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Using a Delphi process and the Analytic Hierarchy Process (AHP) to evaluate the complexity of projects

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ABSTRACT

Project complexity is ever growing and needs to be understood, analysed and measured better to assist modern project management. The overall ambition of this paper is therefore to define a measure of project complexity in order to assist decision-making, notably when analysing several projects in a portfolio, or when studying different areas of a project. A synthesised literature review on existing complexity measures is firstly proposed in order to highlight their limitations. Then, we identify the multiple aspects of project complexity thanks to the construction and refinement of a project complexity framework thanks to an international Delphi study. We then propose a multi-criteria approach to project complexity evaluation, underlining the benefits of such an approach. In order to solve properly this multi-criteria problem, we first conduct a critical state of the art on multi-criteria methodologies. We then argue for the use of the Analytic Hierarchy Process. In the end, this tool permits to define a relative project complexity measure, which can notably assist decision-making. Complexity scales and subscales are defined in order to highlight the most complex alternatives and their principal sources of complexity within the set of criteria and sub-criteria which exist in the hierarchical structure. Finally, a case study within a start-up firm in the entertainment industry (musicals production) is performed. Conclusions, limitations and perspectives of research are given in the end.

1. Introduction

A project is a temporary and unique endeavour undertaken to deliver a result. This result is always a change in the organization, whatever it is in its processes, performance, products or services. This transformation consists then in a gap between a start and a final state. Time and resources are consumed to produce results, which may be deliverables and/or performance improvement and/or resource improvement (skills, knowledge). Each project is unique because there is always at least one of the following parameters that changes: targets, resources and environment. As projects became more and more present into organizations, and as they had bigger and bigger amounts at stake, it became impossible to let them live without specific and rigorous methodology. As a consequence, project management was created as a formalized and structured methodology. It is usually admitted than modern project management appeared during World War II and was initially dedicated to big military and construction projects.

For all practical purposes, lots of studies have been done, based on statistical calculations or surveys. 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 properly the complete situation at a given time. As a whole, the conclusion of these studies is that current methods have shown their limits, since they cannot face anymore the stakes of ever growing project complexity. For instance, as noted during discussions with consulting practitioners, in the case of oil industry, it is clear that engineering projects today are larger, involve more sophisticated technology and are organised with a higher number of contractors and partners compared to 40 years ago. As a whole, project complexity results in damages or failures for the projects. In other words, project ever growing complexity is an ever growing source of project risks.

Identifying existing project complexity sources and levels of project complexity has thus become a crucial issue in order to assist modern project management. After a review of the literature on project complexity in Section 2, this paper aims at proposing an innovative measure of project complexity which incorporates the multiple aspects of this project characteristic. In order to do so, a methodology is exposed in Section 3 and followed in the next sections. Conclusions and research perspectives about this issue are finally given in Section 9.

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2. Measuring project complexity: a literature review

2.1. Existing project complexity measures

Several authors tried to define complexity measures in order to explain project failures, to identify intricate situations, to understand better project complex phenomena and to help decision-making. Indeed, such a measure is notably to assist decision-makers before engaging their projects/portfolios into too complex situations since too early decisions when facing complex and uncertain situations often fail to deliver the targeted performance.

But before choosing a suitable project complexity measure, one must be able to define a list of criteria that can be used to assess if it is good or not. Latva-Koivisto (2001) proposes a first list in a research report which includes parameters such as reliability, ease of implementation and intuitiveness for instance. As far as this research work is concerned, a literature review on existing project complexity measures (or complexity measures which could be adapted to project management) was performed.

A focus was made on project complexity in terms of project systemic complexity, and not of algorithmic complexity when solving some issues about project management, such as the sequencing and scheduling problem (Akileswaran, Hazen, & Morin, 1983). The works of Edmonds (1999), Latva-Koivisto (2001) and Nassar and Hegab (2006) were crucial sources to generate this list of about 40 complexity measure indicators. For instance, in his Ph.D. thesis, Edmonds (1999) identified formulations and measures of complexity, working on a large scope of fields and applications. As for him, Latva-Koivisto (2001) reviewed complexity measures to assess the structural complexity of business processes. He argued that the complexity of business processes could be assessed through the conversion of process charts (composed of activities, dependencies, information flows, material flows and control flows) to graphs, giving the example of the resource-constrained project scheduling problem. If interested, one should directly refer to these three references for more information on complexity measures and formulations. Then, the obtained list of possible complexity measures was refined thanks to the previously introduced criteria. Four specific complexity measures are given here since among the most appropriate ones for a use in project management.

- The Coefficient of Network Complexity (CNC) defined by Kaimann (1974) applies to both PERT (Program Evaluation and Review Technique) and precedence networks. In the case of PERT networks, the CNC is equal to the quotient of activities squared divided by events. The CNC, thanks to an intuitive definition is a good complexity measure to catch the structural complexity of systems that are modelled thanks to graphs. However they take redundant arcs into account.
- The cyclomatic number defined by Temperley (1981) gives the number of independent cycles in a graph. The equation calculation of the cyclomatic number is Eq. (1). S is the cyclomatic number, A is the number of arcs, N is the number of nodes.

$$S = A - N + 1 \quad (1)$$

- The traditional static entropic measurement of complexity by the Shannon information (Shannon, 1948) is based on the probability of receiving a message, as shown by Eq. (2) where $p\,(n_i)$ is the probability of receiving a message n_i. The Shannon information is also a complexity measure since information and disorder are strongly related.

$$Sha = -\Sigma log_2(p(n_i)) \quad (2)$$

- Arguing that complexity measures such as CNC are imperfect since they take redundant arcs into account and therefore show that the system is more complex than it actually is, Nassar and Hegab (2006) define a measure for project schedules. This measure gives the degree of interrelationships between the activities in a schedule. This complexity measure is the following Eq. (3) for an activity on node project network.

$$\begin{aligned} Cn &= 100 \times (Log(a/(n-1))/Log[(n^2-1)/4(n-1)])\% \text{ if } n \text{ is odd} \\ Cn &= 100 \times (Log(a/(n-1))/Log[n^2/4(n-1)])\% \text{ if } n \text{ is even} \end{aligned} \quad (3)$$

2.2. Limits of existing project complexity measures

Existing measures have shown their limits for several reasons. First, some limits have been highlighted about the reliability of such measures. Indeed, some counterexamples were found: some graphs and networks were sharing the same CNC but were very different considering their easiness to be managed. One of the reasons for this lack of reliability is that these measures mainly refer to a single aspect of (project) complexity, notably in terms of interdependencies.

Second, these measures are often non intuitive for the final users and thus give results which are difficult to communicate on. These mathematical formulations do not permit a reference to real project complexity factors: both the identification of important complexity sources and possible actions for complexity handling/reduction are not facilitated. Moreover, such measures are sometimes difficult to calculate for non-skilled users, which make it all the more complex to perform and analyse them. For instance, in the case of the Shannon number, both difficulties are encountered for all practical purposes.

Finally, these measures mainly refer to a model of the project system. Indeed, measures such as the CNC, the cyclomatic number or the one proposed by Nassar and Hegab refer in essence to an existing network or graph. Such graphs are specific models of the project system, which restrict the view and understanding of project complexity. For instance, a project can be modelled thanks to different WBS (Work Breakdown Structure), PERT networks or Gantt charts, depending on the detail level, willingness of the project manager, etc. Applying such measures to these kinds of elementary models of the project systems cannot properly account for a measure of project complexity since they are in essence relative to the model. As a consequence, in order to overcome the limits of existing measures, this paper aims at defining an index which is as far as possible:

- Reliable, meaning the user can be confident with the measure.
- Intuitive and user-friendly, meaning it should be easily computed and implemented, and that users must understand why it assesses project complexity.
- Independent of the project models, so that the measure is an evaluation of project complexity and not an evaluation of the complexity of a given project model.
- Able to highlight project complexity sources when building up the measure, so that the user can analyse more properly project complexity and thus make his decisions with a better vision of the problem.

3. Research methodology

In order to do so, we propose to carry out the following methodology:

- Performing a broad state of the art to understand the multiple aspects of project complexity through the construction of a project complexity framework (Section 4).