

## Jury Member Report – Doctor of Philosophy thesis.

**Name of Candidate:** Eldar Shakirov

**PhD Program:** Engineering Systems

**Title of Thesis:** Integrated analysis of engineering and manufacturing change management in the additive manufacturing context: a simulation-based modeling framework

**Supervisor:** Professor Ighor Uzhinsky, Skoltech

**Co-supervisors:** Professor Clement Fortin, Skoltech; Professor A. John Hart, MIT

**Name of the Reviewer:** Professor Alexey Nikolaev, Skoltech

I confirm the absence of any conflict of interest

(Alternatively, Reviewer can formulate a possible conflict)



**Date:** 15-06-2021

*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

The thesis of Eldar Shakirov is devoted to important topic of the increasing of the efficiency of industrial manufacturing companies' operations with new integrated engineering and manufacturing processes management frameworks as well as through the application of new technologies (e.g. additive manufacturing). With ever increasing market competition, growing expectations from governments and societies for sustainability and "green" agenda of manufacturing sector, digitalization trends, the thesis is very timely and of high importance. Particular topics addressed by the thesis deal with the development of an integrated framework for engineering and manufacturing change management process, elaboration of the relevant simulation tool enabling quantitative assessment for the informed decision making for the change, as well as the consideration of additive manufacturing technologies as potential "trigger" of these changes and their integral and important part.

The thesis has clear logical structure. The text is prepared with high quality of the both literature review as well as original research performed by the author. The topic of the dissertation is well-correlated with its actual content.

In the research the author uses several research methods. For example, to study how additive manufacturing technologies were introduced to the practices of product design and manufacturing of a real industrial company, the author carried out in-depth interview with the personnel of the company. Such combination of desk study of previous research as well as firsthand field studies provides deep insights, novelty and reliability of the obtained results.

The scientific significance and novelty of the results obtained can be structured around the following themes:

- The author develops the concept of integrated change management (ICM) framework combining Engineering Change Management and Manufacturing Change Management. Closer integration between different functions within a single organization is quite trendy and important direction one can see in various industries. For example, DevOps practices actively applied these days in software engineering have very similar nature – closer integration of Development and Operations functions to decrease "time to market" and "time to quality" in software products.
- As the further elaboration of the theme above, the work presents a simulation-based analytical framework enabling an integrated quantitative assessment of the engineering and manufacturing planning decisions accounting options and opportunities for Additive Manufacturing.
- Also the results obtained by the author from case study with a large energy sector manufacturer applying a metal printing technique to produce and maintain the functional components, revealed important insights and findings of high value for industrial practitioners planning the application of additive manufacturing (AM) technologies as well as companies developing AM technologies or offering AM services.

In addition, the work features well elaborated and detailed literature review covering AM technologies, engineering change management, manufacturing change management, integrated change management frameworks. This creates additional value of the thesis for those looking for comprehensive review of the state of the art in the areas above.

The obtained results, especially in the area of the simulation-based analytical framework enabling integrated quantitative assessment of the engineering and manufacturing planning decisions accounting opportunities for the use of AM technologies, are of very clear and important practical value. Integrated

into real practices for the decision making in industrial companies, the framework will provide management with the opportunity for the informed and data driven decision making increasing decisions quality and transparency, leading to the increased efficiency of the organization and proper use of new perspective AM technologies. At the same time, even though the author discusses the framework validation (Chapter 5), to make the framework a real tool used and recognized by practitioner's community, further research as well as pilot deployments, case studies, etc. are required. Additional validation of the applicability of the framework to real change management processes used in real organizations (accounting legacy processes and frameworks, organization culture, decision making practices, technological, market and organizational features across various industries and particular organizations etc.) as well as adequacy and reliability of the results predicted by simulation are required. This is something to be addressed during the thesis defense or to be considered as possible suggestion for further research of the author. Considering high demand of the industrial sector for new frameworks accounting digitalization, fast and effective data driven decision making, complex engineering-manufacturing environments, opportunities for AM technologies application, the framework has clear potential for real practical application and commercialization. For example, it can be implemented as stand-alone product or service or be combined with existing commercial product lifecycle management software.

Considering all the above, the research presented in the thesis is of high quality having high scientific and practical application significance. It can be recommended for the formal thesis defense procedure.

#### **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*