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THE IMPORTANCE OF A TRANSPORT INFRASTRUCTURE CONSTRUCTION FOR THE IMPLEMENTATION OF BIM

Petr Matějka[1]*

[1] Department of Construction Management and Economics, Faculty of Civil Engineering, CTU in Prague, Thakurova 7/2077, Prague 166 29, Czech Republic

Abstract

The paper focuses on the topic of the transport infrastructure construction – mainly highway construction - when dealing with implementation of the Building Information Modeling (BIM) in the construction market. Transport infrastructure construction sector plays a very important role in the construction industry, especially for public sector, where infrastructure makes up an important share of all funds dedicated for construction projects. When BIM tools are used, the one who usually benefits the most is the owner. Therefore a public sector as a main transport infrastructure construction investor should benefit from the use of BIM. In spite of that, when BIM implementation is being discussed in literature, on the internet or in marketing materials, the discussion is mainly about using BIM in building construction. Since a successful implementation of BIM in the market usually requires support from the public sector, transport infrastructure construction is the sector where BIM implementation should be supported. Public sector usually benefits a lot from the better transparency of BIM. This article examines the topic of BIM implementation in public sector transport infrastructure. It explains the possibilities of BIM use in transport infrastructure construction projects and it verifies the importance of transport infrastructure construction projects for a public sector on a case study of the Czech Republic. It explains not only how transport infrastructure sector may benefit from the use of BIM, but also how the use of BIM in transport infrastructure projects may impact the process of implementation of BIM in the market.

Key words

BIM; building information modeling; highway construction; implementation; public sector; transport infrastructure

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*Corresponding author: Tel.: +420-607-803-814
E-mail address: petr.matejka@fsv.cvut.cz

1 INTRODUCTION

Construction market is very complex and consists of many different construction projects. Project types, however, can be divided into some basic categories, such as:

- Building Structures (Houses, Administrative buildings, Sky-scrapers, etc.)
- Civil Engineering Infrastructure (Transport infrastructure - Road structures and Railway Structures, Mains – Water, Sewage, Gas, Electricity, etc.)
- Special Structures (Hydraulic structures, Power plants, Airports, etc.)

Building Information Modeling (BIM) is considered a modern tool, framework or process for civil engineering. The whole concept is often oriented on building construction, but as already said, construction market does not consist only of buildings. This paper focuses on the possible use of BIM in transport infrastructure, specifically in highway construction. It is aimed at the following goals:

- Review of BIM-oriented literature with regard to transportation infrastructure construction, mainly highway construction
- Examining possible use and impact of BIM on transport infrastructure construction projects
- Explanation of the importance of transport infrastructure in a market
- Description of the importance of transport infrastructure for the implementation of BIM in the market

2 LITERATURE REVIEW

There are numerous books focused on promotion or explanation of BIM. The most important one is Eastman's BIM Handbook [1], which describes the BIM concept thoroughly, but does not pursue the topic of the transport infrastructure. Then there are other publications like Epstein's Implementing Successful BIM [2], Jernigan's BIG BIM little bim [3], Smith's and Tardif's Strategic Implementation Guide [4] or Race's BIM Demystified [5], oriented on implementation process of BIM. More specialized books are often oriented on a specific field of BIM, such as Reddy's BIM for Building Owners and Developers [6], Teicholz's BIM for Facility Managers [7], Deutsch's BIM and Integrated Design [8], Weygant's BIM Content Development [9], Krygel's and Nies's Green BIM [10], etc. These books usually focus on a specific profession during construction project process. There is no literature dealing specifically with BIM and transport infrastructure. In the mentioned sources, case studies are often presented. Nevertheless, out of a total of 27 case studies, only 1 describes a transport infrastructure project (Crusell Bridge [1]).

Scientific papers deal with the topic of BIM and transport infrastructure very scarcely. There is Sibert's short article about using BIM on highway project in south Wales [11], where BIM has been utilized for visual planning, GPS control, communication improvements, change management, etc. [12]. Other papers focus on bridges, like [13], where parametric data exchange is described, [14], explaining the use of Virtual Prototyping Simulation for better planning during design and construction, or [15], where case study of a 4D process is presented. There is also an article [16], dealing with the topic of BIM in the highway construction projects in general, but it mainly focuses on visualization and 4th dimension for scheduling and traffic planning, but this article is already outdated.

The internet and non-scientific sources are much richer in content. Although these are mainly oriented on building construction, it is possible to find articles, which are dealing with the transport infrastructure projects. There are not many sources focused on the traffic infrastructure in general, but it is possible to find much information about highway and bridge construction. These are usually case studies, like [17], where BIM was mainly used for clash detection and collaboration. Sometimes it is possible to find an explanation of how BIM can be used in transport infrastructure construction, like in [18] or [19]. There is also a very interesting article [20], where BIM use in the transport infrastructure is explained more as an Integrated Project Delivery (IPD) workflow, which is very important, because that is why BIM approach is innovative even for transport infrastructure construction, where "*3D visualization and analysis is nothing new*" [20]. The internet sources are moderately rich, although when BIM is searched for, in most cases it is connected with building structures, not with the transport infrastructure. Interest in the use of BIM is rather high in the field of transport infrastructure.

Platt also presents a very interesting report on use of 4D CAD for highway construction projects [21]. The report tries to answer the question "*what are the best applications of 4D CAD for highway construction projects*" [21] using a case study application. This report provides a very thorough and comprehensive analysis of given problem, mentioning that "*4D CAD for highway construction projects have not been adequately researched or defined in academic or industry research*" [21]. Although 4D CAD modeling is not BIM, it is a step forward from 2D and 3D drawings.

3 METHODOLOGY

The main research is based on the literature review. There are four literature sources used in this paper. These are:

- Current world-wide recognized scientific papers
- Current world-wide technical literature
- Current internet sources
- Local sources

Local sources are used mainly for a case study of local environment. For the purpose of this paper, a case study of Czech Republic was used. This case study can be found in chapter 4.3 and it is based on statistical data from 2013 and 2014. Other sources are mainly used in chapters 2, 4.1 and 4.2 for the explanation of BIM and transport infrastructure correlations. Deductive and synthetic methods are then used to achieve goals mentioned in the beginning of this paper.

The research goals target future period of construction industry. They are focused on the market, where BIM is not already supported by government strategies and where it is not common to use these methods in construction projects. For example, such countries are countries in the middle and east Europe like Czech Republic, Slovakia, Hungary, Poland, Croatia, Russia etc., but goals can be applied even to countries where BIM is already more common, like Germany or France. Results presented in this paper are highly dependent on market and legal environment and also on public sector structure and financing scheme. The paper uses current literature and statistical sources to suggest importance of BIM in transport infrastructure and to explain correlations between these two.

To justify the paper, following statements were considered generally true in 2014:

- When used correctly, BIM has positive impact on transparency, productivity and efficiency during whole project life cycle [1], [2], [7].
- Owner benefits from the proper use of BIM in most cases [7].

- The demand of BIM from clients is mandatory for its successful implementation [1].
- The public sector is often the biggest, and therefore a very important, client in the market.
- The public sector governs transport infrastructure construction projects and is either legally or proprietary responsible for their realization or operational phase.

In the environment where these statements are not true, the research may not be reproducible and results may not be valid.

Deductive and synthetic research is based on three pillars:

- Implementation of BIM in the market.
- BIM in transport infrastructure construction projects.
- Importance of transport infrastructure construction projects for a public sector

These pillars are discussed in the following chapter.

4 BIM AND TRANSPORT INFRASTRUCTURE

This chapter is divided into the three different subchapters. Each of them has an unequivocal goal to achieve.

4.1 Implementation of BIM in the market

The implementation of BIM is a complex process. It is very important to define the goal and conditions of implementation. This especially means what the role of BIM in given situation actually is (i.e. how BIM is defined and what exactly is covered by this term – whether it is a tool, a process, a workflow, a methodology, an adoption of specific standards, etc.) and what the final conditions are when the implementation of BIM is considered finished (i.e. specific tool used in a company, 75% deliver in required standards, etc.)

For the purpose of this article, the implementation of BIM in the market was examined. The definition of BIM in this case is not simple, especially because the whole concept of BIM is constantly developing and will develop further in the future. We can stick with the concept of BIM as defined by the NBIMS-US [22]: *“A BIM is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward.”* [22]

For the purpose of this article, the implementation of BIM means using tools, methods and workflows, which together are considered as BIM. Because of the dynamic nature of what BIM actually is, it is important to look at the implementation as a never ending process. While it is not possible to state whether BIM has been fully implemented, it is possible to identify steps that need to be taken for further BIM implementation and it is also possible to compare and further analyze the degree of the implementation in, for example, different companies. It is not necessary to examine only construction companies. The implementation of BIM may be examined in different systems, like in a national markets, construction branches, etc.

The goal of this subchapter is to examine the role of public sector in the process of BIM implementation.

When speaking about the implementation of BIM in a market, more key indicators can be identified, compared to the implementation of BIM into a construction company (such as implementation into legislation, public knowledge, education, etc.). Many of these indicators are dependent on the support from the public sector (i.e. state). Although this support is not mandatory and it is not necessary for BIM to be implemented in a construction company, it is very influential. That is especially because of a legal issues (i.e. building permit, commercial codes, public contracting, etc.) and because of how public sector can boost innovation. This may easily be examined on various case studies from countries, where BIM has been already supported by government, such as Singapore (Singapore BIM Guide) [23], the USA (National BIM Standard) [22], the United Kingdom (Government Construction Strategy) [24] or Finland (Common BIM Requirements) [25]. It is especially important in case of public contracts, because public sector has both the opportunity to require the use of BIM in its contracts, and the ability to establish environment, in which BIM will continue to be used (i.e. can support or require use of BIM, can issue standards, etc.) There is also a major public sector interest for BIM to be implemented, since some of the biggest advantages of using BIM are better transparency, and effective collaboration. These advantages are most important in large construction projects with many stakeholders, which public financed projects usually are.

The public sector support of BIM seems to be crucial for its successful implementation in short time horizon (less than 5 years). Countries, where BIM is not supported by state, are usually struggling with its implementation, which is limited to only few local progressive companies or local daughter companies of international or foreign mother companies that already use BIM.

4.2 BIM in transport infrastructure construction projects

Based on the literature review, it might seem that there is almost no connection between BIM and transport infrastructure. The goal of this subchapter is to briefly examine the actual and possible use of BIM in transport infrastructure construction projects.

To explain, it is important to understand some basic BIM concepts and abbreviations. The first one is CAD, which stands for Computer Aided Design. CAD, put simply, is any use of computer technology for designing construction projects. These might be computer tools, like AutoCAD. The next essential abbreviation is 3D CAD, which stands for use of 3D modeling in design projects. With a 3D model, it is possible not only to better visualize the project, but also to create specific quantity takeoffs. Then there is the fourth dimension, which adds more information into the model. It allows us to parametrically add time stamp to model objects [26]. 4D CAD therefore expands possibilities of the model by allowing users to connect it with time schedules. Then there are other dimensions like money (5D) and other information, mainly used in operating phase of the project (6D+). The important question is, where the place of the BIM in this multidimensional CAD environment is. The answer is pretty simple. The difference between BIM and multidimensional parametric object-oriented modeling is in the workflow. When XD CAD displays merely the existence of a model, BIM provides its users with the framework of how to use this model, how to share it, how to cooperate during its creation, etc. Everything is simply explained on the famous Bew-Richards diagram (so called Wedge diagram), which shows different BIM maturity levels and where the added value of BIM is, opposed to simple multidimensional modeling (can be found for example in [27], but there are many more sources – it is not clear where the diagram was originally published). Speaking about workflow, another abbreviation comes into play. It is Integrated Project Delivery (IPD). The IPD concept is much older than BIM. It is an "*approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design, fabrication and construction*" [28]. This basically means that the sooner we plan, and the more people collaborate during these early stages, the better the results may be. That is where BIM actually widens the world of simple multidimensional modeling.

There are some common misconceptions about BIM in the public knowledge. One of these is a belief that 3D is BIM [26]. This is not necessarily the case. The meaning is, that BIM is more than just an existence of the model. How we actually use it and how we are able to utilize its possibilities are very important preconditions towards its usefulness. When talking about transport infrastructure, the use of 3D is already common and many other CAD dimensions are used too. That's why (at some points) transport infrastructure construction is far beyond the stage where BIM is something completely new. Many software tools are BIM ready by now (the most widely known of these are Autodesk Civil 3D and Bentley Microstation / InRoads Suite). As was already explained, the main possible advantage, which BIM may bring to transport infrastructure projects, is the new workflow. Unfortunately, this issue has not been properly described. BIM workflow has already been partly applied in highway construction, especially for construction of bridges, but it is not common. The key aspects of BIM workflow in transport infrastructure projects are:

- Better use of object-oriented parametric models for facility management, digital fabrication and changes management.
- Higher degree of collaboration during whole project life cycle, especially between owner, contractor and designer (possible design-build and PPP project procurement).
- Application of IPD concept.
- Possible use of automation tools (quantity takeoffs, laser scanning and land surveys, GPS tracking, etc.)

There are also other issues specific for transport infrastructure construction while implementing BIM. For example issues like public sector specifics, legal issues, contracting issues, different approach to construction, etc. It is not the point of this article to explain these thoroughly. The point is to prove that the use of BIM in transport infrastructure construction is possible, although it requires some alterations to the classical BIM concept used in building construction, because of the different nature of mentioned fields.

4.3 Importance of transport infrastructure construction projects for a public sector

Transport infrastructure is one of the most important public assets. The manner of managing transport infrastructure varies a lot, depending on the type of infrastructure and country. In this paper, a case study of the Czech transport infrastructure will be used. The goal of this subchapter is to prove that transport infrastructure is considered important and that it operates with a considerably high amount of money, therefore potential savings should be substantial.

Financing transport infrastructure is not simple. Its cash flow has many different sources and it is not easily deduced which source money paid for which particular part of a construction. Nevertheless, to give some scope, basic data from the Czech Republic will be provided. It is also not necessary to provide exact data to prove the point of this subchapter, therefore amounts were rounded to whole millions. The exchange rate for Czech crowns (CZK), Czech Republic's currency, was considered 28 CZK per euro (€).

In 2014 total capital investments from the Czech Republic budget is going to be around 2 643 mil. € [29]. The Czech Republic has a population of around 10,5 mil. people [30] with GDP per capita 13 563 € in 2014 [31]. The State Fund for Transport Infrastructure (SFDI) considers total income and expenses of around 1 536 mil. € in 2014, of which around 657 mil. € will be covered from state budget [32]. That is around 43% of total SFDI expenses and it is around 25% of total Czech capital investments. Please note there are also other source of financing, which are not mentioned here (EU funds, highway fees etc.) It is also important to understand that that this does not have to necessarily mean that capital investments fund is the source to cover these expenses – it was mentioned just to demonstrate the amount of public money invested into transport infrastructure. Nearly entire SFDI budget is used to finance transport infrastructure projects, mainly road infrastructure with around 975 mil. €, and railroad infrastructure with around 640 mil. € [32]. Please note that only highway and speedway constructions are governed by the state in the Czech Republic - smaller roads are governed by local municipalities and financing scheme is different, so they are not included. Expected costs of repairs and maintenance of highway and speedway constructions in 2014 is around 489 mil. €, which is around 50% of the whole budget for highway and speedway constructions mentioned above. The remaining money is used mainly for new construction [32].

Data presented in this subchapter are very trivial and more detailed description is needed to explain the whole very complicated financing system thoroughly. The point of this subchapter is not to explain the financing system, the point is to outline the basic amounts of public funds invested into transport infrastructure. Based on the numbers presented, it is obvious that potential savings in highway and speedway constructions could be huge. Not only because these are considered expensive investments, but also because the Czech Republic is also owner of all highways and speedways and is therefore responsible for their operating phase. It should be state's considerable interest to achieve lower costs and better efficiency especially during:

- Preparation and construction phase of the project by utilization of IPD approach.
- Operating phase by utilization of IPD approach and by integration of information models into procurement and facility management processes.

Because of long lifespan of highway structures, operating costs usually constitute a major share of total costs during the project life cycle. Proper maintenance system is very important [33] and this is where BIM models can become useful too.

5 RESULTS AND DISCUSSION

In the previous chapters, detailed literature review on the topic of possible use of BIM in transportation infrastructure has been provided. This review shows that although the topic of parametric object oriented modeling is not new in transport infrastructure construction projects, the connection with BIM, which is mostly used for building construction, has not been thoroughly considered or described yet, especially from the scientific perspective.

As the option of BIM usage was acknowledged, the paper further discussed the definition of BIM implementation. It focused mainly on the implementation of BIM in the market and described the important role of public sector during this process. The possible use of BIM in transport infrastructure projects is then explained. The article showed that even though BIM is actually not common in transport infrastructure, many BIM concepts are already being used (especially some parts of n-dimensional and parametric modeling) and there is a development towards adopting BIM workflow. When properly utilized, BIM workflow may hugely and positively affect the efficiency and quality of transport infrastructure projects. The monetary importance of transport infrastructure construction projects is then shown on the case study of the Czech Republic. Possible savings in such publicly financed projects may have serious positive impact.

As a result, following statements can be made:

- The literature dealing with the topic of implementation of BIM in transport infrastructure construction projects is weak, and can be improved.
- Public sector plays an important role during the process of the implementation of BIM in the market. Public sector support is often considered as mandatory for the implementation of BIM in the market.
- It is possible to use BIM concepts in transport infrastructure construction projects, although because of differences between these projects and typical building construction projects makes the use of BIM limited mostly on adopting BIM workflow.
- Public transport infrastructure investments can be considered substantial and therefore possible savings during whole life cycles of these project could be of high priority.

As explained in the chapter focusing on the literature review, there is not sufficient information about possible correlation between transportation infrastructure construction projects and the implementation of BIM in the market. The research presented in this article explains the basic relationships between these fields. Further research is needed, though. To provide better understanding of the problem, following topics should be examined:

- Current practice of BIM use in transport infrastructure construction worldwide, and case studies of the best practice (i.e. tools used, workflows, benefit analyses, possible improvements, etc.)
- Methodology and terminology development of BIM application for specific types of transport infrastructure constructions (i.e. use of BIM for bridge construction, use of BIM for highway construction, use of BIM models in highway operating phase and maintenance, etc.)
- Analysis of country specific obstacles for BIM concepts implementation into transport infrastructure projects (i.e. contracting, legal obstacles, financing, etc.)

This research is very complicated because of lack of usable data and almost impossible generalizations, due to national market differences and construction projects uniqueness. The most common problem is that information and experience from case studies is hard to transfer to different projects. And, on the other hand, too superficial, general information is hard to apply into practice.

It is very important to understand that construction industry consist of many different fields, which may all benefit from BIM somehow. Better BIM propagation in these fields would be very useful not only to these branches, but could help the implementation of BIM in general.

6 CONCLUSION

The literature review and the statements in methodology and results chapters of this article lead to the following conclusion:

The implementation of BIM in the market is beneficial, especially for the owner. It is therefore owner's interest to support the implementation of BIM in the market. Of all the owners, the public sector (state) is the one with extended possibilities to affect the implementation process of BIM in the market. This can be done by the means of large scale contracts, such as transport infrastructure construction projects. Although BIM is mainly oriented on the building projects, it is possible to utilize this approach in transport infrastructure project too. The adoption and propagation of BIM in transport infrastructure projects (mainly in highway projects) may positively impact the implementation of BIM in the market on a national level. This may lead not only to possible savings in transport infrastructure, but also to possible savings in other publicly financed (and also commercial) construction projects.

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REFERENCES

[1] Eastman, C. et al. (2011). BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, *Designers, Engineers, and Contractors*. John Wiley & Sons, Inc. ISBN 978-04-7054-137-1.

[2] Epstein, E. (2012). *Implementing Successful Building Information Modeling*. 2nd ed. Artech House. ISBN 978-16-0807-139-5.

[3] Jernigan, F. E. (2008). *BIG BIM little bim - Second Edition*. 4Site Press. ISBN 978-09-7956-992-0.

[4] Smith, D. K. a Tardif, M. (2009). Building Information Modeling: A Strategic Implementation Guide for Architects, Engineers, *Constructors, and Real Estate Asset Managers*. John Wiley & Sons, Inc. ISBN 978-04-7025-003-7.

[5] Race, S. (2012) *BIM Demystified*. 2nd ed. London: RIBA Publishing. ISBN 978-18-5946-373-4.

[6] Reddy, K. P. (2012). *BIM for Building Owners and Developers: Making a Business Case for Using BIM on Projects.* John Wiley & Sons, Inc. ISBN 978-04-7090-598-2.

[7] Teicholz, P. (2013). *BIM for Facility Managers*. John Wiley & Sons, Inc. ISBN 978-11-1838-281-3.

[8] Deutsch, R. (2011). *BIM and Integrated Design: Strategies for Architectural Practice*. John Wiley & Sons, Inc. ISBN 978-04-7057-251-1.

[9] Weygrant R.S. (2011) *BIM Content Development: Standards, Strategies, and Best Practices*. John Wiley & Sons, Inc. ISBN 978-04-7058-357-9.

[10] Krygel E., Nies, B. (2008). *Green BIM: Successful Sustainable Design with Building Information Modeling*. Wiley Publishing, Inc. ISBN 978-04-7023-960-5

[11] Sibert, B. (2013). Using building information modeling on a highway project. *Proceedings of the ICE – Civil Engineering*, **166**, pp. 9-9. Available at: http://dx.doi.org/10.1680/cien.2013.166.1.9

[12] Carilion A465 Road Project, Synchro Ltd., Available at: http://synchroltd.com/carillion-a465-road-project/ (accessed 19 May 2014)

[13] Karaman, S.G., Chen, S.S. and Ratnagaran, B.J. (2013). Three-Dimensional Parametric Data Exchange for Curved Steel Bridges. *Transportation Research Record*, **2331**, pp. 27-34. Available at: http://dx.doi.org/10.1108/10.3141/2331-03

[14] Li, H., Chan, N.K.Y., Huang, T., Skitmore, M., Yang, J. (2012). Virtual prototyping for planning bridge construction. *Automation in Construction*, **27**, pp. 1-10. Available at: http://dx.doi.org/10.1016/j.autcon.2012.04.009

[15] Zhou, C. and Wang, W. (2009) Highway Bridge Construction Process Simulation Base on 4D Visualization. A*sphalt Material Characterization, Accelerated Testing, and Highway Management*. pp. 138-145. Available at: http://dx.doi.org/10.1061/41042(349)18

[16] Liapi, K.A. (2003). 4D Visualization of Highway Construction Projects. *Seventh International Conference on Information Visualization*. **4**, pp. 639. http://dx.doi.org/10.1109/IV.2003.1218054

[17] rics.org/bim (2012). A Model Solution. *Modus*, **3**, pp. 34-37. Available at: http://edition.pagesuite-professional.co.uk/launch.aspx?referral=mypagesuite&pnum=&refresh=5Fx1M04m3Kf0&EID=7be24f3c-a83b-43e4-b80d-43856b0593a4&skip= (accessed 19 May 2014)

[18] BIM for Infrastructure, ConstrucTech. Available at: http://www.constructech.com/news/articles/article.aspx?article_id=9054 (accessed 19 May 2014)

[19] Miyamoto, M. (2013). *BIM Workflow for Roads and Highways*. Available at: http://ideatesolutions.blogspot.cz/2013/10/bim-workflow-for-roads-and-highways.html (accessed 19 May 2014)

[20] Strafaci, A. (2008). *What does BIM mean for Civil Engineers?* Civil + Structure Engineer Site. Available at: http://www.cenews.com/article/6098/what_does_bim_mean_for_civil_e (accessed 19 May 2014)

[21] Platt, A. (2007). 4D CAD for Highway Construction Projects, Computer Integrated Construction Research Program. Available at: https://www.engr.psu.edu/ae/cic/publications/TechReports/TR_054_Platt_2007_4D_for_Highway.pdf (accessed 19 May 2014)

[22] *National Building Information Modeling Standard – United States Version 2*, National Institute of Building Sciences. Available at: http://www.bim.org.tw/.%5CThesisFile%5C20120629001%5CNational%20BIM%20Standard-United%20States%20Version%202.pdf (accessed 21 May 2014)

[23] Singapore BIM Guide, Version 2, *Building and Construction Authority*. Available at: http://www.corenet.gov.sg/integrated_submission/bim/BIM/Singapore%20BIM%20Guide_V2.pdf (accessed 26 May 2014)

[24] Government Construction Strategy, *Cabinet Office*. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/61152/Government-Construction-Strategy_0.pdf (accessed 26 May 2014)

[25] Common BIM Requirements 2012, *BuildingSMART Finland*. Available at: http://www.en.buildingsmart.kotisivukone.com/3 (accessed 13 Jul 2012)

[26] Matějka, P. et al. (2012). *Základy implementace BIM na českém stavebním trhu*. Fineco. ISBN 978-80-8659-010-3.

[27] Sinclair, D. (2012). *BIM Overlay of the RIBA Outline Plan of Work*, Riba publishing. ISBN 978-18-5946-467-0. Available at: http://www.bdonline.co.uk/Journals/2012/05/15/d/x/f/BIM_Overlay_RIBA_Plan_of_Work_Embargoed.pdf (accessed 20 May 2014)

[28] *Integrated Project Delivery: A Working Definition, Version 2*, AIA California Council. Available at: http://aiacc.org/wp-content/uploads/2010/07/A-Working-Definition-V2-final.pdf (accessed 20 May 2014)

[29] Zeman, M. (2014). *Státní rozpočet 2014 v kostce*. Ministry of Finance of the Czech Republic. Available at: http://www.mfcr.cz/assets/cs/media/Informacni-letak_2014_Statni-rozpocet-v-kostce_II.pdf (accessed 20 May 2014)

[30] *Population*, Czech Statistical Office. Available at: http://www.czso.cz/eng/redakce.nsf/i/population (accessed 20 May 2014)

[31] *Czech Republic: Gross domestic product and Gross domestic product per capita report for 2014*, International Monetary Fund. Available at: http://www.imf.org/external/pubs/ft/weo/2014/01/weodata/weorept.aspx?sy=2014&ey=2014&scsm=1&ssd=1&sort=country&ds=%2C&br=1&pr1.x=39&pr1.y=17&c=935&s=NGDP_R%2CNGDP%2CNGDPRPC%2CNGDPPC&grp=0&a= (accessed 20 May 2014)

[32] Čoček, T. (2013). *Rozpočet Státního fondu dopravní infrastruktury na rok 2014 a střednědobý výhled na roky 2015 a 2016*. Státní fond dopravní infrastruktury. Available at: http://www.sfdi.cz/soubory/obrazky-clanky/dokumenty-2013/2013_rozpocet2014.pdft (accessed 19 May 2014).

[33] Kendrick, M., Taggart, A. (2006). Delivering well-maintained highways. *Proceedings of the ICE – Municipal Engineer*, 159(2), pp. 97-104. http://dx.doi.org/10.1680/muen.2006.159.2.97