Skoltech
Skolkovo Institute of Science and Technology

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: Edward Crawley

I confirm the absence of any conflict of interest	**Date: 14-06-2021**

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

Overall comments:

Unquestionably this is a doctoral quality piece of work, and makes significant contributions.

The thesis actually contains two studies – one on integrated engineering and manufacturing planning. And the other one in the context of additive manufacturing. Together the results are even more important than individually.

First let's examine methodology. Eldar has made good use of Design Research Methodology (DRM). He has used a methodologically rigorous approach, important in this kind of case-based research. Since there is no absolute ground truth (as admitted by the author), the adherence to other types of evidence-based standards, such as are found in social science research, is critically important. DRM fits within this larger social science methodology.

Eldar demonstrates a command of the historical and contemporary literature in Product Development and in Manufacturing. If anything, he has overwhelmed the reader with citations that stretch continuously from chapters 1 to 6. He should consider writing a survey paper to capture and codify this literature.

The thesis makes important contributions in several domains:

- The creation of an integrated modeling framework, in which both engineering and manufacturing can be examined
- The integrated modeling of the product development process, which support the development of -
- Simulation based multi-parameter studies
- An approach to integrated change management
- All of this from the context of Additive Manufacturing

Some changes that would help the readability of the thesis:

There are a number of figures, for example Manufacturing system configuration figure 5.12, that need to be larger for readability.

Need to consistently use *engineering* change and *manufacturing* change (or product change and manufacturing change) but not a mixture.

In the Chapter 5 studies – each study should have a summary of objective, and a summary of result (I see results are in compiled into section 5.10). To the extent practical, each study should have a:

Figure like 5.17 at the beginning of each study – somewhat of a roadmap in DSM form

Figure like 5.18 and/or 5.21 at the end summarizing the study outcomes

Some changes that would enhance the contribution of the thesis if they could be done in the next weeks, but more likely are future work of a post-doc:

The development of a case with a task that is done in an integrated way, and then the exact same task is redone, but with EC and MC separate, so that we can see benefit of the integration.

The development of a case with AM and conventional manufacturing, so that we can see the additional benefit of AM in integrated EC/MC.

The development of a "physical validation case" – to match to either previous EC/MC models or real data.

Provisional Recommendation

X *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*