CZECH TECHNICAL UNIVERSITY IN PRAGUE
Faculty of Civil Engineering
Department of Science and Research
Thákurova 7, 166 29 Praha 6

e–mail: obhajoby@fsv.cvut.cz   tel.: 2 2435 8736

Opponent's review of the Doctoral Thesis

Candidate   Ing. Jakub Veselka

Title of the doctoral thesis   BIM Data Structure in the Building Optimization: Methodology for Model Development

Study Programme Civil Engineering – Building Engineering

Tutor   Doc. Ing. Vladimír Žďára, CSc.; Ing. Jan Růžička, Ph.D.

Opponent   Ing. Václav Venkrbec, Ph.D.

e-mail   vaclav.venkrbec@vut.cz

Topicality of the doctoral thesis theme

Commentary: The proposed dissertation deals with the issue of Building Information Model (BIM) data structure for building design optimisation, with the aim of developing a methodology for the structure of procurement specifications. The thesis also deals extensively with the environmental paradigm in the form of Life Cycle Assessment (LCA) of buildings.

The author also addresses sub-themes. In the context of digital construction, these are the areas of generative and parametric building design, the issue of Digital Twins (DT), Bill of Quantities (BoQ) in the context of Life Cycle Inventory (LCI), native and open formats, Level of Development (LOD) or the description of design phases in the perspective of BIM.

Within the environmental aspects, the author covers topics related to the scope of LCA, such as the definition of system boundaries and uncertainty, generic and EPD databases, and advanced LCA tools. Life Cycle Cost (LCC) is also briefly covered.

The combination of BIM and LCA and the definition of their rational symbiosis is a highly topical and promising issue for today's construction industry, which is more than ever challenged by the implementation of Modern Methods of Construction (MMC), including digitalisation, as well as the application of long-term environmental sustainability principles. All these areas make the work highly relevant.

☒ excellent	☐ above average	☐ average	☐ below average	☐ poor

Fulfilment of the doctoral thesis objectives

Commentary: The objectives of the thesis are clearly stated on page 23. There are 8 objectives. The division of the objectives into primary and secondary objectives is not stated, which means that all objectives should be considered equal. The objectives are preceded by 7 research questions and 2 working hypotheses, which are defined as follows:

1) A data standard that will benefit all participants in the construction process can be defined.

2) There is a growing demand for creating a methodology describing how to work with data.

The hypotheses indicate the author's holistic approach to the research problem. Furthermore, it is clear from the text and especially from the main title of the thesis that the main objective of the thesis is to " Propose a methodology for model development in various project phases".

As part of the thesis, the author has proposed a methodology in which he discusses the various project phases and aspects of building design optimisation in relation to environmental

assessment. The methodology is demonstrated through 11 case studies. The answers to the research questions and hypotheses are given in chapter 5.

It can be stated that the author has clearly understood, elaborated and answered the research questions and working hypotheses and has achieved the objectives of the thesis.

| ☐ excellent | ☒ above average | ☐ average | ☐ below average | ☐ poor |

Research methods and procedures

Commentary: The organisational structure of the thesis follows the structure of the IMRaD scientific approach. The thesis contains a relatively extensive introduction section, which provides an overview of the current state of the art in the area of research, based on the literature review carried out. This is followed by a separate chapter entitled "Proposed Methodology", which continues the previous introductory chapter and in fact extends the overview of the current state of the art. What is missing in this chapter is a more explicit definition of the methodological approach for each case study. However, it should be emphasised that some of the methods used and the process of solving the problem are framed within the individual subsections of the 'Case Studies' chapter. Indeed, the case studies chapter is a collection of specific individual applications of project-oriented applied research. In some of the research projects, including the publication of the results, the author was actively involved. These publications include a full methodological description of each case study.

The case studies should be described in more detail in terms of research methods, and the results should be listed and discussed in more detail directly in the thesis, rather than only in the referenced literature, even if these are the author's own publications.

It would have been helpful if, during the defence, the author had given a brief and concise summary of which case studies he was involved in as a co-author and which studies were only reproduced to provide a broader view of the issue.

In general, as evidenced by the benefits demonstrated in the case studies, it can be stated that the methods were chosen appropriately. The methods demonstrate the excellent scholarship and broad overview of the author of the thesis, and use a high degree of complexity within the case studies.

| ☐ excellent | ☒ above average | ☐ average | ☐ below average | ☐ poor |

Results of the doctoral thesis – dissertant's concrete achievements

Commentary: The results of the thesis are presented in two different ways. Graphs and figures for each case study represent the first part. It should be noted that the results are described rather vaguely and for each case study there is usually only a summary comparative graph, a sample of the model or an example of the software used. It is difficult to read the specific results obtained from the larger number of briefly presented case studies, as the specific values become difficult to read. The thesis does not give semi-steady results or specific calculation equations. It would have made the thesis much more transparent to provide structured and easy to read results directly in the thesis, for example in the form of appendices or data sets.

Furthermore, there is a separate chapter 'Results' in the thesis, in which the results themselves take up very little space on page 85, namely one graph (not counting the answers to the research questions, hypotheses and description of goal achievement). This length seems below average and a better structure, emphasising a similar length for all chapters of the thesis, would be helpful. Once again, it should be pointed out that the author refers to his own publications, in which the results are reported and discussed in a comprehensive manner. However, the reader of the thesis is advised to have a look at the publications of other authors in order to have a full understanding of the scope of the subject matter. This makes the thesis less compact, more difficult to verify and reproduce.

Considering the comprehensive scope of the author's work over the duration of the doctoral studies, i.e. including work on academic publications where results are presented, the author's

international academic and professional activities and efforts over the past few years can be characterised as having very useful and positive results.

| ☐ excellent | ☐ above average | ☒ average | ☐ below average | ☐ poor |

Importance for practice and for development within a branch of science

Commentary: The thesis showed that the differences between the GWP results of different building types using traditional BoQ and BoQ extracted from BIM models are relatively small, based on the results of several case studies. However, it should be emphasised that there are clear benefits and significant advantages to the use of digitisation in construction and its application to the environmental assessment of buildings, due to the efficiency of extracting BoQ from the model, the elimination of the risk of human error in automated data reading and the overall better process management in data handling.

The basic directions of optimisation techniques for building design in different phases of the project life cycle are summarised in this thesis. The author has demonstrated and clearly concluded that the most significant positive environmental benefits can be achieved when environmental issues are part of the design process from the beginning of the project and are implemented in multiple iterations in all three phases of the project life cycle.

The thesis is very practical and pragmatic in its approach and has the potential for direct application in the construction industry, which is currently increasingly being involved in the subject matter of the thesis.

It also provides a framework and defines future research directions in the field of BIM-LCA. The author mentions several projects in which he has been involved, as well as a proposal for a research project for the further development of the LCA issue for the Czech environment.

The work can serve as a basis for application in current and future construction practice, as well as further research.

| ☐ excellent | ☒ above average | ☐ average | ☐ below average | ☐ poor |

Formal layout of the doctoral thesis and the level of language used

Commentary: The work is of a sound linguistic standard and is in accordance with the applicable technical standards and other legal requirements. The author works with publications that are internationally recognised and of a recognised high quality.

There are a few occasional typing errors (Risksk instead of Risks; two identical words in a row, etc.).

Plurals such as 'we will proceed' or 'we have to determine' are often used in the thesis. It would be more appropriate to use the impersonal form in a scientific text.

Some sentences contain a lot of filler and it is difficult to find the "atomic ideas".

The English text is clear, direct, technical and logical. It is, in my opinion, grammatically correct. There are occasional references to US and UK terms (" digitalization" versus "digitalisation"). However, this does not seem to be a significant problem for understanding the text.

The thesis is comprehensive, clear, relatively straightforward and well written from a stylistic point of view.

| ☐ excellent | ☐ above average | ☒ average | ☐ below average | ☐ poor |

Statement on compliance with citation ethics

From the point of view of citation ethics, a check with iThenticate (Crossref Similarity Check) by Prof. Ing. Milan Jirásek, DrSc. without any comments.

The footnote references on pages 40 to 51 are simple web links. They should be structured according to the citation standard.

Apart from the above-mentioned points, I do not have any further reservations about the citation ethics of the thesis.

Remarks

On page 28, the author states "Pre-contract BEP and Post-contract BEP. The former is usually between the investor and the supplier of the project documentation. The latter is between the investor and the leading construction company", which is an inaccurate statement. The pre-contract BEP (or pre-BEP) is a document which is prepared before the tender and signature of the contract and is part of the tender documents for the selection of the main contractor. The Post-Contract BEP is a subsequent document that details the terms and conditions between the investor and the main contractor after the contract has been signed and is a clarification of the previous Pre-BEP document.

On page 30 the author states that "The LODs are called graphical (what the model looks like at that stage) and non-graphical (information defined in parameters within the model)". It would be useful to mention the LOI or iLOD referred to later in the text in relation to the differences between graphical and non-graphical aspects of the details. The differences between the US and UK approaches to LOD would also be beneficial.

On page 32, on Generative Design, the author states "This is an open source graphical programming software available in two variants, as a native Dynamo Studio application or as an add-on to other software such as Autodesk Revit". This should have been defined more generally, e.g. as the iterative design process now widely associated with cloud computing and AI algorithms.

Regarding the statement on page 33 that "The situation with a Digital Twin (DT) term is even more difficult and has not yet stabilised", it would be appropriate to use a definition from the Building Digital Twin Association, which states:

"The digital twin is a virtual representation of a physical manufacturing system, able to run different simulation disciplines and characterised by the synchronisation between the virtual and real system in a bi-directional manner with feed-back loops using sensed data and connected smart devices."

Source: White Paper 1: Digital Twin Definitions for Buildings (Q4 2019) Available at: https://buildingdigitaltwin.org/publications/

The definition of LCI on page 35 is very simplistic. The author moves very quickly to very specific area calculations. In particular, the procedure for carrying out LCA studies consists of four basic phases (standardised in EN ISO 14040 and EN ISO 14044). One of these is the LCI. Providing this broader context would be useful. In addition, the main principle of the LCI is not mentioned, i.e. that it is a phase of the life cycle assessment in which we identify everything that is included in the product system being assessed. All material and energy flows in and out of the product system are identified and quantified in the inventory analysis phase. This involves collecting data on the energy and material consumption of all the processes involved, as well as calculating and allocating the outflows. A set of values summarising the material and energy flows across the product system boundaries is the output of the inventory analysis. It should be noted that this set of data is referred to as the inventory profile or the eco-vector.

A weighted SWOT analysis could be used for the SWOT analysis on page 56. An explicit scoring of the results would be beneficial to make the results more explicit.

A more in-depth discussion of the results on page 85 would enhance the work. What are the implications of the graph in Figure 59?

Only GWP is used in the graph in Figure 59. Has consideration been given to the comparison of other indicators such as acidification potential (AP), eutrophication potential (EP), photochemical ozone creation potential (POCP), ozone depletion potential (ODP), abiotic depletion potential (ADP) or water depletion potential (WDP)?

Has the author considered the data structure for LCA assessment or data transfer between the BIM modelling environment and the LCA study environment and/or reimporting into the BIM environment? Does the author have recommendations for doing so, such as using specific IFC Open Format Sets?

Does the author have experience with the latest version of the IFC data format (IFC4 Add2) or with the integration of environmental impact information into the BIM environment using the PSet_EnvironmentalImpactIndicators and PSet_EnvironmentalImpactValue sets?

Final assessment of the doctoral thesis

It can be stated that the doctoral candidate approached the assigned task comprehensively regarding content and expertise. In my opinion, the methods and procedures chosen were appropriate. Minor comments and shortcomings are listed above.

The dissertation deals with highly relevant issues of digitalisation of construction in the context of sustainable construction, the work is based on applicable technical standards and other legal regulations. References are included in the thesis as bibliographic citations. These include highly relevant and influential international references. The body of the thesis is comprehensive, clear, concise and well written.

The author's refereed publications are of a very good quality and include upper quartile JCR WoS influential journals (Journal of Cleaner Production, Sustainability). The author has a Web of Science h-index of 3 and WoS citations show regular year-on-year growth.

The author has demonstrated the ability to independently solve the research problem, understand the issue, conduct a systematic literature search, define research methods and objectives, appropriately present and discuss the results, and structure the conclusions of new knowledge. The author has demonstrated the ability to work independently in all aspects of the creative process of scientific research. The author has demonstrated his own intellectual capacity to solve research problems and to translate the knowledge gained into real results that can be used not only by professional researchers but also by the general public.

Having examined the scope, content, quality and degree of attainment of the objectives of the dissertation in accordance with the professional qualifications attained in the work submitted, I am of the opinion that the dissertation submitted by Ing. Jakub Veselka clearly meets the standards generally required for the degree of Doctor of Philosophy. Therefore, I recommend the submitted doctoral dissertation for defense.

Following a successful defence of the doctoral thesis I recommend the granting of the Ph.D. degree

yes ☒   *no* ☐

Date:

5. 6. 2023

Opponent's signature:..