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# Towards an Integration of Systems Engineering and Project Management Processes for a Decision Aiding Purpose

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**Abstract:** This article proposes an integrated process that combine Systems Engineering processes and Project Management ones. These processes are defined according to the industrial standard processes existing in the literature. The main idea is to define a common information model enabling the federation of all the points of view of the different actors with regards to Systems Engineering, Project Time Management, Project Cost Management and Project Risk Management. The resulting integrated project graph encompasses all the scenarios established after defining all the coupling points between those processes. The definition of the graph is based also on the available knowledge and the capitalized experiences resulting from experience feedback on previous projects. The scenario selection optimization is then performed using a decision-aided tool that aims to build a panel of Pareto-optimal solutions taking into account uncertainties on project objectives (cost and duration). This tool will also enable the decision-maker to select one scenario according to an acceptable level of risks. The integrated process, the optimization tool based on Ant Colony Optimization (ACO) and the method for decision making are described in the paper.



*Keywords:* Project Management, Systems Engineering, Processes Integration, Risk, Uncertainty, Ant Colony Optimization, Decision Aiding.

## 1. INTRODUCTION

The conception and the generation of new systems are industrial activities that are very complex to manage within an increasing competitive market. The high-risk nature of systems engineering projects and the difficulties to make efficient links between systems engineers and project managers are factors that increase this complexity. A trade-off between systems engineers' activities and project managers' responsibilities is necessary in order to efficiently meet customer requirements in terms of cost and time while controlling risk. In such a context, both systems engineers and project managers need an efficient risk management process to cope with different technical and programmatic risks that might be faced during projects (SEBOK (2014)). Some previous studies have defined the interactions between system design and project planning processes for better controlling and monitoring them. In these works, a structural interaction making bijective connections between project and system structures has been defined in (Abeille et al. (2010) and Coudert et al. (2011)). Then, a behavioral interaction model has been proposed in (Vareilles et al. (2015)) enabling a synchronization of system design and project planning by defining specific integrated models and rules. Moreover, the SEBOK Guide (SEBOK (2014)) highlights the necessity to have an overlap between systems engineering and project management by considering all the common concerns between both disciplines. In fact, the PMBOK Guide (PMBOK (2013)) describes the project management processes considering the technical aspects as an input of the project. Moreover, the risk management is an important aspect in these standards. However, it is not performed during the earliest phases when uncertainties occur. It is rather performed during activities such as duration estimation and scheduling (see the description of the Project Time Management (PTM) process in sub-section 2.1). The structure of the system is well known and all the activities that are necessary to design, produce and deliver have to be defined with their resources. In this context, our contribution is to define an integrated process where systems, projects and risks' analysis are early and conjointly built using ad hoc coupling mechanisms and tools.

Risks exist whenever uncertainty exists (Better et al. (2008)). In some studies, the risk management processes are considered as project uncertainty management ones (Ward et al. (2003)). In other works, the risk is considered as uncertainty on the durations of tasks (Sobel et al. (2004), Creemers et al. (2012) and Bourne et al. (2014)). In our approach, uncertainty is considered as the effect of the occurrence of unknown situations on project objectives (cost and duration) and should be taken into account to make decisions on the structure of systems and projects. Then, the management of uncertainties during decision making can be seen as a way to take into account risks. This necessity to optimize very early the technical choices conjointly with the project ones was emphasized in previous studies performed


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in (Pitiot et al. (2010)). A multicriteria evolutionary optimization method based on a knowledge-based evolutionary algorithm was proposed. It enables the optimization of project scenarios selection taking simultaneously into account the technical choices (design choices) and the PTM ones. A scenario is a set of tasks with precedence constraints which have to be planned. The goal was to obtain a set of Pareto-optimal scenarios in a two-dimension objective space (global cost and duration). However, in order to improve this method, a third dimension can be integrated: the risk one. In (Baroso et al. (2014)), the integration of risk as a third objective to minimize has been first proposed. A multi-objective Ant Colony Algorithm (MOACO) has been developed for this problem for its ability to solve such relevant combinatorial optimization problem in a reasonable amount of time. First results provided by this algorithm were presented in (Lachhab et al. (2016)). Following on these works, an important improvement is to define a decision-aided tool, based on the optimization model, that integrates the standard industrial processes (the systems engineering process (SEBOK (2014)) and the project management one (PMBOK (2013))) in the early first phases.

Thus, this article aims at defining an approach where Systems Engineering (SE) and Project Management (PM) (including cost and risk management) processes are articulated together efficiently. The coupling of these domains and their principal interactions will be carried out and are supported by a multicriteria decision-aided tool based on a multi-objective ACO algorithm. The decision-aided tool is integrated within the processes cited above to select scenarios in a project graph that gathers all possible alternatives and choices of design and realization of a new system. It also allows to minimize the project objectives in terms of cost, duration and risk. The risk is considered as a third objective to optimize and represents the uncertainty on project duration and cost. The SE and PM processes are fed up by a knowledge/experience base to control uncertainties about project cost and duration. The tool enables to generate a panel of Pareto-optimal scenarios (solutions). From this panel, one scenario can be selected in order to be scheduled and realized under the control of the project manager.

In the next section, the industrial standard processes related to Project Management and Systems Engineering scopes are described. The purpose of theses depictions is the proposition of an integrated process that takes into account the different interactions between all the processes and the sub-processes belonging to PM and SE processes. In section 3, the PM and SE processes interactions are formulated, the definition of project scenarios is given, an algorithm of the multi-objective ACO is described, and then a multicriteria decision-aided tool is presented. Finally, conclusions and perspectives are given in section 4.

## 2. INDUSTRIAL STANDARD PROCESSES

### *2.1 Project Management Process*

The project management encompasses all project activities, techniques and tools in order to meet the customer requirements in terms of cost, time, quality, performance, etc. According to the Project Management Institute (PMI), the Project Management comprises five process groups defined in the Project Management Book of Knowledge Guide (PMBOK (2013)): Initiating, Planning, Executing, Monitoring/Controlling and Closing process groups. The **"Initiating"** process group includes two main processes that perform the stakeholders' identification. The **"Planning"** process group integrates all planning management activities that are necessary for developing a project management plan in accordance with the key stakeholders. The **"Executing"** process group allows to carry out all the necessary activities to reach the initial stated objectives of the project. The **"Monitoring and Controlling"** process group involves the control of the executed activities and the measurement of project performance. They also involve risk register updates and risk response plans. Finally, the **"Closing"** process group allows to capitalize all the lessons learned from the project realization and to evaluate the customer satisfaction.

Three main domains of knowledge of the PM process are then presented according to the PMBOK Guide (PMBOK (2013)) to highlight, in the section 3, the possibility of coupling them together and with other existing standard processes. These processes are ordered as follows: Project Time Management, Project Cost Management (PCM) and Project Risk Management (PRM).

- **Project Time Management Process**

The PTM process allows to manage the completion time of a project by means of six processes that interact with each other. The processes are: Define and Sequence Activities, Estimate Activity Resources and Durations, Develop Schedule and finally Control Schedule. The process **"Define Activities"** identifies the actions to be achieved to meet project goals taking into account constraints, assumptions, environmental factors, the scheduling methodology and lessons-learned from previous projects about similar activities listed in a knowledge base. The Working Breakdown Structure (WBS) is a decomposition technique carried out to structure the project into sub-projects by defining all the components of the project deliverable. The expert judgment is necessary to take profit from previous experiences in the activities definition process. Each activity has its own attributes that characterize them together with their schedule development (activity name, predecessor and successor activities, etc). After defining the list of activities and their associated attributes, the process **"Sequence Activities"** is realized. It allows to define the logical relationships between activities. During this step, the updating of activity lists, activity attributes and the risk register is necessary. The process **"Estimate Activity Resources"** is subordinated by the "Estimate Cost" process that will be defined in the Project Cost Management process part and it requires to know all information about resources to perform project activities like human resources, equipment and material. The process **"Estimate Activity Durations"** gives an approximation about the amount of work periods that is required to perform activities in accordance with estimated resources. Thus, the duration of activities is