Combining complex systems modeling and mathematical decision-aiding for managing projects

Adapting the world to ourselves has yielded increasing complexity of our systems, and indirectly of the projects that design, develop and build them. This implies the need to improve our capacity to design and manage such complex projects through the development of academically original and industrially relevant models, methods and tools. The Dependency and Structure Modeling approach supports complex project management by focusing attention on project elements and their interdependencies related to product, process and organization domains. It contributes to support mastering the amount of information required to better model, analyze, and then make decisions about the project or a part of the project, like the product components, the activity schedule, or the organizational communication patterns. This modeling phase is based on three types of matrices:

- the square matrix DSM (Design Structure Matrix) which models the interdependencies between elements of a single type;
- the rectangular matrix DMM (Domain Mapping Matrix) which models the interdependencies between two types of elements;
- and the square matrix MDM (Multi Domain Matrix) which models the interdependencies between several types of elements, as a combination of several DSM and DMM.

This means that heterogeneous elements related to multiple dimensions like risks, decisions or deliverables can also be integrated into such models. Modeling complex projects using DSM-based principles enables anticipating the potential behavior of the project and supports decision-making. Many developments have recently been made in complex project management based on DSM models in order to create or improve techniques to analyze projects and make decisions. This can be done either in early phases for designing, planning, and organizing resources, or during the execution phase for controlling, managing change and keeping the project on track.

It is the object of this Special Issue to focus on these technical developments, aiming at providing decision-makers in projects with more accurate understanding about the potential behavior or about the potential consequences of their decisions. The consistence of the Special Issue is based on the fact that every concept and application use the same initial data structure, the DSM approach. This implies modeling DSMs, DMMs or MDMs of a project, then applying heuristics, simulation, graphical tools, or analytical methods to better understand its structure and making appropriate decisions. This Special Issue represents a broad overview of the state-of-the-art on the development and application of DSM-based analysis and decision-making techniques. There are a significant number of papers with industry authors or co-authors, reflecting this balance and synergy between conceptual development and real-life industrial application, which are in the genes of the DSM Conference series. We would like to thank **Journal of Modern Project Management** editor-in-chief Zózimo for his assistance coordinating the process. We are also very grateful to all reviewers who helped review these papers. This Special Issue collects fifteen papers organized into three blocks:

- **Clustering techniques development;**
- **Simulation and optimization techniques development;**
- **Application of clustering, simulation and optimization techniques.**

The following summaries provide a brief overview of the papers and the relationships between them.

CLUSTERING TECHNIQUES DEVELOPMENT.

One powerful tool once the DSM model is established is to find clusters. They may emerge from the structure of the model and may be revealed through different algorithms using for instance eigenvectors or modularity metrics. Otherwise, they may be shaped by the will of decision-makers to group elements according to some objectives *(e.g., facilitating the coordination between people)* and constraints *(e.g., the maximal size of the cluster)*. **Behncke, Maurer, Schrenk, and Lindemann** explore the generation of possible exclusive clusters configurations. They are assessed through multi-criteria evaluation then proposed to the decision-maker as a ranked portfolio. **Lan and Liu** use event logs to discover hidden tasks and their interactions through a three-step approach combining text mining, interaction measurement based on overlapping time and exchanged information, and clustering to highlight the hidden structure of this process. **Pointurier, Marle, and Jaber** develop a clustering strategy based on three established algorithms, testing them with different problem configurations in order to analyze the sensitivity of the proposed solution. The application to a complex system delivery project shows that managerial decisions of grouping risk owners to better coordinate product-, process- and organization-based decisions may be assisted by a deep mathematical analysis of the structure of the project risk network. **Sarkar and Dong** propose a new spectral clustering and partitioning software for the identification of modules in complex networks. The globally optimal number of modules is identified, as well as overlapping modules. Particularly, the membership of overlapping elements to modules can be visualized in terms of a continuously varying membership function. **Jung and Simpson** propose new modularity indices to assess the cluster validity, or quality. Moreover, they combine these indices with a genetic algorithm with extended chromosomes.

SIMULATION AND OPTIMIZATION TECHNIQUES DEVELOPMENT.

These techniques are particularly appropriate for planning and scheduling projects, as developed in the first two papers of this block, but also for system development-related decisions, as in the later three papers. **Schlick, Terstegen, and Duckwitz** introduce an estimation of Work Transformation matrices in large-scale concurrent engineering projects with periodically correlated work processes. The proposed approach captures the cooperative processing of the development tasks with short iteration length. Moreover, it helps to anticipate long-scale effects of withholding the release of information on purpose. Yassine proposes a mathematical formulation to optimize product development investment decisions. The model maximizes the performance based on the architecture and the resource constraints. **Petz, Terstegen, Duckwitz, and Schlick** combine DSM and discrete event simulation to support service development decisions as well as identification of improvement levers. **Gaertner, Terstegen, Schlick, Zibull, and Heuer** apply scheduling techniques to functional integration projects, which are characterized by multi-level dependencies, iterative processing, limited resources, last-minute changes, and a multi-project context. It helps to synchronize teams and tasks, to make priorities, and to anticipate changes. **Karthaus, Roth, Binz, Schenk, and Bertsche** finally propose an approach to support the recirculation of knowledge gathered during tests for assisting product development. They present relevant measurement signals for interpreting failures detected by test benches, which can be used for automatically generated measurement signal diagrams. This allows new dependencies to be modeled, distributed and used.

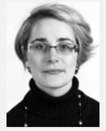
APPLICATION OF CLUSTERING, SIMULATION AND OPTIMIZATION TECHNIQUES.

The last block is made of application of previously presented techniques. This means that the application is original, even if the algorithm is classical. **Bauer, Kasperek, Maisenbacher, and Maurer** test and validate the applicability of structural criteria to specific industrial case-study, showing which criteria can add value to the structural analysis of the system. **Kherbachi and Yang** introduce a multi-domain matrix to identify communication-based interdependencies within development teams. The outcome is the teams' communication process and associated analysis and efficiency improvement requirements. **Lagerström, Baldwin, MacCormack, and Dreyfus** use DSM to visualize and measure software portfolio architectures. These measures are used for predicting the architectural change costs. They model 407 elements in a biopharmaceutical application, showing that the network structure can be classified as a core-periphery structure. This classification of structures has been shown to be a significant predictor of architectural change costs. **Farsad and Malaek** develop an application of a standard clustering algorithm to air traffic control management, modeling the possibility of aircraft conflicts in a DSM. This is a contextual and dynamic application of such techniques, since the model has to be refreshed frequently. It identifies non-conflictual clusters of aircrafts, and lets the air controllers manage the potential conflicts within each cluster, which is easier to manage with less workload and a lower risk of error. **Kasperek, Maisenbacher, and Maurer** present the combination of structure modeling and System Dynamics for simulating the dynamic behavior of engineering design processes.

The papers in this special issue are consistent and complimentary, since some of them develop decision-making techniques which are applied by others. Future research may build on the concepts embodied here but also branch into exciting research opportunities in multi-project management, risk treatment plan optimization, social analysis of communication and coordination patterns, human-centered management, and complex projects multiple dimensions visualization, among others. It is our hope that this Special Issue will stimulate further research and discussion on this topic, thus helping the community make new, rigorous advances in analyzing and making decisions to keep projects on track and making them successful.


Franck Marle
Ecole Centrale Paris
franck.marle@ecp.fr


Steven Eppinger
Massachusetts Institute of Technology
eppinger@mit.edu


Marija Jankovic
Ecole Centrale Paris
marija.jankovic@ecp.fr


Bernard Yannou
Ecole Centrale Paris
bernard.yannou@ecp.fr

JMPM SPECIAL ISSUE
16TH INTERNATIONAL DEPENDENCY AND STRUCTURE MODELLING CONFERENCE
DSM 2014 PARIS, FRANCE, JULIY 2 – 4, 2014 ECP – École Centrale Paris