

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 Amaresh Chakrabarti, IISc Bangalore, India

I confirm the absence of any conflict of interest	
Amaresh Chakrabarti	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

- Brief evaluation of the thesis quality and overall structure of the dissertation.

The thesis consists of an introduction, three chapters, a conclusion, five appendices, and 157 pages of text, 29 figures, and 19 tables. Two of the chapters report on the original contributions of the author: 'ontology, approach, and models', and 'case studies'. The overall structure is as good as expected in a PhD thesis: starting with an overview of the background and main problems, the thesis delves into existing literature to identify specific, significant gaps in the literature, leading to formulation of objectives. These are then addressed by first developing a new ontology and a prescriptive approach, and then implementing these in two models that are tested via four case studies.

- The relevance of the topic of dissertation work to its actual content

The goal of the thesis is to improve selection of the concepts and architecture for decision making in the design of innovative, complex, engineering systems. This is significant since the number of technological innovations and complexity of new engineering systems continue to grow, and design of these systems requires application of a multidisciplinary approach that integrates systems engineering, systems analysis, design of complex systems, and innovation theory.

- The relevance of the methods used in the dissertation

The thesis used DRM – a methodology commonly used in carrying out design research. DRM has four stages: Research Clarification, Descriptive Study I, Prescriptive Study, and Descriptive Study II. For each of these stages, specific, appropriate research methods were used, e.g., a series of case studies in Descriptive Study II to evaluate the support that was developed during the Prescriptive Study stage. The methods and methodology used are relevant and appropriate for the objectives of the thesis.

- The scientific significance of the results obtained and their compliance with the international level and current state of the art

The thesis makes several scientific contributions. It proposes an ontological model of systems' emergent properties based on the systems thinking approach. It also proposes a model that divides all emergent properties of a system into strategy-level and engineering-level properties and links these to the system's values. Finally, by extending the current Value-Based Decision-Making approach, it proposes a new approach to design decision-making in development of innovative complex engineering systems.

- The relevance of the obtained results to applications (if applicable)

Two decision-making models were implemented using the proposed ontology and the decision-making model and tested in four case studies from the oil and gas industry. The case studies demonstrated the workability of the new proposed approach and its advantages, including reduction of resource, over the current approach in decision making for developing innovative complex engineering systems.

- The quality of publications

The thesis led to five publications, of which four are in Web of Science and Scopus indexed journals and conferences including those in reputed organisations such as ASME and the Journal of Physics. Overall, the quality and volume of publications have both been above average in the area of its study.

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

The following need to be clarified/revised/added in the thesis:

1. Page 11: "Such systems, also called technological innovations of new complex systems, possess both characteristics of complex engineering systems and technological innovations." What are these characteristics? Please enlist the two sets of characteristics upfront in the thesis.
2. Same page: "The development of successful innovative complex engineering systems cannot be done in the traditional ways and represents a current-day relevant engineering problem." Why not? Please specify the specific reasons.
3. Page 19: "Development and approbation of a modified decision-making approach for good concept selection of innovative complex systems from systems engineering and systems analysis positions." Please explain what 'good' in the above sentence means, since that is the criterion that would be used to assess whether the development meets the expectation.
4. There are a number of typographic and grammatical errors. The author is urged to carry out a thorough revision in this regard. A few examples are given below to illustrate the point:
 - a. Page 17: "The "Intelligence" phase assumes the information-gathering activities on the decision problem." I suppose this is a typo: and "Intelligence" should be "Investigation".
 - b. Page 94: "Its hull envelope constitutes one of its most critical subsystems, which preliminary concept selection was performed using the value approach..." should be "Its hull envelope constitutes one of its most critical subsystems, for which preliminary concept selection was performed using the value approach..."
 - c. Page 94: "It allowed, to a first approximation, understand how would be the primary function of the hull envelope (keeping gas inside) converted to its form (a particular type of textile)." The sentence should be "It allowed, to a first approximation, an understanding of how the primary function of the hull envelope (keeping gas inside) should be converted to its form (a particular type of textile)."
 - d. Page 128: "Case study 1 was conducted that tested the possibility to apply STOEP as a tool for concept selection of the hull envelope subsystem for IRTA using the emergence approach." Should be "Case study 1 was conducted that tested the possibility of applying STOEP as a tool for concept selection of the hull envelope subsystem for IRTA using the emergence approach."
5. For each case study, please emphasise and clearly specify what each DRM phase has achieved: research clarification for identifying success criteria, and the overall research objectives and questions. The list should include all success criteria (e.g. for Case 1, it is to improve performance while reducing the time taken in decision-making) and all objectives/research questions (i.e. the objectives/research questions for DS I, PS and DS II). Similarly, the subsequent DRM phases should clarify what was tried to be achieved and what was achieved (e.g. DS I in Case 1 identified the areas of weakness in current decision making methods in achieving the success criteria, i.e. performance and time of decision making). Where were time getting wasted or performance issues were getting compromised? Similarly, PS should report on identifying what areas of weakness to be addressed in the new decision-making approach and how. DS II should focus on how the new approach was tested as to whether it indeed improved decision-making in terms of the success criteria (e.g. performance and time for Case 1).
6. Please discuss the specific findings in each case study, especially when the success criteria were partially achieved, and how this learning was used in improving the proposed support.
7. The thesis claims that "Good concept selection of innovative complex systems can be achieved through considering their innovativeness and complexity" (P132). However, it is not indicated which of the emergent properties and associated requirements fall in which of these categories, and how novelty and complexity issues are addressed by turning them into requirements. It is important to discuss this.

Provisional Recommendation

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

***X** 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 (**X: This is the option selected by this Member of the Defence Jury**)*

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