modélisation par les systèmes en situations complexes". Laboratoire d'Informatique appliquée de Commissariat à l'Energie Atomique. Paris, Parix XI Orsay
- PMI, S. C. (2004). "A guide to the project management body of knowledge" (PMBOK) (2004 ed.). Newton Square, PA, USA. , Project Management Institute.
- RODRIGUES, A. and J. BOWERS (1996). "The role of system dynamics in project management." International Journal of Project Management 14(4): 213-220.
- SAATY, T. (1991). "Response to holder's comments on the Analytic Hierarchy Process." The Journal of the Operational Research Society 42(10): 909-914.
- SAATY, T. (1999). "Decision-making for leaders: the Analytic Hierarchy Process for decisions in a complex world". Pittsburgh, Pennsylvania, RWS Publications.
- SCHLINDWEIN, S. and R. ISON (2005). "Human knowing and perceived complexity: implications for systems practice." Emergence: complexity & organisation 6(3): 19-24.
- SCHMIDT, R. K., K. LYYTINEN, et al. (2001). "Identifying software project risks: an international Delphi study." Journal of Management Information Systems 17(4): 5-36.
- SHENHAR, A.J. (2007). "Introduction". in Shenhar, A.J., Milosevic, D., Dvir D. and Thamhain, H. (Eds.) *Linking Project Management to Business Strategy*, Newtown Square, Pennsylvania, Project Management Institute, Inc.
- SHENHAR, A.J. and D. DVIR (2007). "Reinventing Project Management - The diamond approach to successful growth and innovation". Harvard Business School Press, Part one: chapters 1-3. Boston.
- SHERWOOD JONES, B. and P. ANDERSON (2005). "Diversity as a determinant of system complexity". GIST technical report G 2005-1.
- SINHA, S., A.I. THOMSON, and B. KUMAR (2001). "A complexity index for the design process". International Conference on Engineering Design, Glasgow, Professional Engineering Publishing, Bury St Edmunds.
- SKULMOSKI, G.J., F.T. HARTMAN, and J. KRAHN. (2007). "The Delphi Method for Graduate Research." The Journal of Information Technology Education 6.
- STACEY, R. (2001). "Complex responsive process in organizations: learning and knowledge creation". London, Routledge.
- STEFFENS W., MARTINSUO M. and K. ARTTO (2007). "Change decisions in product development projects". International Journal of Project Management 25(7): 702-713.
- STEWART, D. (1981). "The Design Structure Matrix: a method for managing the design of complex systems." IEEE Transactions in Engineering Management 28(3): 71-74.
- VIDAL, L.A., F. MARLE and J.C. BOCQUET (2007). "Modeling project complexity". International Conference on Engineering Design, Paris, FRANCE.
- VIDAL, L.A. and F. MARLE (2008). "Understanding project complexity: implications on project management." Kybernetes, the International Journal of Systems, Cybernetics and Management Science.
- VIDAL, L.A., F. MARLE AND J.C. BOCQUET (2010). "Measuring project complexity using the Analytic Hierarchy Process". International Journal of Project Management. doi:10.1016/j.ijproman.2010.07.005
- WILLIAMS, T. M. (1999). "The need for new paradigms for complex projects." International Journal of Project Management 17(5): 269-273.
- WILLIAMS, T.M. (2002). "Modelling Complex Projects". Wiley, 2002.
- WILLIAMS, T.M. (2003). "The contribution of mathematical modelling to the practice of project management". IMA Journal of Management Mathematics 14(1):3-30
- WOOD, M. (2002). "Mind the gap ? A processual reconsideration of organizational knowledge." Organization 9(1): 151-171.

AppendixA

Project complexity teleological and genetic aspects

The genetic aspect of a project system describes its evolution (i.e. the phases it evolves in). As for it, the teleological aspect of a project system addresses the issue of project values creation by identifying the expected target values (objectives) of a project (by identifying the project stakeholders and environment). Project complexity teleological and genetic aspects are to be mainly related to these aspects of the project system. As explained, several project complexity factors regarding project teleological and genetic aspects were identified and gathered under a common denomination. These factors are notably:

- **Competition**
A competitive context is a more demanding and complex one since the targeted business is to choose the best products, processes, etc... in terms of expected values. Competition can be either technological or organisational.
- **Environment complexity (networked environment)**
Environment complexity in terms of network (networked environment) is to increase project complexity and make its management harder. Indeed, the management of the relationships with the project environment is one of the core activities of project management. Performing this activity in a networked environment is more complex since the impact of any relationship or decision is to propagate through this network.
- **New laws and regulations**
New laws and regulations (in both organisational and technological aspects) can increase project complexity since they may result in the need for changes in the processes/outcomes, given the requirements of new laws and regulations (such as security norms for instance).

Project complexity functional aspects

The functional aspect of a project system focuses on what the project system executes in terms of tasks and processes. This functional aspect is the principal cause of interactions and interrelationships within the project system since resources, actors, information systems, etc... interact when project tasks are executed. Project complexity functional aspects are thus to be mainly related to these aspects of the project system. After gathering factors under a common denomination, we obtain a list of functional factors. Here are some examples :

- **Availability of people, material and of any resources due to sharing**
Projects may share their people, material and all their resources within the firm. Moreover, within a given project some resources may be shared between people, tasks, etc... Such a non-availability of resources during a project make it in essence more complex.
- **Dependencies between schedules**
Dependencies between schedules make it all the more complex to manage people within a project. Indeed, for instance, if a change happens in a project team member schedule, then other project team members schedules may change. But, these schedules are constrained (notably by permanent organizations). As a consequence, the needed changes may not be possible, which make project management processes even more complex.
- **Relations with permanent organizations**
In most cases, within a firm, several projects have to coexist with several permanent organisations. Any project team member is to be involved in one or several projects and in one or several permanent organisations. Relations with permanent organizations make it more complex to manage a given project since these permanent structures may exert constraints on the project. For instance, the dependencies between the corresponding schedules generate complexity when trying to accommodate them and meet the requirements of each of them.

Project complexity ontological aspects

Finally, the ontological aspect of a project system focuses on what the project system is in terms of its constituting elements which permit the execution of tasks and processes (resources, actors, information systems, etc...). Project complexity ontological aspects are thus to be mainly related to these aspects of the project system. These factors, gathered using common denominations, are for instance:

- **Diversity of staff (experience, social span ...).**
When the staff is varied, notably in terms of work experience, social span or culture, then the project coordination and control appear to be more complex.

FIGURES TO BE INSERTED



Figure 1. Drivers of project complexity

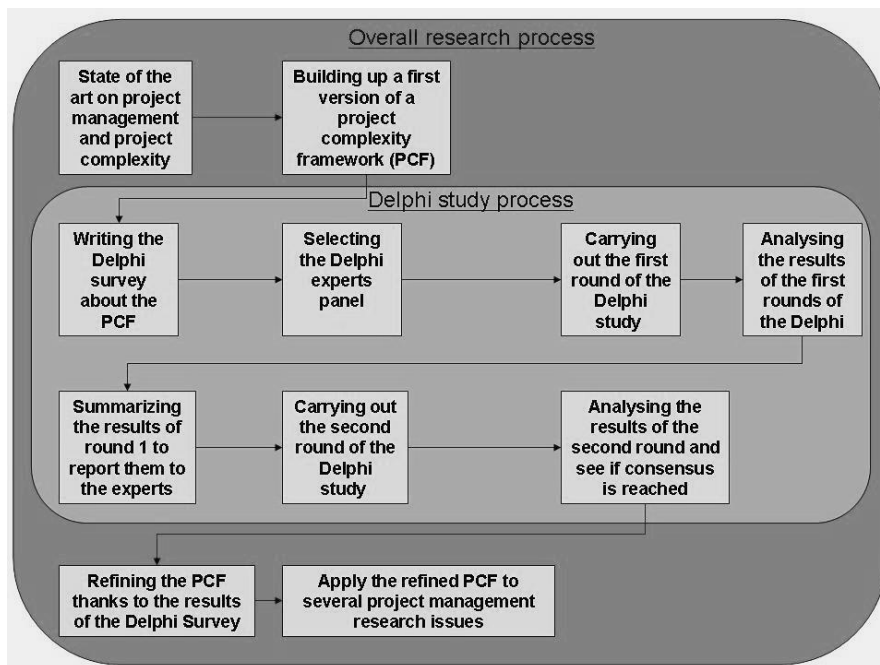


Figure 2. Overall research process including Delphi study

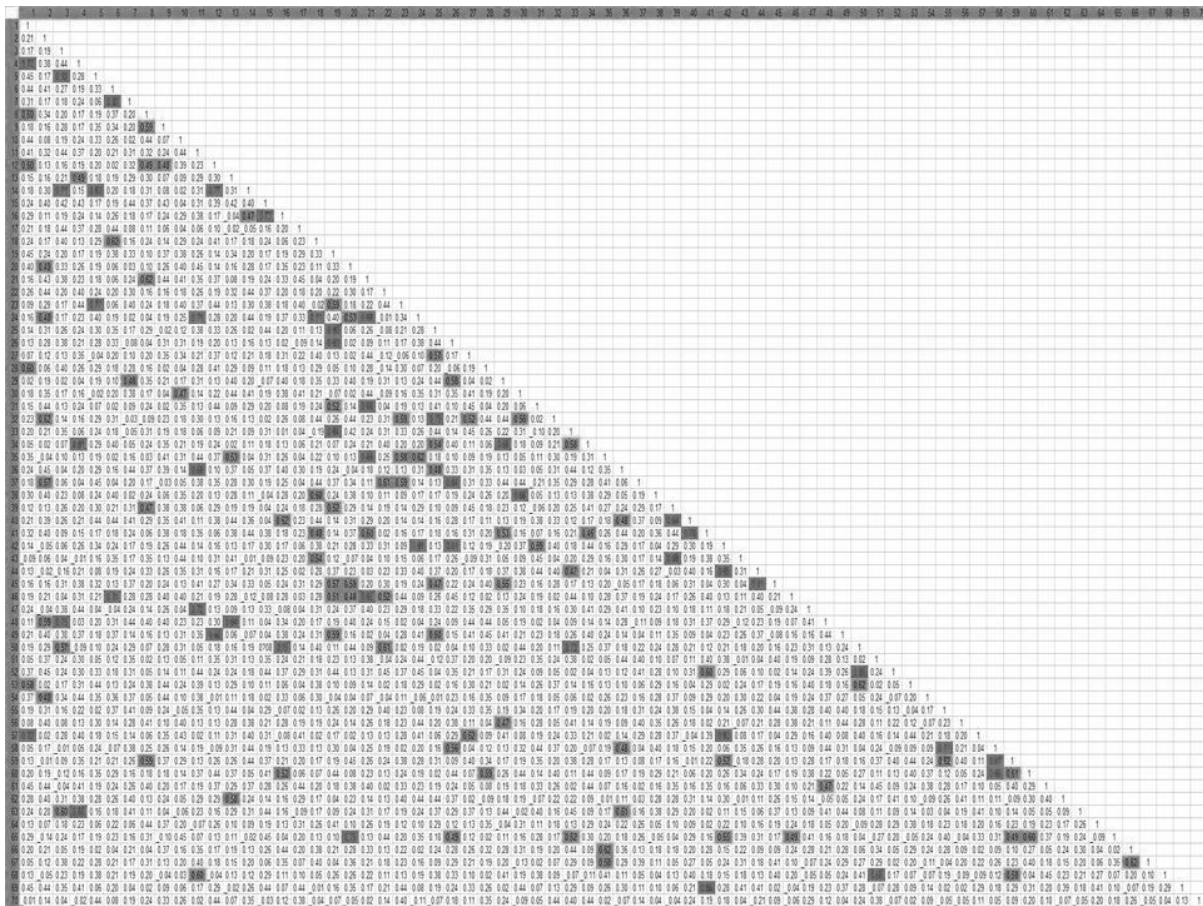


Figure 3. Correlation matrix of the project complexity factors

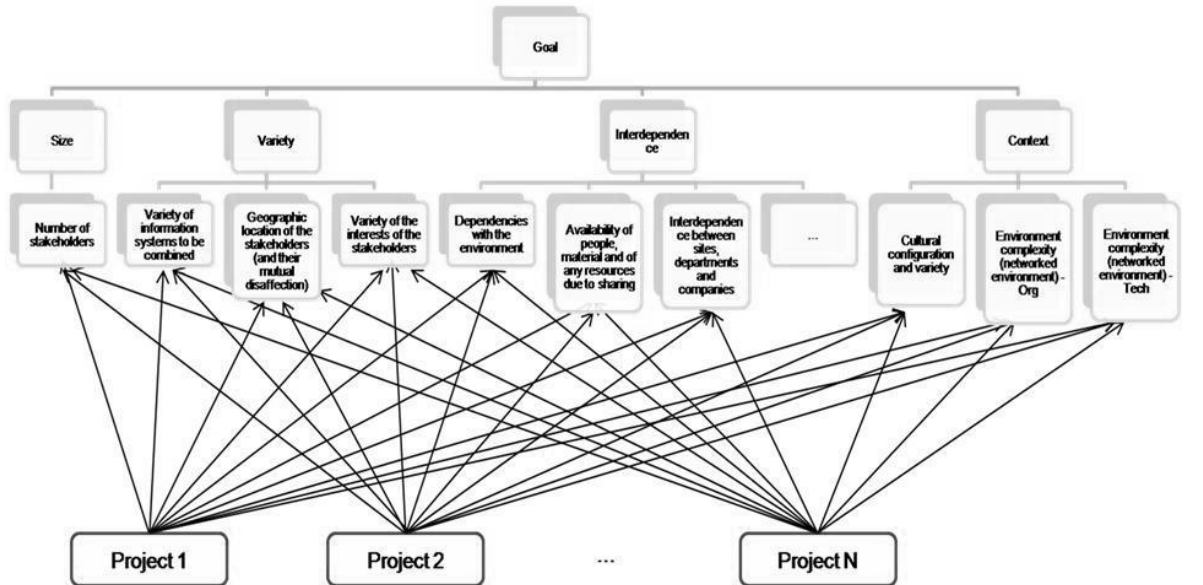


Figure 4. AHP-based assessment of project complexity

TABLES TO BE INSERTED

Family	Organisational complexity (Org)	Technological complexity (Tech)
Project System Size	Number of stakeholders	Largeness of scope (number of components, etc...)
	Number of information systems	Number and quantity of resources
	Number of structures / groups / teams to be coordinated	
	Number of companies / projects sharing their resources	
	Number of departments involved	
	Number of deliverables	
	Number of objectives	
	Largeness of scope (number of components, etc...)	
	Number and quantity of resources	
	Number of hierarchical levels	
	Number of investors	
	Number of activities	
	Largeness of capital investment	
	Staff quantity	
Number of decisions to be made		
Duration of the project		
Project System Variety	Variety of information systems to be combined	Variety of the technologies used during the project
	Geographic location of the stakeholders (and their mutual disaffection)	Variety of the product components
	Variety of the interests of the stakeholders	Variety of resources to be manipulated
	Diversity of staff (experience, social span ...)	Variety of technological dependencies
	Variety of the stakeholders' status	Variety of technological skills needed
	Variety of hierarchical levels within the organisation	
	Variety of financial resources	
	Variety of organisational interdependencies	
	Variety of organisational skills needed	
Variety of project management methods and tools applied		
Interdependence within the Project System	Dependencies with the environment	Specifications interdependence
	Availability of people, material and of any resources due to sharing	Interdependence between the components of the product
	Interdependence between sites, departments and companies	Technological processes dependencies
	Interconnectivity and feedback loops in the task and project networks	Resource and raw material interdependencies
	Team cooperation and communication	
	Dependencies between schedules	
	Interdependence of information systems	
	Interdependence of objectives	
	Level of interrelations between phases	
	Processes interdependence	
	Stakeholders interrelations	
	Combined transportation	
	Interdependence between actors	
Number of interfaces in the project organization		
Dynamic and evolving team structure		
Relations with permanent organizations		
Elements of Context	Cultural configuration and variety	Environment complexity (networked environment)
	Environment complexity (networked environment)	Technological degree of innovation
	Organisational degree of innovation	Cultural configuration and variety
	New laws and regulations	New laws and regulations
	Institutional configuration	Demand of creativity
	Local laws and regulations	Local laws and regulations
	Competition	Scope for development
		Institutional configuration
		Significance on public agenda
		Competition

Table 1. Project complexity framework : classification of project complexity factors

Project complexity Factors	Renault Espace Development Project	Renaul Twingo Development Project
SIZE-ORG FACTORS		
Number of stakeholders	3	Negligible
Number of information systems	Negligible	Negligible
Number of structures / groups / teams to be coordinated	3	1
Number of companies / projects sharing their resources	2	Negligible
Number of departments involved	2	2
Number of deliverables	1	1
Number of objectives	2	2
Largeness of scope (number of components, etc...)	2	2
Number of hierarchical levels	Negligible	Negligible
Number of investors	1	Negligible
Number of activities	2	2
Largeness of capital investment	2	2
Staff quantity	1	1
Number of decisions to be made	2	1
Duration of the project	2	2
SIZE-TECH FACTORS		
Largeness of scope (number of components, etc...)	1	1
Number and quantity of resources	1	1
VAR-ORG FACTORS		
Variety of information systems to be combined	Negligible	Negligible
Geographic location of the stakeholders (and their mutual disaffection)	2	1
Variety of the interests of the stakeholders	3	Negligible
Diversity of staff (experience, social span,...)	3	2
Variety of the stakeholders' status	1	Negligible
Variety of hierarchical levels within the organisation	Negligible	Negligible
Variety of financial resources	Negligible	Negligible
Variety of organisational interdependencies	Negligible	Negligible
Variety of organisational skills needed	1	Negligible
Variety of project management methods and tools applied	1	3
VAR-TECH FACTORS		
Variety of the technologies used during the project	2	1
Variety of the product components	Negligible	Negligible
Variety of resources to be manipulated	2	1
Variety of technological dependencies	1	1
Variety of technological skills needed	1	Negligible
INT-ORG FACTORS		
Dependencies with the environment	2	1
Availability of people, material and of any resources due to sharing	2	1
Interdependence between sites, departments and companies	2	1
Interconnectivity and feedback loops in the task and project networks	1	1
Team cooperation and communication	3	1
Dependencies between schedules	3	1
Interdependence of information systems	Negligible	Negligible
Interdependence of objectives	1	2
Level of interrelations between phases	2	2
Processes interdependence	Negligible	Negligible
Stakeholders interrelations	2	2
Combined transportation	Negligible	Negligible
Interdependence between actors	2	2
Number of interfaces in the project organization	Negligible	Negligible
Dynamic and evolving team structure	1	Negligible
Relations with permanent organizations	1	1
INT-TECH FACTORS		
Specifications interdependence	1	1
Interdependence between the components of the product	3	3
Technological processes dependencies	3	2
Resource and raw material interdependencies	2	2
CONT-ORG FACTORS		
Cultural configuration and variety	3	1
Environment complexity (networked environment)	2	1
Organisational degree of innovation	1	3
New laws and regulations	1	1
Institutional configuration	Negligible	Negligible
Local laws and regulations	2	1
Competition	2	2
CONT-TECH FACTORS		
Environment complexity (networked environment)	1	1
Technological degree of innovation	3	1
Cultural configuration and variety	2	1
New laws and regulations	1	1
Demand of creativity	3	2
Local laws and regulations	1	1

Table 2. Synthesis of the retrospective project complexity analysis

Criterion	Family	Compl. Type	Average	Std Dev
Dependencies with the environment	Int	Org	4.889	0.323
Cultural configuration and variety	Cont	Org	4.833	0.514
Availability of people, material and of any resources due to sharing	Int	Org	4.722	0.461
Interdependence between sites, departments and companies	Int	Org	4.722	0.461
Environment complexity (networked environment)	Cont	Tech	4.722	0.575
Variety of information systems to be combined	Var	Org	4.667	0.594
Interconnectivity and feedback loops in the task and project networks	Int	Org	4.667	0.594
Specifications interdependence	Int	Tech	4.667	0.485
Environment complexity (networked environment)	Cont	Org	4.667	0.594
Team cooperation and communication	Int	Org	4.611	0.502
Number of stakeholders	Size	Org	4.556	0.511
Dependencies between schedules	Int	Org	4.556	0.511
Interdependence of information systems	Int	Org	4.556	0.705
Interdependence of objectives	Int	Org	4.556	0.922
Geographic location of the stakeholders (and their mutual disaffection)	Var	Org	4.500	0.707
Variety of the interests of the stakeholders	Var	Org	4.500	0.514
Level of interrelations between phases	Int	Org	4.500	0.618
Processes interdependence	Int	Org	4.500	0.514
Number of information systems	Size	Org	4.444	0.784
Number of structures / groups / teams to be coordinated	Size	Org	4.444	0.511
Diversity of staff (experience, social span ...)	Var	Org	4.444	0.856
Stakeholders interrelations	Int	Org	4.444	0.705
Interdependence between the components of the product	Int	Tech	4.444	0.616
Technological processes dependencies	Int	Tech	4.444	0.616
Number of companies / projects sharing their resources	Size	Org	4.389	0.698
Combined transportation	Int	Org	4.389	0.698
Largeness of scope (number of components, etc...)	Size	Tech	4.333	0.686
Interdependence between actors	Int	Org	4.333	0.594
Technological degree of innovation	Cont	Tech	4.333	0.686
Variety of the technologies used during the project	Var	Tech	4.278	0.895
Organisational degree of innovation	Cont	Org	4.278	0.826
Number of departments involved	Size	Org	4.222	0.647
Variety of the product components	Var	Tech	4.222	0.878
Cultural configuration and variety	Cont	Tech	4.222	0.732
Number of deliverables	Size	Org	4.167	0.985
Number of objectives	Size	Org	4.167	0.707
Variety of the stakeholders' status	Var	Org	4.167	0.618
Largeness of scope (number of components, etc...)	Size	Org	4.056	0.725
Variety of resources to be manipulated	Var	Tech	4.056	0.802
Number and quantity of resources	Size	Tech	4.000	0.767
Number of interfaces in the project organization	Int	Org	4.000	0.707
Number and quantity of resources	Size	Org	3.944	0.802
Variety of hierarchical levels within the organisation	Var	Org	3.944	0.639
Resource and raw material interdependencies	Int	Tech	3.944	0.725
Variety of financial resources	Var	Org	3.889	0.758
Variety of technological dependencies	Var	Tech	3.889	0.583
New laws and regulations	Cont	Tech	3.889	0.471
Number of hierarchical levels	Size	Org	3.833	0.707
Number of investors	Size	Org	3.833	0.618
New laws and regulations	Cont	Org	3.833	0.618
Demand of creativity	Cont	Tech	3.778	0.808
Number of activities	Size	Org	3.722	0.752
Variety of organisational interdependencies	Var	Org	3.556	0.922
Variety of organisational skills needed	Var	Org	3.556	0.856
Largeness of capital investment	Size	Org	3.500	0.786
Variety of technological skills needed	Var	Tech	3.500	0.707
Institutional configuration	Cont	Org	3.444	0.616
Local laws and regulations	Cont	Tech	3.444	0.511
Scope for development	Cont	Tech	3.444	0.511
Local laws and regulations	Cont	Org	3.389	0.502
Institutional configuration	Cont	Tech	3.389	0.698
Staff quantity	Size	Org	3.167	0.707
Dynamic and evolving team structure	Int	Org	3.000	0.594
Significance on public agenda	Cont	Tech	2.833	0.857
Number of decisions to be made	Size	Org	2.722	0.752
Relations with permanent organizations	Int	Org	2.667	0.767
Competition	Cont	Tech	2.611	0.850
Variety of project management methods and tools applied	Var	Org	2.556	0.616
Duration of the project	Size	Org	2.500	0.786
Competition	Cont	Org	2.278	0.826

Table3. Synthesis of Delphi results for each criterion, sorted by decreasing average

(Please note that the table above is table 4 and not table 3, we placed it here because of the size of the different tables)

	Org		Tech		Global	
	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
Size	3,854	0,717	4,167	0,726	4,010	0,722
Variety	3,978	0,708	3,989	0,773	3,983	0,741
Interdependence	4,319	0,605	4,375	0,610	4,347	0,608
Context	3,817	0,642	3,667	0,670	3,742	0,656
Global	3,992	0,668	4,049	0,695	4,021	0,682

Table4. Global Delphi results for each category

	Org				Tech			
	Academics		Industrials		Academics		Industrials	
	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
Size	3,825	0,717	3,891	0,723	4,350	0,542	3,938	0,873
Variety	4,030	0,674	3,913	0,742	4,040	0,723	3,925	0,817
Interdependence	4,362	0,556	4,266	0,631	4,425	0,524	4,313	0,726
Context	3,914	0,551	3,696	0,692	3,790	0,631	3,513	0,698
Global	4,033	0,624	3,941	0,697	4,151	0,605	3,922	0,779

Table5. Professional comparison of the Delphi study

	Org				Tech			
	Male		Female		Male		Female	
	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
Size	3,743	0,796	3,925	0,736	4,154	0,507	4,150	0,883
Variety	4,065	0,798	3,930	0,738	4,000	0,795	3,960	0,800
Interdependence	4,306	0,663	4,332	0,619	4,471	0,510	4,300	0,676
Context	3,739	0,730	3,771	0,709	3,556	0,791	3,700	0,709
Global	3,963	0,747	3,990	0,701	4,045	0,651	4,028	0,767

Table6. Gender comparison of the Delphi study

Family	Organisational complexity (Org)	Technological complexity (Tech)
Project System Size	Number of stakeholders	
Project System Variety	Variety of information systems to be combined	
	Geographic location of the stakeholders (and their mutual disaffection)	
	Variety of the interests of the stakeholders	
Interdependence within the Project System	Dependencies with the environment	Specifications interdependence
	Availability of people, material and of any resources due to sharing	
	Interdependence between sites, departments and companies	
	Interconnectivity and feedback loops in the task and project networks	
	Team cooperation and communication	
	Dependencies between schedules	
	Interdependence of information systems	
	Interdependence of objectives	
Level of interrelations between phases		
Elements of Context	Cultural configuration and variety	Environment complexity (networked environment)
	Environment complexity (networked environment)	

Table 7. Refined project complexity framework after the Delphi study