

Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Mikhail Nikolaev

PhD Program: Engineering Systems

Title of Thesis: Concept selection of innovative complex engineering systems considering systems emergent properties

Supervisor: Professor Clement Fortin, Skoltech

Name of the Reviewer: Professor Rob Vingerhoeds, ISAE-SUPAERO

I confirm the absence of any conflict of interest

Date: 16-11-2022

The purpose of this report is to obtain an independent review from the members of PhD defense Jury before the thesis defense. The members of PhD defense Jury are asked to submit signed copy of the report at least 30 days prior the thesis defense. The Reviewers are asked to bring a copy of the completed report to the thesis defense and to discuss the contents of each report with each other before the thesis defense.

If the reviewers have any queries about the thesis which they wish to raise in advance, please contact the Chair of the Jury.

Reviewer's Report

Reviewers report should contain the following items:

- Brief evaluation of the thesis quality and overall structure of the dissertation.
- The relevance of the topic of dissertation work to its actual content
- The relevance of the methods used in the dissertation
- The scientific significance of the results obtained and their compliance with the international level and current state of the art
- The relevance of the obtained results to applications (if applicable)
- The quality of publications

The summary of issues to be addressed before/during the thesis defense

Report on the thesis of Mr Mikhail NIKOLAEV

entitled

"Concept selection of innovative complex engineering systems considering systems emergent properties"

for obtaining the degree of Doctor of Philosophy of The Skolkovo Institute of Science and Technology

The thesis was prepared at the Skolkovo Institute of Science and Technology under the supervision of Professor Clément Fortin. The thesis, of 157 pages, is written in English and is organized in an introduction, 3 chapters, a conclusion and 5 appendixes.

The introduction explains the relevance of the research topic addressed by the candidate, who based on different literature definitions of the topic (concept selection) and related topics (e.g., decision and decision-making) then defines the definitions he uses in the thesis, so that there can be no ambiguity. From this first contextual description, the candidate derives 5 research purposes: clarification of core research-related terms, literature review of design decision-making techniques and tools, ontology of emergent properties for complex systems, formulation for combining innovativeness and complexity as complementary features and development of a decision-making model (or models). The candidate then briefly highlights the contributions. The problem is well posed, and the objectives are clearly defined, and the candidate shows he masters the topic of the thesis.

Chapter 1 "Literature analysis and Review" provides an overview of different definitions of terms related to the research topics, followed by a more specific review, based on over 50 publications, on decision-making in technological innovation. This chapter is an updated version of the paper M. Y. Nikolaev, C. Fortin. "A literature review of design decision making in disruptive technological innovations of new products", Proceedings of ASME 2020 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference / American Society of Mechanical Engineers. – 2020. – Vol. 6. – 9 p. – DOI: 10.1115/DETC2020-22093, a Q1 International Scientific Journal. The candidate demonstrates a good knowledge on the systems engineering in general, on the challenges of concept selection, setting the scene for the remainder of the thesis.

Chapter 2 "Ontology, Approach and Models" presents the development of the systems thinking ontology of emergent properties for complex systems (STOEP), the emergence approach to design decision making in innovative complex systems, and combined decision-making models of two levels (essential process-based decision-making and an extension of this base model). The candidate describes ontologies and adapts it to systems thinking. An observation needs to be made as to

«Generally, an ontology in the design represents a documentation of the terminology used to describe objects, properties, and associations in a particular domain. No single correct way exists for its development.»

"No single correct way" suggests that any framework would do. In reality, a lot of work has been done, both on engineering domains and beyond, to come up with a framework that can help to structure ontology developments, for example "Ontology Development 101". It would have been nice if the

candidate could have taken this on board in his research and in the thesis. Maybe he did but such approaches were not sufficient, in which case it would have been nice to learn from this and to feed back this experience to the ontology communities. Maybe this can be considered for future work.

The development approach chosen by the candidate is logical and well-documented. He presents the proposed ontological model schematically and in tables. It would have been nice if the candidate could have built his ontological model in tools such as Protégé, which tools also would have allowed for verification of the model consistency (class inferences, object property inferences, data property inferences, ...).

The candidate then addresses the principle of complementarity (in organisation and in systems of systems), that in complex systems turns out to be linked with their emergence. It demonstrates the possibility to consider the combination of innovativeness and complexity in innovative complex systems through emergence from the perspective of organizational economics.

The candidate then proposes a Level-1 decision-making model and a Level-2 decision-making model, combining different approaches (DSM, QFD, Delphi, ...), so to arrive at flexibility of combined decision-making models that can be extended or modified based on the needs of decision-makers.

Chapter 3 "Case Studies" presents 4 realistic case studies that the candidate realised for his research; one case-study on STOEP, and three case-studies on the decision-making models. All case-studies are well-documented and the process of applying the framework and the models, using the different complementary techniques the candidate has brought together, becomes very clear. The logical flow from the previous two chapters allows to see how different complementary techniques can be used to enhance decision-making for concept selection.

The conclusions of the thesis are then presented, along with a discussion of the work. The candidate highlights the key points of the thesis based on the 5 papers published during this research, partially taken, and extended in the abovementioned chapters and indicates the contributions made. The candidate then discusses some limitations of the approaches presented in the thesis and concludes with ideas for several perspectives for future research. The candidate has shown a good scientific maturity as to his own work, having a critical view on his work and identifying pertinent areas for future work.

Conclusion

The subject treated in this thesis is of scientific and industrial interest. The contributions of thesis open up a first step to address these objectives; it needs to be more largely applied and extended on more projects. In addition, the ontological model could benefit from further attention in future research, such as in the use of specific tools that allow model consistency verification, in addition to validation on case-studies. It must be underlined that with 5 papers published over the research period, of which one in a well-recognised Q1 international scientific Journal, that the candidate has a very good scientific production.

As a result, I issue a favourable opinion to the defence of the PhD thesis of Mr Mikhail NIKOLAEV before a jury with a view to obtaining the degree of Doctor of Philosophy of The Skolkovo Institute of Science and Technology.

Toulouse, on 16-11-2022

R.A. Vingerhoeds

Professor of Systems Engineering

ISAE-SUPAERO, Université de Toulouse

Provisional Recommendation

I recommend that the candidate should defend the thesis by means of a formal thesis defense

I recommend that the candidate should defend the thesis by means of a formal thesis defense only after appropriate changes would be introduced in candidate's thesis according to the recommendations of the present report

The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense