Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences
Graduation Plan: All tracks

The graduation plan consists of at least the following data/segments:

<table>
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<tr>
<th>Personal information</th>
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<tr>
<td>Name</td>
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<tr>
<td>Student number</td>
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<td>Telephone number</td>
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| Argumentation of choice of the studio | During my Minor in the Bachelor I did an internship. For this internship I went to one of the big contractors in Netherlands. The project they were working on was a large new premises for a European anti-crime organisation. This project had entered the construction phase and the team was mostly busy with the engineering of the different parts (werkvorbereiding) and the procurement of subcontractors. Within this project they made use of a Building Information Model (BIM). 

During this internship I found that the model was mostly used for the extraction of quantities. Most of the time this was not possible, because of the lack of embedded information. A small planning simulation of different components was made, even after the components where already built. The organisation of the site was put in to the model, to check whether the specified crane locations were right. Some might say that the model was mostly made because the client specified it.

After having seen the use of BIM in this project, my thoughts went out to what could be improved to further reveal the added value of such a model. Not only the added value in the calculation of cost, but the organisation on the jobsite itself as well.

A large part of the budget within the construction industry is the expenses on labour, whilst the productivity in construction is rather low. This raises the question in which way BIM can help to improve the labour productivity on construction sites. In special what the added value is in terms of costs for the contractor and its subcontractors if BIM is used to plan, arrange and place different components.

Whilst the bachelor is mostly focused on the design of the built environment my interest went out to the construction phase itself. The master programme gave more insight about the construction phase and organisation. Nevertheless, the costs calculation in
construction drew my attention. This together with the possibilities of BIM that are not used at its full potential in the construction industry as yet.

<table>
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<th>Graduation project</th>
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<td><strong>Title of the graduation project</strong></td>
<td>Increasing labour productivity by building information modelling</td>
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<td><strong>Location:</strong></td>
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<td>The posed problem, research questions and design assignment in which these result.</td>
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**Problem introduction**

Labour productivity in the construction industry is low. With labour productivity on construction sites between 40 and 50% it is relatively low compared to other industries (Aziz & Hafez, 2013; Forbes & Ahmed, 2011; Platform Logistiek in de Bouw, 2014). Meaning that 50 to 60% of the work executed is seen as unproductive. Whereas, in the Dutch construction industry labour takes up 40 to 60% of the total construction costs and is therefore one of the largest expenses (Nasirzadeh & Nojedehi, 2013; Platform Logistiek in de Bouw, 2014). This becomes even more evident when only 25% of the construction costs are used for the materials (Platform Logistiek in de Bouw, 2014). The improvement of labour productivity can have advantages for the competitiveness and profit of contractors and lead to lower costs for the clients (Eastman, Teicholz, Sacks, & Liston, 2011). Therefore, labour productivity can be of great importance in establishing the financial success of construction projects (Jarkas, 2010).

The low labour productivity has multiple causes. Problems that contribute to this low labour productivity are for a large part labour related to waste and inefficiency of labour, materials and controls, which is between 25-50% of the construction costs. Problems as too much construction workers into a confined space; movements of construction workers on construction sites that are not necessary or materials that are not placed in an efficient manner (Alarcon, 1997; Aziz & Hafez, 2013). Or problems related to the bad supervision of construction workers (Aziz & Hafez, 2013; Loera, Espinosa, Enríquez, & Rodriguez, 2013). These examples of problems contribute to the low productivity on construction sites.

**Problem statement**

Within the last paragraph different problems are named contributing to the low labour productivity in the construction industry. The problems presented causing the low labour productivity are mostly related to time and place flaws. Different solutions can be found to solve these problems. An important aspect of the research of TKI Dinalog and NWO (2016) is the innovation in the chain management which entails the integration of logistical information and mathematical models in building information models. Currently building information models are mostly used in the design and engineering phase of the project. In which it combines the data of different parties into one model. 4D building information model provide the link between space and time (Eastman et al., 2011). As 3D building information models offers the possibility to be converted to a 4D model, it can help to solve parts of the problems. In a 4D building information model the 3D data is linked to the schedules of the different parties involved within the construction project (Eastman et al., 2011). This considers the sequencing of the different building elements in chronological order.

Nevertheless the labour that is actually needed to place the different building elements on site is not added to the 4D building information model. By actually adding the labour needed to place these building elements in the 4D building information model too, this factor can be analysed and visualised. Which helps to enlarge the insight of labour on the construction site and search for potentials for interventions. Wherefrom, interventions can be made to make the construction process more efficient and increase the labour productivity.

**Research questions**

As this research focuses on how a 4D building information model can contribute to a higher labour productivity on construction sites, the main research question is as follows.
To what extent does the modelling of labour and movement of workforce into a 4D building information model have the ability to give insight into and indicate potentials to increase the labour productivity on construction sites.

This research question consists of two parts. The first part introduces to the ability of modelling labour and movements of workforce in a 4D building information model. Second, how can this 4D building information model (BIM) contribute to a higher labour productivity on construction sites.

The conceptual model presented in Figure 1 shows an abstract flow of information necessary to give insight in the labour productivity when labour and movements of workforce are added to a 4D BIM. The focus of this research lies within the implementation of labour and movements of workforce into a four dimensional BIM to provide insight and potentials for a higher labour productivity. The different parts of the research will be divided into sub-questions.

- What is the definition of productivity?
- Which data is needed from all parties to be integrated into a 4D Building Information Model?
- How to accurately model the data into a 4D Building Information Model with labour and movements of workforce?
- What are the possibilities of visualising the data into a 4D Building Information Model with labour and movements of workforce?
- How to model interventions into a 4D Building Information Model with labour and movements of workforce?
- What is the simulated change in productivity?
- Can this simulated change in productivity be proved by the physical project?

Research goal
As described in the introduction making the labour and movement of workforce on construction sites more productive can be described as the aim of this research. The final product will be a framework consisting out of two parts.

The first goal, provide insight into labour and movement of workforce with a 4D building information model. This focuses on how to model and visualise the element of labour and movements of workforce into a 4D building information model. The final product of this part will be the framework
in which the labour and movement of the workforce can be added to the 4D BIM. A framework that describes which data from different parties is needed to properly model the labour and movement of workforce; how to accurately model this into the 4D BIM; and how this can be visualised within this 4D model.

The second goal, provide insight and indicate potentials with this 4D building information model to increase the labour productivity on construction sites. This part focuses on how this 4D building information model can contribute to a higher labour productivity on construction sites. The product of this part will focus on the framework provided in the first part. It provides a framework how an intervention that might increase the labour productivity can be modelled; and how to gain insight in the simulated change in labour productivity. Which will be validated by a physical project in the form of interviews with the project team.

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**Study design**

For the collection and analysis of data a framework is needed which is provided by the research design (Bryman, 2012). The exploratory design is chosen to conduct this research. According to Fellows and Liu (2015) the exploratory design is to test, or explore aspects of a theory. A central feature within this design is the use of hypotheses. Either an hypotheses is set up and then tested via research (data collection, analyses, interpretation of results) or a complex array of variables is identified and hypotheses are produced to by tested by further research (Fellows & Liu, 2015). The latter is the one that applies to this research. As this research look into the extent in which a 4D building information model can provide insight in labour and movements of workforce and can help to indicate potentials for the increase of labour productivity, further research has to find out what the actual change in labour productivity when this framework is applied.

According to Fellows and Liu (2015) the empirical design of a exploratory research can be either a case study or field study. An exploratory case study is theory-driven as the theory acts as a guide to tell you where to look for what you want to observe (Fellows & Liu, 2015). The empirical design of this research is a case study. Because the theoretical framework that largely derived from an in-depth literature study, provides the theory behind the research. This theoretical framework acts as a guide for which variables to collect, adopt and analyse. The case used within this research is the construction of the ‘Noordgebouw’ in Utrecht, which will be elaborated in paragraph 4.4. Since this research is mainly focussed onto a single construction project and does not provide concrete number, qualitative research is chosen as the overall strategy.

**Sub question 1**

*What is the definition of productivity?*

**Deliverables**

The deliverables for this sub questions can be divided in three parts: One, an equation of labour productivity that is based upon literature; Two, the definition of the elements of which the equation is built up; three, and overview of how lean construction contributes to labour productivity. The main deliverable is therefore an equation enriched with the information needed to fill in the equation.

**Method**

The method for this sub question is literature review. Literature is used for the three different deliverables. For part one and two literature on productivity and labour productivity is used. For part two more specific literature is used that describes differences between value and non-value adding activities. For the third part literature is used on lean construction.

**Sub question 2**

*Which data is needed from all parties to be integrated into a 4D Building Information Model?*

**Deliverables**

The main deliverable is an overview of all information that needs to be present to be able to implement labour and movements of workforce into 4D BIM. This deliverable can be divided into two parts. One, an overview of the existing 4D BIM applications of how they are built up and which information is needed. Two, an overview of the information that needs to be added to the 4D BIM that is specifically used to model labour and movements of workforce in 4D BIM.
Method
The method for this sub question is literature review and exploration. Part one of the deliverables derives from a literature study. Literature about 4D BIM is used that described the process of making the model and how it is used in practice. Part two will be partially based on literature. Literature is used that describes the use of 4D BIM with additional features. Within the exploration the literature about 4D BIM and productivity is used to define the specific data, and explore if additional data is needed.

Sub question 3
*How to accurately model the data into a 4D Building Information Model with labour and movements of workforce?*

Deliverables
The deliverable for this research question is a framework that combines the results given from research question one and two. It provides a framework of how to accurately model labour and movements of workforce. This framework needs to provide insight in how the data provided in sub question two could help to calculate the labour productivity.

Methods
The method used for this research question is exploration and modelling. The data extracted from sub question one and two needs to be combined. Within this exploration calculations are made which will be modelled into 4D BIM with the data provided in question two to give the results needed for question one.

Sub question 4
*What are the possibilities of visualising the data into a 4D Building Information Model with labour and movements of workforce?*

Deliverables
The deliverable for this research question is a framework of how the labour and movement of workforce can be visualised.

Methods
The method used for this modelling and simulation. The data needed to visualise the labour and movement of workforce is modelled in the 4D BIM. Accordingly the simulation is made which visualises the labour and movement of workforce and calculates the labour productivity.

Sub question 5
*How to model interventions into a 4D Building Information Model with labour and movements of workforce?*

Deliverables
A framework will be delivered for this research question. This framework will describe how interventions can be modelled within the 4D BIM and how this affects the data set.

Methods
The methods used are modelling and simulation. The 4D model will be adopted to accepted different intervention from the business as usual model. This will be followed by simulation to check if the
adoption works.

**Sub question 6**

*What is the simulated change in productivity?*

**Deliverables**

A framework will be delivered that describes how the change in productivity between different simulations can be monitored. Changes are made to the 4D model in order to reach a change in productivity. This framework helps to create insight in how the different changes affect the productivity.

**Methods**

The method used for this research question is modelling. A model will be made that generates an overview of the different interventions, the changes to the dataset and the changes in productivity.

**Sub question 7**

*Can this simulated change in productivity be proved by the physical project?*

**Deliverables**

The deliverable for this research question is a validation of the simulation. The simulation runs two times, one time as business as usual and one time with the interventions made. These simulations result in a certain change in labour productivity. The check is made with the physical project if this change is valid.

**Methods**

The method used for this research question is interviewing. Based on the simulations the project team is asked if the results of the simulation have a certain amount of reliability.

**Literature and general practical preference**

**Literature on the problem:**


TKI Dinalog, & NWO. (2016). *Accelerator - Kennis en innovatie voor een concurrerende logistieke sector*. Retrieved from on Delft:


**Literature on labour productivity**


**Literature on 4D BIM**


Literature on research methods.


Reflection

Relevance

Scientific relevance

Although construction labour productivity has received attention since 1975, the labour productivity in the building industry is still relatively low compared to other industries (Koskela & Vrijhoef, 2001; Thomas et al., 1990). The improvement of labour productivity is something that is currently worked on in the construction industry. Looking at the improvement of labour productivity in terms of added value, the construction industry in the Netherlands among other sectors, has the highest increase in labour productivity (CBS, 2016d).

This research is based on former research that has been carried out by TKI, a consortium of TNO, Dinalog and NWO (TKI Dinalog & NWO, 2016). The goal of this research is to test new concepts in construction logistics with logistic information and mathematical models in building information models. Within the first round, the goal of the research was to define measures that could help to improve construction logistics. The presented outcome of this first round showed that making use of a hub and shifting the transport of employee from private to public transport has the most potential (Klerks et al., 2012).

Based on the results found several logistic measures were implemented in the second round. These
measures were implemented in two pilot projects in order to conduct a case study and validate if the expected results were met. According to TKI Dinalog and NWO (2016) the results were twofold. First, results showed that the implementation of the logistics measures were positive in terms of sustainability and decreasing the lead time and costs of the project. Second, The implementation of software to collect and manage data was difficult. As the construction industry is rather fragmented and conservative, it was found hard to convince all parties to use a different approach. Furthermore it was found hard to avoid assumptions, since a lack of data. E.g. most of the parties did not know the exact costs of certain elements as transport.

Solving these problems was the research focus of the third round. In which the main focus point are measuring performance of logistics measures, researching the use of BIM for the management of logistics and performance research on company transcending supply chain management, with for instance 4C Control Towers (TKI Dinalog & NWO, 2016).

This research focuses on one of these focal point presented in the third round, namely the use of BIM for the management of logistics and performance research. Whereas the research of TKI Dinalog and NWO (2016) primarily focussing on the issue related to the transportation from and to the construction site, this research will take it one step further. Namely, this research is focusing primarily on the logistics within the construction site itself, more specifically that of the employees working on site. Whereas a lot of research has been done into abilities of 4D building information models, in terms of site layout and construction sequencing (Bryde, Broquetas, & Volm, 2013; Eastman et al., 2011). Nonetheless, not much research has been done on the integration of labour and movements of workforce within this model.

**Social relevance**

The building industry has a large socio-economic influence in the Netherlands from different viewpoints. From a demographic point of view, the Dutch building industry provided a total of 457,000 jobs in 2015, which is about 5,2% of the total labour volume (CBS, 2016a). In economic sense the operating income of the Dutch building industry is 78.8 billion euro, which is 11,9% of gross domestic product in 2014 (CBS, 2016b, 2016c). As the figures above indicate the Dutch construction industry has a substantial share within the Dutch economy and employment of its inhabitants.

Furthermore the sustainable employability of construction workers in the Netherlands is relatively low. Among the different sectors the construction industry in the Netherlands has one of the lowest retirements ages (Kraan, Wevers, Geuskens, & Sanders, 2011; Robroek, Burdorf, Beumer, van der Sluis, & Weel, 2011). The legal retirement age during the research was 65 years; a majority of the construction workers is not able to work until this age. The work strain among this sector is relatively high, because the job is physically demanding (Kraan et al., 2011). The goal of this research is to find opportunities to increase the labour productivity on construction site. Increasing the labour productivity on construction site might therefore help to reduce the amount of unnecessary activities that increases the work strain on construction workers.

**Time planning**
Research phasing presented on next page
P1 Research proposal
Preliminary research design and methods

- In-depth literature study
- Defining the correct research methods for data collection
- Explorative meeting

Theoretical framework
- Definition of labour productivity
- Data provision for modelling
- Accurate modelling
- Visualisation

Research framework
- Research design
- Data collection
- Data analysis

P2 Research proposal & Literature study
Final research design, method and theoretical framework

- Start internship
- Collection data and implementation according to theoretical framework

Deliverables
- 4D BIM model with implemented labour and movement of workforce
- Framework for indicating and executing interventions with improved labour productivity

P3 Research results
Complete data collection, overview of preliminary results

- Processing data
- Finalising results

Final products
- Framework to implement labour and movements of workforce in 4D BIM
- Framework to indicate potential for that can contribute to a higher labour productivity

P4 Research results
Complete overview of research and final results

- Finalizing the report
- Making the presentation

P5 Final presentation
Preliminary research design and methods