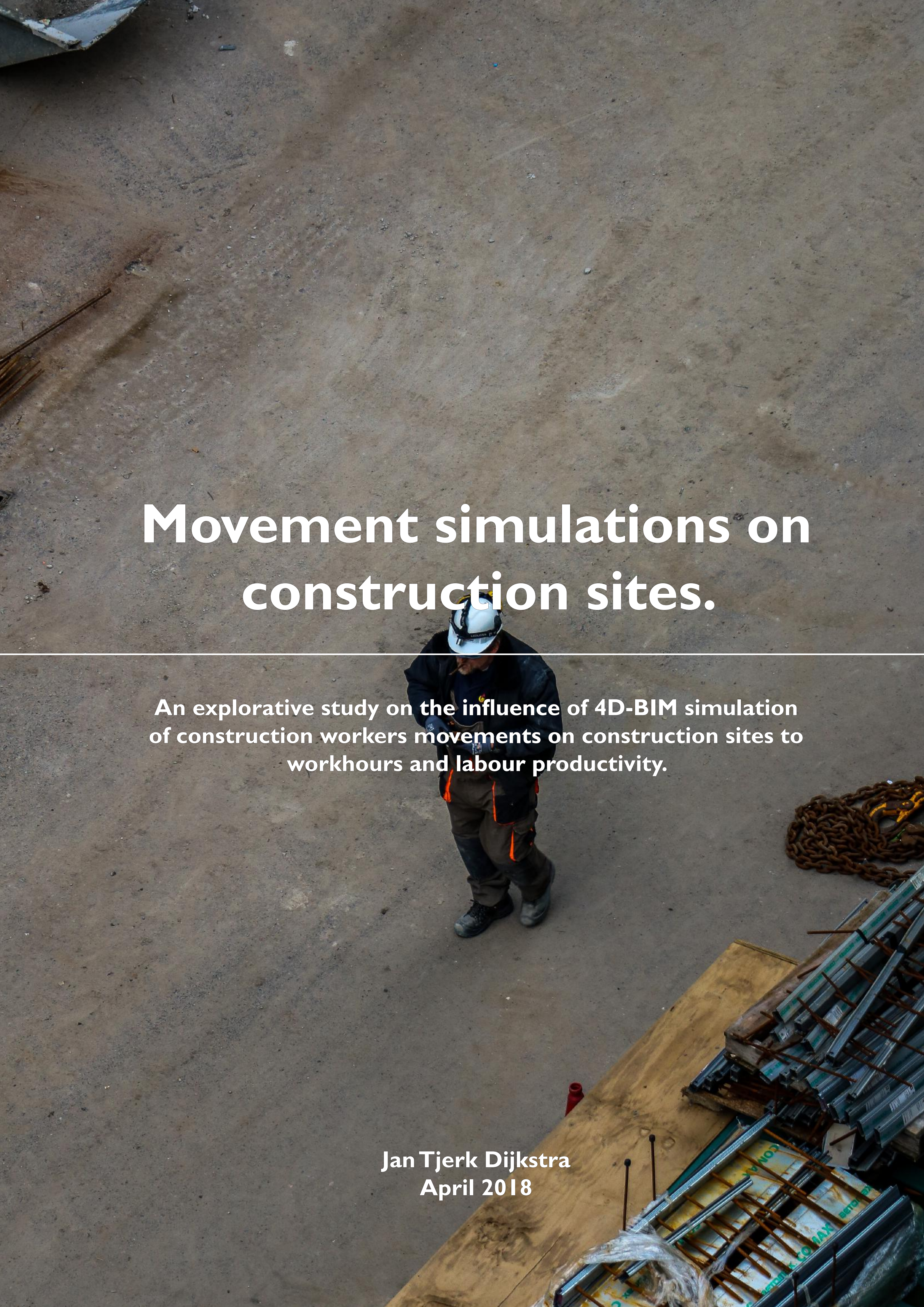

Movement simulations on construction sites.

An explorative study on the influence of 4D-BIM simulation of construction workers movements on construction sites to workhours and labour productivity.

Jan Tjerk Dijkstra
April 2018

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“Paths are made by walking.”

Franz Kafka.

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I - Colophon

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II - Preface

Whilst the bachelor is mostly focused on the design of the built environment, my interest went out to the construction phase itself. 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 had entered the construction phase and the team was mostly busy with the engineering of the different parts (*werkvoorbereiding*) and the procurement of subcontractors. Within this project they made use of a Building Information Model (BIM).

During this internship, I found that the BIM was used for basic activities. 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. The master programme gave more insight about the construction phase and organisation. This together with the possibilities of BIM that are not used at its full potential in the construction industry as yet.

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 sub-contractors if BIM is used to plan, arrange and place different components.

Furthermore, I would like to thank multiple people for supporting me during this last stage of my university adventure. My mentors from the TU Delft; Ruben Vrijhoef and Alexander Koutamanis for their guidance and support. Arjen de Feijter for the guidance and opportunity to do my graduation at Dura Vermeer. Further, my friends and family for supporting me during the graduation process. Glenn for helping me writing some codes used within this research. In special, my father, stepmother, sister, brother-in-law, brother and girlfriend for their unconditional support. At last I would like to remember my late mother, who sadly is not able to witness this personal achievement.

Jan Tjerk Dijkstra
5th of April 2018

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III – Summary

Introduction

Introduction

Building Information Modelling (BIM) has proven to have several benefits in visualisation, automatic generation of drawings, code reviews and construction sequencing (Eastman, Teicholz, Sacks, & Liston, 2011; Papadonikolaki, Vrijhoef, & Wamelink, 2015). In terms of planning, BIM can be used to do four-dimensional modelling. According to Doloi (2013), one of the attributes that influences the cost performance in construction projects at a high level are planning and scheduling deficiencies.

Site planning could also benefit from advancements in probabilistic optimisation to generate automated site layouts. Simulations can perform fast and efficient search through a very large number of possible solutions for enhanced site layouts (Tawfik & Fernando, 2001). With the improvement of the planning, the duration of the construction planning or clashes between different actors in the construction planning may be reduced and the resources can be used more efficiently. Therefore, this might increase the labour productivity on the construction site and respectively lower the costs spent on labour.

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). 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). The improvement of labour productivity can have advantages for the competitiveness and profit of contractors and lead to lower costs for the clients (Eastman et al., 2011). 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.

Problem statement

The problems 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 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-BIM provides the link between space and time (Eastman et al., 2011). As 3D-BIM offers the possibility to be converted to a 4D model, it can help to solve parts of the problems. In 4D-BIM the 3D data is linked to the schedules of the different parties involved within the construction project (Eastman et al., 2011).

By adding the labour needed to place these building elements in the 4D-BIM, this factor can be analysed and visualised. Which helps to enlarge the insight of labour on the construction site and search for potentials for optimisation. Wherefrom, optimisations can be made to make the construction process more efficient and increase the labour productivity.

Research objective

The aim of this research is to provide a framework containing labour and movements of workforce on the construction site that gives insight into how to increase productivity on site. The final product will be a framework consisting out of two consecutive parts.

The first goal, provide insight into labour and movement of workforce with a 4D-BIM. This focuses on how to model and visualise the element of labour and movements of workforce into a 4D-BIM. A framework will follow, in which the labour and movement of the workforce can be added to make the 4D-BIM. This framework describes what data is needed from different parties 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-BIM.

The second goal, provide insight and indicate potentials with this 4D-BIM to increase the labour productivity on construction sites. This part focuses on how this 4D-BIM can contribute to a higher labour productivity on construction sites. 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.

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). 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 BIM. NWO (2016) primarily focussing on 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-BIM, in terms of site layout and construction sequencing (Bryde, Broquetas, & Volm, 2013; Eastman et al., 2011), not much research has been done on the integration of labour and movements of workforce within this model.

Social relevance

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). 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 of physical demands in the job (Kraan et al., 2011). 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.

Research methodology

Research design

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. As this research look into the extent in which a 4D-BIM 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. 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. Since this research is mainly focussed onto a single construction project and does not provide concrete numbers, qualitative research is chosen as the overall strategy.

Case

The case used for the data collection within this research is the construction project of *het Noordgebouw* near the central station of Utrecht. Because the construction project itself is relatively large this research will narrow down on several aspects of the construction. Modelling all objects of the project into the 4D-BIM and add the labour and movements of workforce would be too time-consuming. Therefore, the choice is made to narrow to specific objects. This research will focus on the construction of the metal-stud walls used within the hotel of the building.

Research questions

As this research focuses on how a 4D-BIM 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-BIM have the ability to give insight into and indicate potentials to increase the labour productivity on construction sites.

To provide an answer to this main research question, the following research questions are set up.

- Which definition and aspects of productivity to be used?
- Which data is needed from all parties to be integrated into a 4D-BIM?
- How to accurately model the data into a 4D-BIM with labour and movements of workforce?
- What are the possibilities of visualising the data into a 4D-BIM with labour and movements of workforce?
- How to model interventions into a 4D-BIM 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?

Theoretical background

4D BIM

BIM can help implement lean construction techniques in a better way. To ensure that work can be performed when the appropriate resources are on site, lean construction techniques require careful coordination between the general contractor and subcontractors. Doing so reduces the on-site availability of materials and minimizes effort. BIM reduces costs and allows for better collaboration at the job site (Eastman et al., 2011; O'Brien, 2003).

As indicated by Eastman et al. (2011) 4D models have several benefits. First, the planned construction process can be visually presented to other stakeholders in the project. With the 4D model both the temporal and spatial aspects of a schedule are presented, and this way of communication is more effective than a traditional Gantt chart. Second, 4D models provide a basis for multiple stakeholder impact. As it can function as a community forum to present to laypersons how a project might influence other aspects. Third, it helps planners with site logistics. In which its helps to coordinate laydown areas, access to and from within the site, location of large equipment like cranes and more. Fourth, it can help coordinate the trades on the construction project. It will assist planners with the coordination of expected time and space flow of trades on site as well as the coordination of work in small spaces. Fifth, project managers can compare different schedules easily, and the can quickly identify whether or not the project is behind schedule or on track.

Dynamo is the software used within this research, that is based on visual programming provided by Autodesk. In principle it has two tasks, it creates its own geometry with parametric relationships. And reads and writes to and from external databases. Dynamo creates its own geometry and reads and writes to external databases. Simply put Revit is the database of parametric geometry to and from which Dynamo is able to write and read (Sgambelluri, 2014).

Walking paths

The simulation and analysis of a dynamic subject, like pedestrian circulations, relies on a representation consisting of a number of interrelated components which are presented by Koutamanis et al. (2001).

Table A: Route analysis data (Koutamanis et al., 2001)

Actors	One or multiple persons who travel.
Starting point	The location from where one or multiple actors depart. In buildings, the centroid of a space can be seen as starting point or a doorway. Multiple starting point indicate an aggregation of routes.
Destination	The endpoint of an actor, the place it wants to end at. Multiple destinations are not necessarily product of aggregation, a route can also have intermediate destinations. Points like stairs, elevators, cam be seen as intermediate destinations.
Path	The path has a starting point and destinations which can be complemented by intermediate destinations. The path can be the actual path or an approximation of it by for example the straight-line or city-block method.
Means of transportation	How movement is achieved along the path, this includes the speed the actor travels at and the capacity of these means.
Activities	These are the activities that take place along the path. Two options appear: activities related to the transportation; or the intervening opportunities, such as relations to other routes or other activities and actors in the building.

Walking path distances

The Euclidean distance, also called straight-line distance, this metric is inspired by the real world distance, namely the distance on the ground (Pan et al., 2013). The Euclidean distance is the square root of the sum of squared differences in the variables' values (Sarstedt & Mooi, 2014). Which can be identified as the Pythagorean theorem.

The city-block uses the sum of the variables' absolute differences. In modern cities the city-block distance is more close to the real distance (Pan et al., 2013). In the research of Manning, Kahana, and Sekuler (2006) they found that when an direct path is possible, the ideal path distance is equal to the city-block distance. Therefore, the city-block distance is a better representation of a real-world distance.

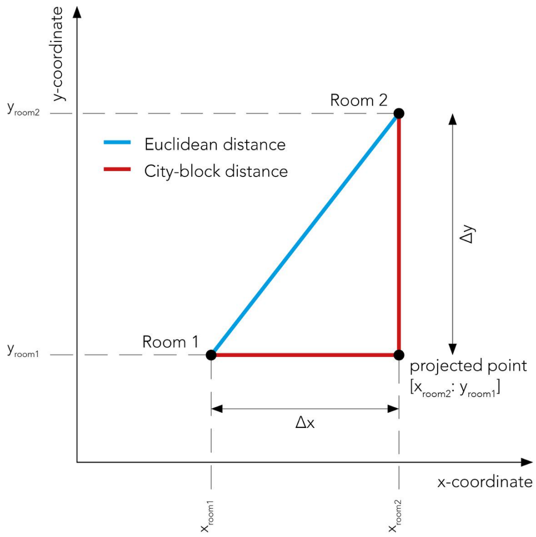

Figure A: Representation of the Euclidean and City-Block method.

Productivity

Productive time is well connected to output and productivity. If the productive time is known, the output of construction can be calculated. For instance, waiting time is also related to productivity, productivity thereby improves when waiting times are reduced or by reducing the delays, the productive time is increased (Thomas et al., 1990).

Furthermore, this definition is used for the measurability of the research. As this research focusses on the modelling of labour and movement of workforce and its ability to increase labour productivity it is hard to express movements of workforce in term of units of work or installed quantity. However, the movement of workforce can be expressed in terms of time, as movements have a travelled distance and speed for example.

$$\text{labour productivity} = \frac{\text{input}}{\text{output}} = \frac{\text{total working time}}{\text{productive time}}$$

Equation A: Definition of labour productivity used within this research

Waste is seen as activities that do not add value to the client's end product. More specifically it can be defined into value adding and non-value adding activities. Value adding activities are those, which convert materials and/or information in the search to meet client's requirements. Non-value adding activities, those which are time, resource, or space consuming, but do not add value to the product (Aziz & Hafez, 2013). Vrijhoef (2016) and Eaton (2013) show that the activities can be divided into three categories. First, productive time, which is time that adds value to the product. Second, unproductive time, Muda type 1: time that is used for activities that indirectly add value. Third, unproductive time, Muda type 2: not necessary and not value adding.

In this research the activities are divided between walking, waiting and working. From which working is seen as productive time. Figure B shows the sum of the activities divided between working, waiting and walking. This ratio will help to identify and verify the simulations performed in the upcoming part of this research.

	Alarcon (1997)	El Asmar (2012)
Working time	Productive (47,0%)	Productive (41,8%)
	General instructions (4,2%)	Charging batteries (2,0%)
	Others (3,5%)	Handeling/changing hand tools (3,1%)
	Measuring (3,5%)	Other waste; shovelling snow; removing tarps; streching cords (7,1%)
	Cleaning (3,1%)	Change of tasks; start-up and clean-up (9,2%)
	Personal needs (0,6%)	Locating tools/ladders (3,1%)
	Rework (0,4%)	Locating materials (4,1%)
Walking time	Transporting (13,7%)	Transportation; moving equipment; walking; using vehicles (9,2%)
	Traveling (6,0%)	Travel from and to lunch (3,1%)
Waiting time	Waiting (9%)	Morning coffee break (4,1%)
	Idle time (6,8%)	Restroom visits (4,1%)
	Resting (2,0%)	Waiting for instructions or materials (9,2%)

Figure B: Division on working, walking and working

Implementing Dynamo

Implementing model

As basis for the final model a backbone is necessary to know which steps have to be taken in which order. In Figure C this overview is given, within this overview the flows of information needed, and data generated are elaborated.

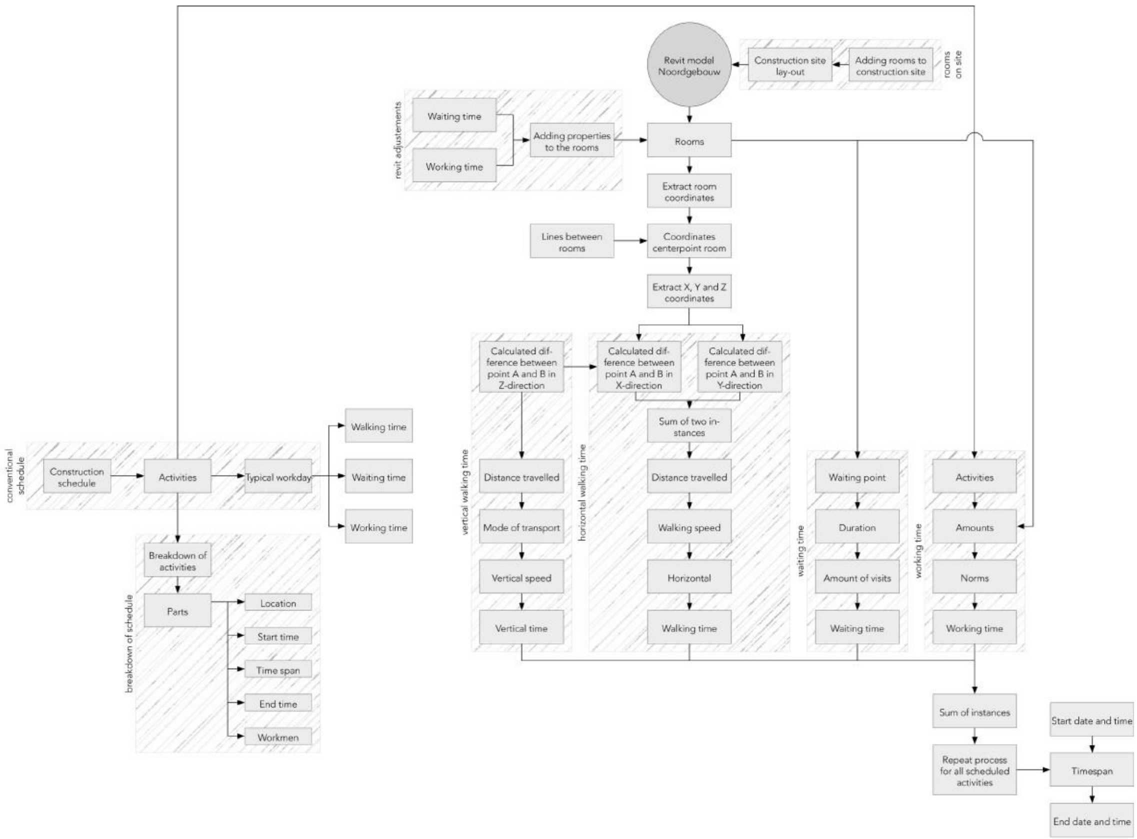

Figure C: Overview of Dynamo backbone

The backbone starts with the Revit model. This is the Revit model of the case used within this research *het Noordgebouw*. First, additional information needs to be added to the model, of which the construction site layout is one. Second, is the addition of the waiting and working times of certain rooms.

The next step is to read out the rooms, and the room location, with its coordinates. With the help of the rooms the lines of the travelled path can be drawn. These coordinates of the rooms can be used to calculated different distances. The vertical distance together with the means of transport, and the average speed related to that mean of transport gives the time needed for the vertical travel.

The horizontal walking distances need the addition of the city-block method, for which the X and Y-coordinates are needed. The distance calculated is then used together with average walking speed to calculate the walking time over a horizontal distance.

The waiting time of certain rooms is added to the Revit model. This waiting time is then used with the rooms which are passed by the construction worker and the amount of time he passes these rooms. Adding up these individual waiting times the total waiting time is calculated.

The working time is also added to the room. This resembles the norm and the amount of work that needs to be executed within the rooms. And gives the amount of time needed to execute the activities in a certain room.

The rooms that the construction workers visits are resembled in the typical workday. This typical workday is derived from the construction schedule. To which the activities are elaborated with the location and amount of people.

Adding up the walking, working and waiting times gives the total amount of time the construction worker spends on a day in total and trough the three categories. From these calculation different simulations can be compared among different the different levels of the building and categories.

Simulations

Introduction to simulations performed

A total of five simulations are performed within this research. The characteristics of the simulation and the results will be presented in Table B. These five simulations can be subdivided into two groups; the benchmark and the interventions.

Table B: Overview of performed simulations

Simulation 1	Benchmark	Simulation with the characteristics which are similar to the current construction site layout and typical workday.
Simulation 2	Intervention 1: Extra elevator	The capacity of the elevator is doubled, from one to two elevators. Assumed is that this intervention decreased the waiting time for the elevator by half.
Simulation 3	Intervention 2: Toilets on levels	This intervention eliminated two up and down movements per typical workday. Achieved by placing toilet on every level of the building.
Simulation 4	Intervention 3: Elevator to corner	The elevator and stairs are relocated from the centre of the building to the corner of the building. This should decrease the walking distance on ground level.
Simulation 5	Intervention 4: Elevator near work	The elevator is relocated from the front side of the building to the rear side, next to the workspace. This reduces the walking distance on the building levels but increases the walking distance on ground level.

Results in terms of time

The working time stays constant among all categories, but the other categories do changes during the simulation. The sum of the other categories (sum of city-block time; vertical time by elevator; vertical time by stairs and waiting time) is presented in Figure D. This figure shows the results of all changeable categories during simulations per level.

From Figure D, the following trends can be noted. First, for all simulations a large difference appears between level 4 and level 5. Which is the result of the head- contractor's elevator policy.

Second, the increase of time per simulation rises when the level increases. This results from with an increase of level, the vertical distance travelled increases. Due to the fact that the travel time is a product of vertical height.

Third, comparing the different interventions with the benchmark, this results in the following ranking. First, Intervention 4 is the only intervention that is longer than the benchmark, with 1 minutes and 2 second on average per level. Second, Intervention 3, that is only slightly shorter than the benchmark, with an average improvement of 1 second per level. Third, is Intervention 1, has a shorter total travel time than the previous two interventions, of 21 minutes and 38 second on average per level. Fourth, the largest improvement from the benchmark is made in Intervention 2. This intervention has in average improvement of 33 minutes and 28 seconds per level.

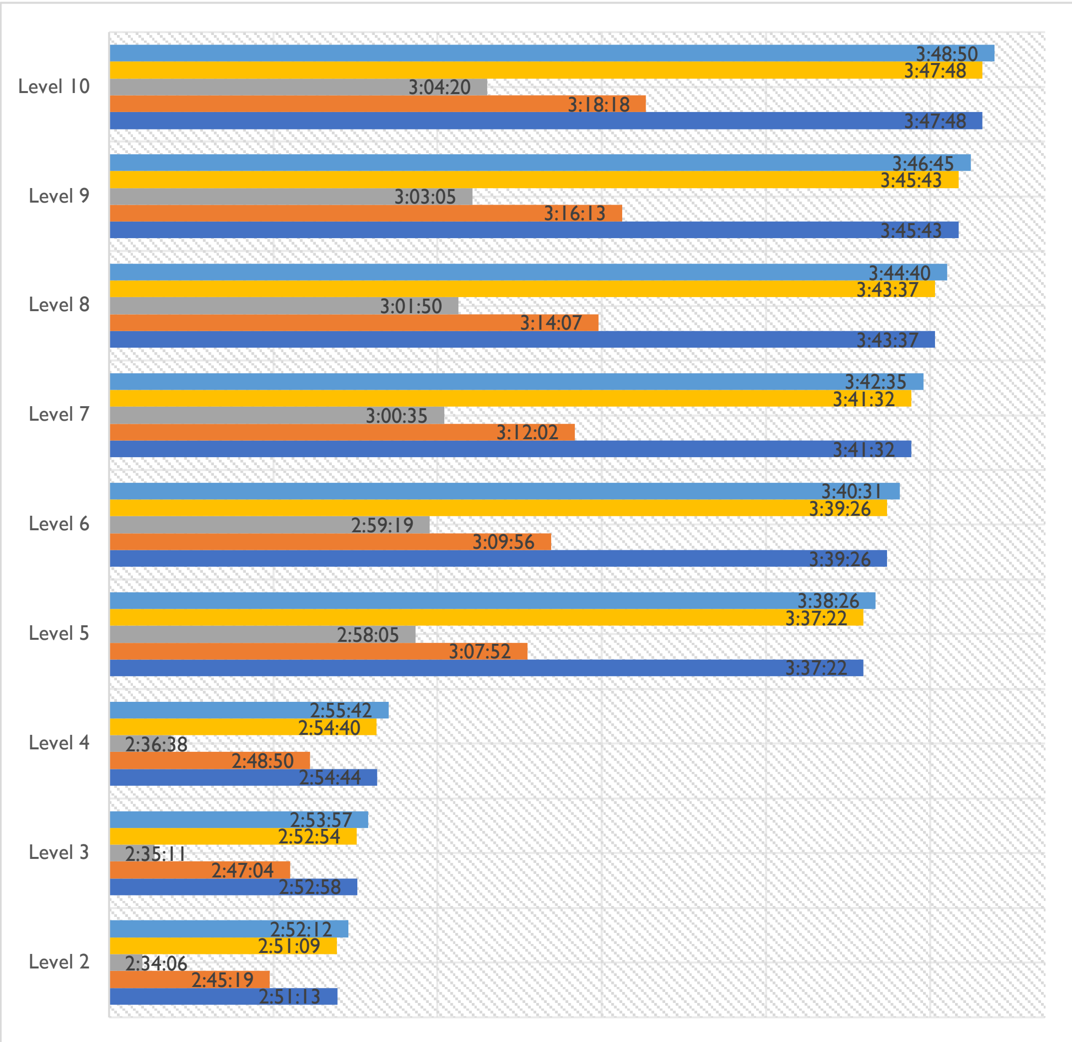

Figure D: Total traveling time
(sum of city-block time; vertical time by elevator; vertical time by stairs and waiting time)

Results in terms of productivity

The ratio between walking working and waiting was defined. This showed that with this categorization the productivity is between 62,3% and 70,4%. Looking at the Benchmark figures in Figure E, it shows that in total the productivity is 53.0%. Nevertheless, when comparing the activities performed by the dry-wall contractor and the crew it is not comparable with the productivity figures found in previous research.

Intervention 4 is the least effective in improving the productivity among. It even lowers the productivity slightly. Second, is the Intervention 3 which improves the productivity just a hair, it is almost equal to the benchmark. Third, is Intervention 1 which shows the second-best improvement of productivity. For the total time the improvement in productivity is approximately 2,7%. Fourth, the best improvement in productivity is made in Intervention 2. An improvement of approximately 4.3% in productivity is made.

This becomes clear when looking at the formula of productivity in which the working time is divided by the total time. The working time remains constant during all simulations. The total time is a product of the different categories, and therefore the intervention that lowers the total time the most will give the largest improvement in productivity.

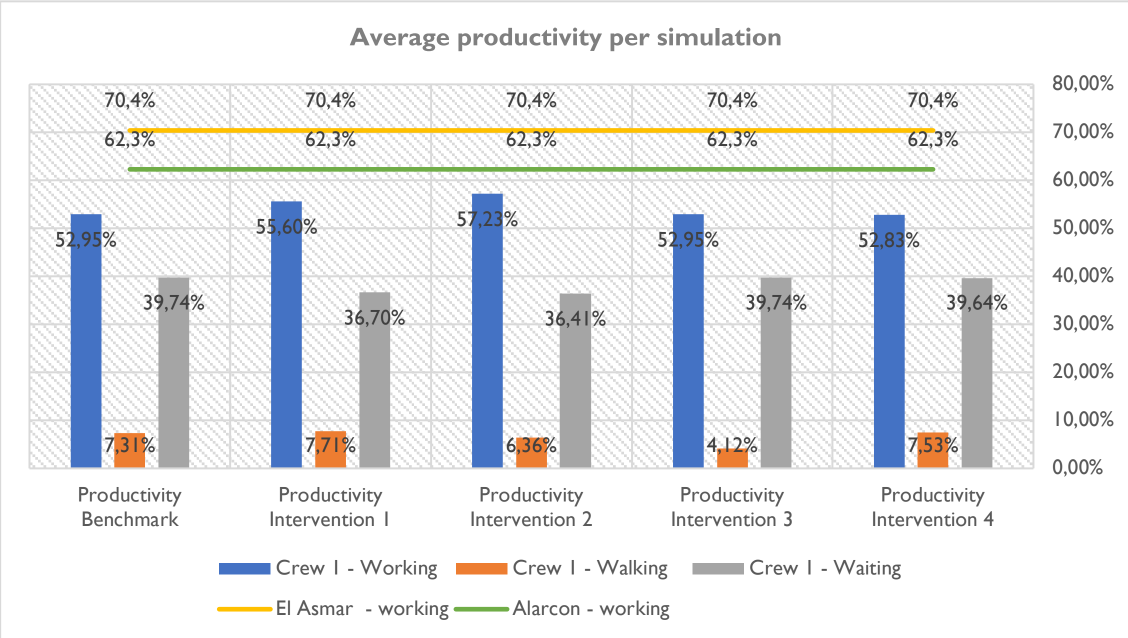

Figure E: Average productivity per simulation

Expert panel

This model could make people conscious about the waste and offer a foundation to make decisions. As at this moment the site-layout is made upon experience and gut-feeling.

According to one of the panel members, one of the basics of the model, the rooms from which the typical workday and coordinates are derived, should be available early in the process as the architect is making its first sketch models.

Next, the panels point out the influence of the building phase. For example, the difference between the structural construction and the finish construction. In the structural construction, less construction workers are on site. This could lead to the decision to start with one elevator and during construction add a second elevator. According to the panel members, it becomes more interesting when several different (sub-)contractors are working on site, which is different from the current model where only one subcontractor's activity is simulated. Also interesting according to the panel is the order of operations: is there an effect on working in a specific order or not?

Even more interesting are dependencies between the different parties on site. This followed by the connection of the model with the times and schedules. As one of the panel member point out a returning problem is found on the dependencies of subcontractors.

Another aspect pointed out to the panel is the dependencies of the projects size and shape. Examples are named of a long project of about 300 meters or a very large project with a floor area of 62,000 m^2. What is the influence of these aspects on the walking lines and distances by the construction workers.

As mentioned before the panel points out that the productivity figures presented in this research are set for traditional projects. The project of *het Noordgebouw* is a project which makes use of smart building logistics, this should increase the productivity on site.

As suggestion, the panel members pointed out several new interventions which could have an effect on the productivity. A few of the examples give is to place the coffee break-room; equipment storage container; saw-shed; or lunchbreak-room on the levels that the construction workers are working.

Discussion and conclusion

Discussion

Typical workday: The order in which these rooms are placed is discussable, because of two contradictory reasons. First, the model presented within this research is meant to be used in the early stages of a project. Within the early stages, it is generally hard to tell which sub-contractor is going to execute the job and what the operational process is going to be. Furthermore, the process can be influenced by other actors on site, which could change the typical workday initially used. Second, During the early stages of the construction process, uncertainty is high (Winch, 2010). Thus, the typical workday can help generate certainty. As the typical workday is used as part of the model to help make decisions in i.e. the construction site layout, it helps to provide information within the process.

Waiting times: As discussed by the expert panel waiting times differ per project. Traditional construction logistics have been used within previous research. Within the case of *het Noordgebouw* smart construction logistic are used. Therefore, the waiting times for the elevators used within this research are relatively higher compared with real project, according the expert panel.

Walking lines: Within the model presented in this research, the horizontal walking lines are drawn on the ground level or on the different levels of the building. Excluded from the current model are the walking lines on the building levels, to i.e. the place where the materials are stored, or where waste is collected. This increase the walking distances of the construction worker and makes this category of the model more prominent.

Necessity of working times: Within this research the working time, which is set as a constant, is used to gain productivity numbers that can show this productivity increase. Without the working time the different simulations can be compared with each other to show which construction site layout is the most productive, since the model focusses on the decrease of time spend on non-value adding activities. Nevertheless, the importance of the working time can be explained when different projects want to be compared. Without the working time, no productivity figures can be presented, and it becomes hard to compare different projects.

Ratio between walking, working and waiting time: The ratio between walking, waiting and working time ratio is used to compare the results of the simulations with the data found in literature. Items categorised are for example ‘locating tools/ladders’ or ‘locating materials’ which are categorised under working time. It can be questioned if this does not belong to walking time, which would make walking time increase by 7,2%.

Conclusion

The answers to the research questions discussed in the previous paragraph lead up to answering the main research question: *to what extent does the modelling of labour and movement of workforce into a 4D-BIM have the ability to give insight into and indicate potentials to increase the labour productivity on construction sites?*

In short: 4D-BIM can possibly increase labour productivity on construction sites to a big extent.. Currently, no models exist to provide insight in walking, waiting or working times of construction workers, or to visualise the movements, waiting and working times of construction workers. This model is a first step in providing this insight, as it shows how simulation can be done which generates figure on walking, waiting and working times of construction workers. Furthermore, it generates visual images that provide more insight the movements and waiting times of construction workers.

Providing insight into movements and waiting times of construction workers shows the user of 4D-BIM where non-value adding activities can be found. With this knowledge, interventions to decrease the non-value adding activities can be designed. As a consequence, labour productivity on construction sites can rise since (labour) productivity is the ratio between value adding and non-value adding activities.

Recommendation

Ratio working, waiting, walking: Further research has to be done on the ratios between working, walking and waiting. To gain more insight in the productivity projects with smart construction, logistics need to be researched.

Multiple actors: Interdependencies between different actors are an important problem in the current construction industry, as one of the panel member indicated. By modelling multiple actors in the model, it becomes more realistic and evident where potential in the construction site layout can be found. By modelling multiple actors, it provides insight in which locations activities are performed. Furthermore, a link to the construction schedule helps to define these interdependencies.

Building shape: What are the influences of the building's shape? As buildings can be different in shape it could have influences on different categories, i.e. the walking time may be influenced.

Order of construction: Further research should be done on the influences of construction order. Together with the relations between different actors the order of fulfilling certain activities can be changes and might influences the productivity on sight.

Visualisation of lines and waiting times: To help the visualisation of the walking lines and waiting time of the construction workers the following could help to improve this. Improvements could be made on color-coding the waiting times and walking lines.

Waiting time elevator: Elevators have several peak hours during the day, usually when the day starts or ends, and during breaks. The time a construction worker waits for the elevator to arrive thus depends on when the construction worker wants to take it. To refine the model even more, it could be beneficial to gain data about the different waiting times during the day and introduce this to the model.

General construction site costs: One of the items within a construction project budget are the general construction site costs. The current general construction site costs are based on experience and rough estimates. The added value of the model proposed here is to provide support for decision making on this item. The model allows for optimisation of the construction site.

Furthermore, the moment of introducing of the model in a project is important. Introducing the model in the early stages of the project, preferably during tendering, can help to introduce a better bid. This also influences the effectiveness of the model, because during the tender the costs are named and changes to the budgets can be made. After the bid is handed in, it becomes harder to make changes.

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Table of contents

part I

This first part will form the introduction to the research, and is divided into two chapters. In the first chapter, the research is introduced: the problem statement, research questions, social and scientific relevance and reading guide are discussed. The second chapter introduces the research design: research background, case and methods used are presented.

Introduction

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1 Research introduction

1.1 BIM

Building Information Modelling (BIM) has proven to have several benefits in visualisation, automatic generation of drawings, code reviews and construction sequencing (Eastman, Teicholz, Sacks, & Liston, 2011; Papadonikolaki, Vrijhoef, & Wamelink, 2015). In terms of planning, BIM can be used to do four-dimensional modelling. 4D-BIM generally defined as the link between time and space, which represents a type of graphic simulation of the construction schedule (Eastman et al., 2011; Kumar, 2015).

According to Doloi (2013), one of the attributes that influences the cost performance in construction projects at a high level are planning and scheduling deficiencies. Accurate planning and monitoring emphasizes the technical competence of the project team in clearly understanding the project scope, development of appropriate statement of work, realistic estimation of activity duration and baseline planning for controlling and monitoring over the execution stage of the project (Doloi, 2013).

Site planning could also benefit from advancements in probabilistic optimisation to generate automated site layouts. Simulations can perform fast and efficient search through a very large number of possible solutions for enhanced site layouts (Tawfik & Fernando, 2001). With the addition of the four-dimensional model of the construction schedule, the contractor might be able to gain more insight in the project planning, and make it easier to monitor during the construction phase. With the improvement of the planning, the duration of the construction planning or clashes between different actors in the construction planning may be reduced and the resources can be used more efficiently. Therefore, this may increase the labour productivity on the construction site and respectively lower the costs spent on labour. Besides, the transport of products from and to building sites might become more efficient and reduce the amount of traffic. Improving the labour productivity can help to eliminate the time and costs overruns (Nasirzadeh & Nojedehi, 2013).

1.2 Labour productivity

Labour productivity in the construction industry is low: labour productivity on construction sites is between 40 and 50%, which is relatively low compared to other industries (Aziz & Hafez, 2013; Forbes & Ahmed, 2011; Platform Logistiek in de Bouw, 2014). As a consequence 50 to 60% of the work executed is seen as unproductive. 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 et al., 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 take up between 25-50% of the construction costs. For example, 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). Furthermore, problems that are 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.

1.3 Problem Analysis

The reason why the labour productivity in the construction industry is relatively low, may be because of multiple reasons.. The overall productivity in construction has been greatly affected by regulatory controls, the environment, climate effects, costs of energy and other factors. Improvement of productivity has never been the focus of the construction industry, probably due to the lack of a model that ties all the different fragments of the process together (Forbes & Ahmed, 2011).

Therefore, the labour productivity in the construction industry is marked as productive between 40 to 50%, the remaining 50 to 60% is marked as unproductive (Aziz & Hafez, 2013; Forbes & Ahmed, 2011; Platform Logistiek in de Bouw, 2014). Different problems, that contribute to the low the labour productivity in construction can be defined. Loera et al. (2013) name different problems that contribute to the low labour productivity: flaws in the design; changes in the design during construction; lack of surveillance of employees; overloading employees in confined spaces; high staff turnover; planning and delivery flaws; communication problems; or bad safety conditions.

Forbes and Ahmed (2011) give more details on three reasons why the labour productivity in the construction industry is low. First, from the total project cost about 10% is spent on repair works. Second, between 25-50% of the construction costs is due to waste and inefficiency of labour, materials and controls. Third, communication problems are mostly the cause of flaws being made in the transition from the design to the construction itself. As previously mentioned it is important to improve the efficiency of the construction processes. At the moment only 40-60% of the time is spent on value adding work and the remains are seen as non-value adding. Satisfactory productivity can be beneficial for the project costs, quality, timeliness, safety and budget adherence (Forbes & Ahmed, 2011).

Among the eight causes of the high level of waste three directly apply to the waste caused by labour. First, construction workers spend a lot of time waiting. Related to the idle time caused by synchronisation and levelling of materials and pace of work by different groups or equipment. For example, the idle time caused by the lack of workspace available for a certain crew. Second, the transportation involved with the internal movement of materials on site. Excessive handling, the use of inadequate equipment or bad conditions of pathways. Can cause this waste. Usually related to poor layout and the lack of planning of material flows. With waste of man hours, waste of energy, waste of floor space on site and the possibility of materials waste during transportation as consequences. Third, the movements made by the workers during their job. The waste produced with unnecessary or inefficient movements of the works can be caused by inadequate equipment, ineffective work methods or a poor site arrangement (Aziz & Hafez, 2013).

These wastes can be divided into three controllable wastes, which associate with flows, conversions, and management activities. These wastes will be presented in Table 1. According to

Alarcon (1997), modelling, evaluation of wastes, and performance in construction projects have been challenging the construction industry for decades. Table 1 indicates tangible problems that occur during the construction project, that contribute to the low productivity on construction sites. Most of these problems have the ability to properly manage the labour by addressing problems related to materials or equipment.

Table 1: Controllable causes associated with flows, conversions and management activities. Adopted from Alarcon (1997)

Controllable causes associated with flows.	Resources	Materials: lack of materials at the work place; materials are not well distributed; inadequate transportation means;
		Equipment: non-availability; inefficient utilization; inadequate equipment for work needs;
		Labour: personal attitudes of workers; rebellion of workers.
	Information	Lack of information;
		Poor information quality;
		Timing of delivery is inadequate.
Controllable causes associated with conversions.	Method	Deficient design of work crews;
		Inadequate procedures;
		Inadequate support to work activities.
	Planning	Lack of work space;
		Too much people working in reduced space;
		Poor work conditions.
	Quality	Poor execution of work;
		Damages to work already finished.
Controllable causes associated with management activities.	Decision making	Poor allocation of work to labour;
		Poor distribution of personnel;
	Ineffective supervision/control	Poor or lack of supervision.

Furthermore, there is an emergence of subcontracting. General contractors increasingly take on the role of construction manager, with individual contracts and with specialised subcontractors (Forbes & Ahmed, 2011). The number of stakeholders with different interests thus increases, making projects become more complex. As a result proper management is needed (Winch, 2010).

Despite the extent of the on-going digitalisation and computerisation of architecture, especially in practice, it still deals primarily with illustrations. A problem with the current developments is the limited integration, utilization and enrichment of knowledge. Human interaction within the built environment has been one of the knowledge components that is frequently underplayed in research, development and practice (Koutamanis, van Leusen, & Mitossi, 2001).

Site planning in terms of organising the site layout to facilitate construction activities is among the most challenging tasks of the construction planning process, and involves several steps of human interpretations and manipulation of data and knowledge. Despite the significance of this stage, the spatial organisation of the construction site layout in terms of the allocation and arrangement of the different spaces on the site has not been satisfactorily accounted for by Information Technology (IT) modelling tools. This task tends to be carried out manually by planners, despite the implications of an increased cost and risk of activities at the site (Tawfik & Fernando, 2001).

Recent research suggests that 20% of reported construction accidents can be attributed to poor site logistics, and that low productivity is highly linked to inefficient space planning and conflicts between subcontractors. The spatial domain is critical to construction projects and efficient tools to handling changing spatial arrangement on the site, over time is still yet to be developed. The placement of the temporary facilities on site, a key site layout planning task, is still carried out by planners based only on their experience and intuition, usually resulting in increased transportation costs, loss of time, and inefficient use of resources (Tawfik & Fernando, 2001).

1.4 Problem statement

In the preceding paragraph, different problems that contribute to the low labour productivity in the construction industry are discussed. Those problems presented are mostly related to time and place flaws, and can be solved in multiple ways. 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 a building information model (BIM). BIM is three-dimensional and is mostly used in the design and engineering phase of the project at present, in which it combines the data of different parties into one model. As mentioned before, BIM can also be four-dimensional (4D). In 4D-BIM the link between space and time is provided as well (Eastman et al., 2011), which is especially important due to the solvability of previous named problems with this provision. Currently, 3D-BIM is used oftentimes. However, the transition to 4D-BIM may increase the labour productivity as 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 is needed to place the different building elements on site is not added to 4D-BIM. By adding the labour needed to place these building elements in 4D-BIM, this factor can be analysed and visualised. This helps to enlarge the insight of labour on the construction site and search for potentials for optimisation. From there, optimisations can be made to make the construction process more efficient and increase the labour productivity.

1.5 Research questions

As this research focuses on how a 4D-BIM 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-BIM 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-BIM. Second, how can this 4D-BIM contribute to a higher labour productivity on construction sites.

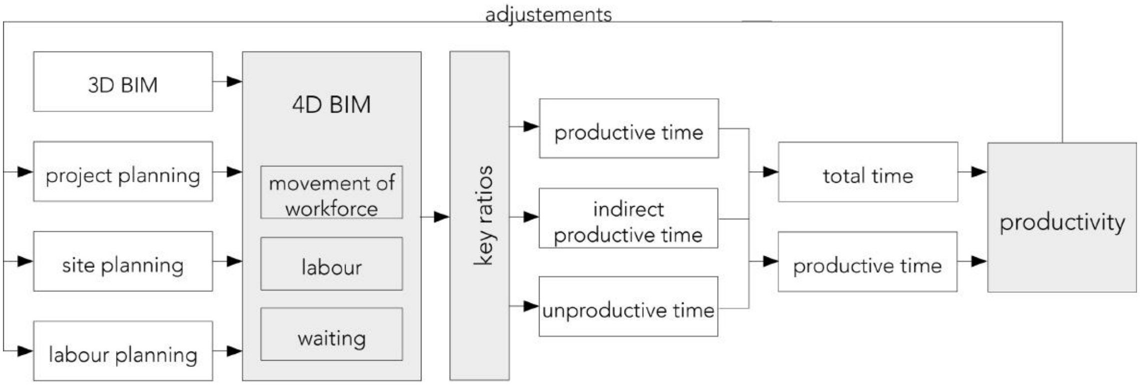

Figure 1: Conceptual model

Figure 1 shows the conceptual model, in which 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 is shown. The focus of this research lies within the implementation of labour and movements of workforce into a 4D-BIM to provide insight and potentials for a higher labour productivity. The different parts of the research will be divided into sub-questions.

Which definition and aspects of productivity to be used?

This first question derives from the last part of the conceptual model. It focusses on how the productivity is defined so it can be measured and provides a sensible outcome.

Which data is needed from all parties to be integrated into a 4D-BIM?

According to the current abilities within 4D BIM what is the information needed for the current model and what information needs to be added to the model to be able to model the labour and movements of workforce.

How to accurately model the data into a 4D-BIM with labour and movements of workforce?

This research questions builds onto previous questions, as it combines the outcomes of these questions to provide a framework in which the labour and movements can be accurately modelled.

What are the possibilities of visualising the data into a 4D-BIM with labour and movements of workforce?

The focus on this research question lies within the visualisation aspect of BIM. The different possibilities that exist in visualising labour and movements of workforce that enables the users to have proper insight in the construction site.

How to model interventions into a 4D-BIM with labour and movements of workforce?

A 4D-BIM simulates a productivity level, wherefrom possible bottlenecks in the current use of space and time are identified. This question focuses on which intervention is chosen and how it is simulated in the 4D-BIM.

What is the simulated change in productivity?

Interventions follow from the 4D-BIM. When administered a change in productivity of the project can be expected. The focus of this question is how to monitor the change in productivity between the two simulated options.

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

Until now, simulations with the 4D-BIM measure the productivity. If the same intervention is done in the physical representation of the project, does this lead to the validation of the simulations.

1.6 Research objective

The aim of this research is to provide a framework containing labour and movements of workforce on the construction site that gives insight into how to increase productivity on site. The final product will be a framework consisting out of two consecutive parts.

The first goal, provide insight into labour and movement of workforce with a 4D-BIM. This focuses on how to model and visualise the element of labour and movements of workforce into a 4D-BIM. A framework will follow, in which the labour and movement of the workforce can be added to make the 4D-BIM. This framework describes what data is needed from different parties 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-BIM.

The second goal, provide insight and indicate potentials with this 4D-BIM to increase the labour productivity on construction sites. This part focuses on how this 4D-BIM 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.

1.7 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). Currently, the construction industry is still working on improving labour productivity. 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 BIM. 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, 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 points 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. This research focuses 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-BIM, in terms of site layout and construction sequencing (Bryde, Broquetas, & Volm, 2013; Eastman et al., 2011). Research on the integration of labour and movements of workforce within this model is slim. This research focusses on the possibility of developing a model that can provide insight in the movements of construction workers on construction sites. This model allows for exploration of alternatives in site and time planning.

1.8 Social relevance

The building industry has a large socio-economic influence in the Netherlands. 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). These figures thus indicate that 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. Compared to other sectors within the Netherlands, the construction industry 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, but a majority of the construction workers is not able to work until this age. The work strain in this sector is relatively high, because of physical demands in the job (Kraan et al., 2011). The goal of this research is to find opportunities to increase the labour productivity on construction sites, to help reduce the amount of unnecessary activities that increases the work strain on construction workers. Thus, workers may more easily reach the legal retirement age in the construction industry.

1.9 Reading guide

This report is structured in eight parts. Part I will be an introduction to this research and elaborates on the research methodology. Part II is the theoretical background of the research in which the different concepts used within this research are elaborated. Part III shows the different modelling steps taken to build the model used for the simulations. Part IV is an elaboration on the different input variables of the model and shows the background information of the input variables. Part V starts with an introduction on the input variables of the model and shows the characteristics and results of the different simulations performed and the verification of the model. Part VI includes the discussion, limitation, conclusion, recommendations and reflection of the research. Within part VII the references, indexes of figures, tables and equation and the appendices are presented.

2 Research design

2.1 Research background

As explained in the previous chapter the basis of this research is found in previous research that is conducted by TKI. This research showed that more research is necessary on the topic of using BIM and mathematical models for new concepts in construction logistics. This research merely focuses on the logistics of the construction site itself in introduces a new concept of modelling the labour and movements of workforce into a BIM. It does this because it was found that the labour productivity on construction sites is relatively low.

Therefore, this research aims to solve the problem of low labour productivity by creating insight in labour and the movement of workforce with 4D-BIM. This results in the main research question being:

> 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.

2.2 Research 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 an 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 *het 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.

2.3 Case: *het Noordgebouw*

The case used for the data collection within this research is the construction project of *het Noordgebouw,* near the central station of Utrecht. A building of 23.000 m^2 and houses offices, dwellings, retail, restaurants/cafes and a hotel. Within this construction project, the main contractor is using BIM, and this model is enriched with the models of subcontractors.

Because the construction project itself is relatively large this research will narrow down on several aspects of the construction. Modelling all objects of the project into the 4D-BIM and add the labour and movements of workforce would be too time-consuming. Therefore, the choice is made to narrow to specific objects. This research will focus on the construction of the metal-stud walls used within the hotel of the building.

A large amount of data to conduct this research is provided by Dura Vermeer. First, the 3D-BIM is provided. Second, the site planning is modelled in BIM, through Dura Vermeer's own site planning library. Third, multiple schedules of Dura Vermeer were made available: the overall project planning is made available, and more detailed schedules such as week and employee schedules of the subcontractors. Fourth, Dura Vermeer provided access to the project team and subcontractors for interview to retain that was not available. Fifth, Dura Vermeer is fitted with an Autodesk licence, which helped to use the needed software.

2.4 Research methods

The research question is subdivided into the following seven questions.

1) Which definition and aspects of productivity to be used?
2) Which data is needed from all parties to be integrated into a 4D-BIM?
3) How to accurately model the data into a 4D-BIM with labour and movements of workforce?
4) What are the possibilities of visualising the data into a 4D-BIM with labour and movements of workforce?
5) How to model interventions into a 4D-BIM with labour and movements of workforce?
6) What is the simulated change in productivity?
7) Can this simulated change in productivity be proved by the physical project?

These seven questions are answered through different research methods, which will be described in the following paragraphs.

2.4.1 Literature review

Literature review was used throughout this research, for example to define productivity, to comprehend what data was needed to be able to model the project, and to understand what data needed to be used as input for the model.

2.4.2 Interview

An interview with the stud contractor was conducted to retain information on the typical workday of the metal stud contractor. Within this interview in typical day scheduling, working procedure, gang of workmen, and work schedule were examined. The interview was semi-structured, which means that preconceived questions were asked, but the stud contractor was able to elaborate on them.

2.4.3 Observation

Multiples observations were done in this research, most of which to quantify factors of the construction workers on the construction site of *het Noordgebouw*. For example, the walking speed of workers was observed on stairs, as was the traveling speed of the elevator. These observation results were used as input for the different variables of the model.

2.4.4 Modelling

With the help of literature review, interview and observations boundaries, variables and concepts where defined for the model. The software Dynamo, from Autodesk, was used to program the framework for the simulation of labour and movement of workforce. The model was programmed in several steps, and tested during the development.

2.4.5 Expert panel

After the model and simulations where performed, the results were handed over to an expert panel, with expert from different professions. They discussed the structure of the model and the results of the simulations.

2.5 Research organisation

This MSc thesis research is part of the mastertrack Management in the Built Environment. More specifically, is this thesis is part of the graduation lab Business model for Robotics in Construction which is chaired by the domain of Design and Construction Management.

Dr. Ir. Ruben Vrijhoef is the first mentor, based at the TU Delft at the department of Design and Construction Management. Vrijhoef is involved in the overall research conducted by TKI and arranged that this research became part of the graduation laboratory. Vrijhoef's experience with BIM and Lean Construction complements this research.

Dr. Ir. Alexander Koutamanis, based at the TU Delft at the department of Design and Construction Management is the second mentor. Koutamanis his experience with computational design, information management and BIM complements this research.

Dura Vermeer is the graduation company for this research. Dura Vermeer is a contractor in the Netherlands with its head office in Rotterdam. Arjen de Feijter, who is project manager construction logistics at Dura Vermeer, is the company's supervisor for this research. The research focusses on the construction of *het Noordgebouw*. Arjen de Feijter is also involved within the research of TKI.

part II

Part II will present the theoretical background of this research and is divided into four chapters. First, the concept of 4D-BIM and data provision is elaborated. Second, the measurement of walking paths is presented. Third, the classification of walk, wait, work used within this research is elaborated. Fourth, labour productivity in general and subdivisions in labour productivity are elaborated.

Theoretical background

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3 4D-BIM and data provision

3.1 4D-BIM at use

The empirical evidence of BIM's impact on project performance is sought after by organisations so they can justify the costs of transitioning to BIM. The increase of labour productivity by BIM is one of the reported benefits that can directly influence the organisations bid (Poirier, Staub-French, & Forgues, 2015). Therefore it is important for contractors and construction manager to be familiar with the methods leading to evaluate the productivity of the equipment and the labourers in different crafts (Shehata & El-Gohary, 2011).

BIM can help implement lean construction techniques in a better way. To ensure that work can be performed when the appropriate resources are on site, lean construction techniques require careful coordination between the general contractor and subcontractors. Doing so reduces the onsite availability of materials and minimizes effort. BIM reduces costs and allows for better collaboration at the job site (Eastman et al., 2011; O'Brien, 2003). By providing an accurate model of the design and material resources required for each segment of the project, it helps improve planning and scheduling of subcontractors, and helps just-in-time delivery of materials, equipment and people (Eastman et al., 2011).

Construction planning and scheduling involves sequencing of activities in space and time, this considers procurement, spatial constraints, resources and other concerns in the process. Traditionally, bar charts where used to plan projects, but these charts were unable to show the interdependency between different activities, and could not calculate the longest (critical) path method. The critical path method is mostly used today, with the help of software like Microsoft Project, Vico Control or Primavera Suretak. This software helps to create, update and communicate schedules using different kinds of report and displays. With this software the interdependencies between the different activities can be linked and allows for the calculation of the critical path (Eastman et al., 2011).

However, traditional methods do not adequately capture the spatial components related to these activities. They do not directly link to the design or building model, which causes that only people that are familiar with the project and the way of construction are able to see if the schedule is feasible (Eastman et al., 2011).

In the 1980's, large organisations developed 4D models and tools which were used in constructing complex infrastructure, power and process projects in which schedule delays or errors had significant impact on costs. From the mid 1990's, custom and commercial tools evolved. This was facilitated by manually creating 4D models with automatic links to three-dimensional geometry. With BIM schedulers are able to create, review and edit 4D models more frequently. This has led to the implementation of better and more reliable schedules (Eastman et al., 2011).

As indicated by Eastman et al. (2011), 4D models have several benefits. First, the planned construction process can be visually presented to other stakeholders in the project. With the 4D model, both the temporal and spatial aspects of a schedule are presented and this way of communication is more effective than a traditional Gantt chart. Second, 4D models provide a basis for multiple stakeholder impact. As it can function as a community forum to present to laypersons how a project might influence other aspects. Third, it helps planners with site logistics. In which its helps to coordinate laydown areas, access to and from within the site, location of large equipment like cranes and more. Fourth, it can help coordinate the trades on the construction project. It will assist planners with the coordination of expected time and space flow of trades on site as well as the coordination of work in small spaces. Fifth, project managers can compare different schedules easily, and the can quickly identify whether or not the project is behind schedule or on track.

Important for a 4D model to function properly, the three-dimensional model of the building has to be appropriate, so it can be linked to a project schedule. Experience and knowledge with 4D models is needed to understand the needed level of detail within the model to function at it's full potential. Within this there are several software, which establish these links (Eastman et al., 2011).

As BIM tools do not have the capability to model time a specific 4D model is needed. Appendix I shows an overview of available software packages. Within this overview the main capabilities and characteristics of the tools are shown.

3.2 Introduction to Dynamo

From this list of software introduced in the previous paragraph, initially Navisworks was chosen to perform the simulation. Because of its availability of licences and compatibility with Revit because of the same developer. Quickly was found that Navisworks did not support the customisability needed for this research. Therefore, a different software was used, which had large potentials of customisability and still has it relation with the Revit model. This software was Dynamo. According to Sgambelluri (2014) Figure 2 gives a schematic representation of what Dynamo is and does.

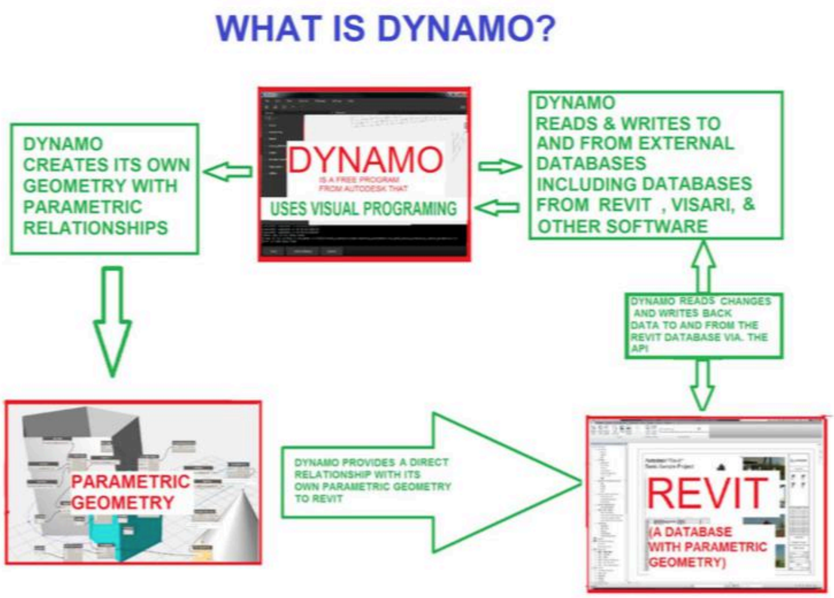

Figure 2: Overview of Dynamo (Sgambelluri, 2014)

Dynamo is a program software provided by Autodesk that uses visual programming. In principle it has two tasks, it creates its own geometry with parametric relationships. And reads and writes to and from external databases. Dynamo creates its own geometry and reads and writes to external databases. Simply put Revit is the database of parametric geometry to and from which Dynamo is able to write and read (Sgambelluri, 2014).

With the help of visual programming data can be extracted from Revit and with the functions in Dynamo the data can be used to perform different actions. The results of this data are shown in lists, these lists can be used accordingly with the different functions. Dynamo has a range of embedded functions, but additional packages can be downloaded, and own scripts can be written and used. The programming language used within this script is Python.

3.3 Data needed for simulations

According to J. P. Zhang and Hu (2011) the process of making a 4D-BIM can be divided into four steps. First, the building needs to be modelled in 3D. Second, a Work Breakdown Structure and corresponding schedules according to prearranged construction scheme needs to be created. When assembling the time schedule of the construction project each task needs to be determined. The duration of the activities depends on the quantity, and other parameters like construction method, complexity of the project, boundary conditions, assigned personnel resources and equipment (Tulke & Hanff, 2007). Third, the 3D models need to be divided into construction segments in accordance with the Work Breakdown Structure. Fourth, the segments need to be linked to the corresponding Work Breakdown Structure nodes and schedules (J. P. Zhang & Hu, 2011).

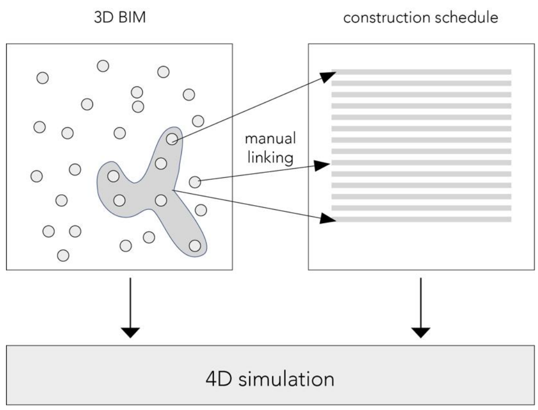

Figure 3: Relationships between 3D-BIM and schedule tasks adapted from Tulke and Hanff (2007).

Next, the 4D-model with the labour and movements of workforce needs to be drawn up. In a similar case 4D-BIM was used to control safety problems during construction. To get this enriched model, three steps were taken. First, the 4D-BIM was enriched by appending project properties, e.g. resources, site layout, construction activities, schedules, processes, etc. Second, linking elements to material properties, control parameter for meshing, extended the structural information, activity-based loads etc. Third, the 4D structural information model was established by organic and automatic integration of the information mentioned in the previous steps (J. P. Zhang & Hu, 2011).

In the BIM preparation, considering object-based modelling, all building objects should associate with specific object type and attributes. This information forms the basis for checking geometric features. Therefore, this information requirement is stricter when used for 4D-BIM then the existing 2D drawing and 3D modelling requirements. Compared to an existing BIM application, as BIM-based quantity take-off or clash detection, is that each building object carries information, for example, object name, type, attributes, relationships and metadata including object identification number, date, and author creating model elements (S. Zhang, Teizer, Lee, Eastman, & Venugopal, 2013).

Schedule data needs to be linked to the building object since the assigned protective system needs to be updated accordingly. In addition, the spatial structure to each building object needs to be well organised, e.g. by floor or sections. Which helps to classify the model and space constraints more easily. This means that parametric model is a necessary condition to extract the required values (S. Zhang et al., 2013).

Using this 4D-BIM to model labour and movement of workforce can be drawn up into three steps. These three steps are adopted from the research of J. P. Zhang and Hu (2011) in which 4D-BIM is used for the control of safety problems during construction.

Step one considers the basic information. Which is the basic 3D geometry discussed earlier. It needs to meet basic BIM applications: the objects need to carry all the basic information. For example, object name, type, attributes, relationships and metadata including object identification number, date, and author creating model elements (J. P. Zhang & Hu, 2011).

Step two considers the 4D information. Within this step addition information is added to the model in which the Work Breakdown Structure is used to link the object with activities in the schedules. Additional information needs to be provided as well as resources, site layout, construction activities, schedules and processes (J. P. Zhang & Hu, 2011). Within this schedule the work needs to be broken down in accordance to the object modelled. The information coming from the schedule needs to be the starting point of an activity and the end point of an activity, which defines the durations. The site layout needs to entail the drop off or storage place of materials, as is the place where equipment is installed, dropped off or stored.

Step three differs from the approach given by J. P. Zhang and Hu (2011). Within this step, additional information specifying the structural aspects of the components, e.g. types, profiles (including area, centroid, moment of inertia), local axes, materials, loading conditions is provided. With this information computer programs could build up structural analysis models. When applying this to the addition of labour and movements of workforce additional information is needed as well. The sequence of these three steps, and thus an overview of the needed data, is represented in Figure 4.

3D BIM	basis	**Object.**		**X**
		Properties.	Coordinates.	XYZ
			Measurements.	Width,Length,Height
			Material.	aplha
			[Additional basic object information]	
4D BIM	project parameters	**Object**		**X**
		Activity		aa.bb.c.d
			Startpoint	dd-mm-yyyy hh:mm
			Endpoint	dd-mm-yyyy hh:mm
			Duration	[endpoint - startpoint]
		Site lay-out		
		Materials	Location	XYZ
			Delivery	dd-mm-yyyy hh:mm
		Equipment	Location	XYZ
			Delivery	dd-mm-yyyy hh:mm
			Removal	dd-mm-yyyy hh:mm
4D BIM with labour and movements of workforce		**Object**		**X**
		Activity		aa.bb.c.d
		Workmen	Amount	y
			Code	specialism
		Measured	Startpoint	dd-mm-yyyy hh:mm
			Endpoint	dd-mm-yyyy hh:mm
			Duration	[endpoint - startpoint]

3D BIM	**Object.**		**Lavatory type B**
	Properties.	Coordinates.	1236;4567;10
		Measurements.	210;3600;3200
		Material.	Stone
		[Additional basic object information]	
4D BIM	**Object**		**Lavatory type B**
	Activity		46.10.2.6
		Startpoint	21-07-2017 07:30
		Endpoint	21-07-2017 08:30
		Duration	1 hour
	Site lay-out		
	Materials	Location	345;74849;9292
		Delivery	20-07-2017 17.00
	Equipment	Location	223;47458;22
		Delivery	21-07-2017 07:30
		Removal	21-07-2017 08:30
4D BIM with labour and movements of workforce	**Object**		**X**
	Activity		46.10.2.6
	Workmen	Amount	2
	Code	Plumber 1	
			Plumber 2
	Measured	Startpoint	21-07-2017 07:40
		Endpoint	21-07-2017 08:15
		Duration	35 minutes

Figure 4: Showing the different data needed throughout the three steps. Left: the general framework. Right: an example of framework filled in for an activity.

Within the next paragraph, the use of this data is elaborated to accurately model labour and movement of workforce in 4D-BIM.

4 Walking paths

4.1 Measurement of walking paths

The measurement of walking paths can be done along different routes. The following paragraph will elaborate on the computerization of walking paths and the measurements systems used.

4.1.1 Computerization of walking paths

The architectural computerization of pedestrian circulation is relatively neglected. Following Koutamanis et al. (2001) five reasons can be stated.

First, the high complexity of dynamic human interaction with buildings. During the transition from one space to the other humans process a wide spectrum of information to make the decision where to go. In this process, they take conscious and unconscious actions relating, not only to the purpose of movement, but also to different contexts at the same time.

Second, the computer simulations are highly complex in terms of reproducing dynamic human interaction with buildings, which require high precision and accuracy as well as computational power for implementation, testing and use (Koutamanis et al., 2001).

Third, the lack of availability in comprehensive and integrated data of the dynamic human interaction with buildings. There is no unified verifiable body of data available that could drive computer simulations of human movement in the built environment available. Nevertheless, technologies for capturing human movement and the extend of relevant cognitive and ergonomic research is available (Koutamanis et al., 2001).

Fourth, programmatic and functional analyses are relatively weak. For pedestrian simulation or evaluation of designs produced on the basis of the building brief insufficient guidance is given by the building brief. This is elaborated in the normative abstraction of building codes and general professional guidelines. Most analyses of designs and programs appear to accept the reductive logic of such codes and guidelines (Koutamanis et al., 2001).

Fifth, there is a lack of integration with design synthesis. The representations and other data used in analyses are frequently kept separate from the instruments and environments used in synthesis. The result is that performing the analysis becomes a tedious, redundant task, and there is a lack of direct feedback that constrains the further developments of designs. Therefore, computational design is by the designer seen as a cumbersome, time consuming alternative to intuitive analysis (Koutamanis et al., 2001).

The simulation and analysis of a dynamic subject, like pedestrian circulations, relies on a representation consisting of a number of interrelated components, as presented by Koutamanis et al. (2001) in Table 2.

Table 2: Route analysis data (Koutamanis et al., 2001)

Actors	One or multiple persons who travel.
Starting point	The location from where one or multiple actors depart. In buildings, the centroid of a space can be seen as starting point or a doorway. Multiple starting point indicate an aggregation of routes.
Destination	The endpoint of an actor, the place it wants to end at. Multiple destinations are not necessarily product of aggregation, a route can also have intermediate destinations. Points like stairs, elevators, cam be seen as intermediate destinations.
Path	The path has a starting point and destinations which can be complemented by intermediate destinations. The path can be the actual path or an approximation of it by for example the straight-line or city-block method.
Means of transportation	How movement is achieved along the path, this includes the speed the actor travels at and the capacity of these means.
Activities	These are the activities that take place along the path. Two options appear: activities related to the transportation; or the intervening opportunities, such as relations to other routes or other activities and actors in the building.

In addition to Koutamanis Wu and Chen (2012) found that for the route analysis multiple data is needed. This was done by node and edges, in which node represented a location and an edge represents path. The node consists of the following data: an identifier, 3D-position (x- y- and z-coordinate), a floor, a name and walking speed. And edge contains: an identifier, a start node, an end node, a name, a length, a walking speed and traversal time. These values are comparable with the value presented by Koutamanis et al. (2001).

Wayfinding analysis at low dimensionality (for example mostly relating to the internal interactions of pedestrians and streams) and a relatively high abstraction provides useful insights into the potential of autonomous mechanisms in circulation simulation. Nevertheless, the complexity of interaction in real buildings appears to be too high for effective and reliable solutions yet (Koutamanis et al., 2001).

Wu and Chen (2012) conducted research on 3D spatial information for fire escape routing. Within this research the authors developed a method to quickly locate destinations and show the shortest and safest path to the destination. The locations, the x- and y-coordinates, for rooms and stairs are derived from the centroids of the polygon. This results in a x- and y-coordinates that indicate the centroid of a certain space. The z-coordinate of the space is obtained from the elevation where the space is located.

For mapping the hallway, a long rectangle, Wu and Chen (2012) used an algorithm that computed the medial axis of a simple polygon. The distance from one space to the nearest exit is calculated by a straight line, from the centre of the space; to the centre of the door opening; to the medial axis of the hallway. As schematised in Figure 5.

The distance from point P to L is calculated with the help of a projected point, called P'. Formulas are used to compute the distance from P to L. When the coordinates of the project point P' are known, the distance from P to P' and form P' to L can be calculated. Together with the Pythagorean theorem this can be used to calculate the distance between P and L, which will be discussed in the following paragraph.

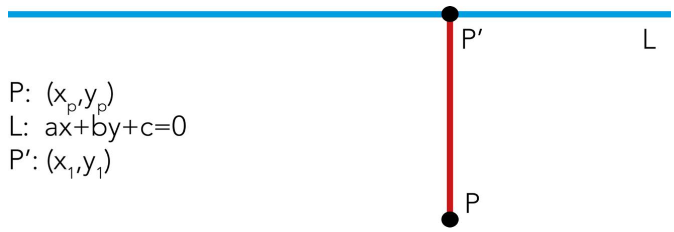

Figure 5: Projection of point onto edge; adopted from Wu and Chen (2012).

4.1.2 Euclidean distance

The distance calculated by Wu and Chen (2012) can be described as the Euclidean distance, as shown in Figure 6. The Euclidean distance, also called straight-line distance, is inspired by the real world distance, namely the distance on the ground (Pan et al., 2013). The Euclidean distance is the square root of the sum of squared differences in the variables' values (Sarstedt & Mooi, 2014), which can be identified as the Pythagorean theorem.

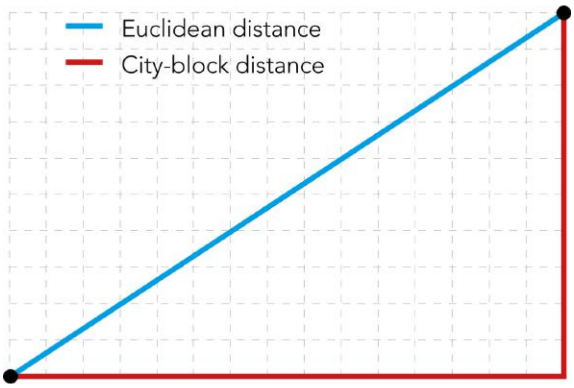

Figure 6: Overview Euclidean and City-block distance; adopted from Sarstedt and Mooi (2014).

4.1.3 City-block distance

Another distance measurement is the city-block distance. The city-block uses the sum of the variables' absolute differences. This is often called the Manhattan metric as it is relating to the walking distance between two points in a city like New York's Manhattan district, where the distance equals the number of blocks in the directions North-South and East-West (Sarstedt & Mooi, 2014).

City-block distance calculates the distance that would be travelled to get from one location to the other if a grid-like path is followed, like the Manhattan-grid. In modern cities the city-block distance is more close to the real distance (Pan et al., 2013). Manning et al. (2006) found that when a direct path is possible, the ideal path distance is equal to the city-block distance. Therefore, the city-block distance is a better representation of a real-world distance, than the Euclidian distance.

The Euclidian and city-block distance measurement systems explained above are only applicable in a single flat plane.

4.2 Mathematical backbone

Dynamo models can get complicated to work with, as they get more complex. To help the programmer understand the Dynamo model, a certain backbone can help overcome this. The following figures, equations and elaboration served as backbone for this Dynamo model.

As defined in previous paragraphs, the distance between two points can be calculated in different ways. Two of these distance measurement systems are the Euclidian distance and the City-block distance. These two measurement systems are included in the Dynamo model. To understand the steps that have to be taken in the model, the two measurement systems will be translated into equations, as envisioned in Figure 7.

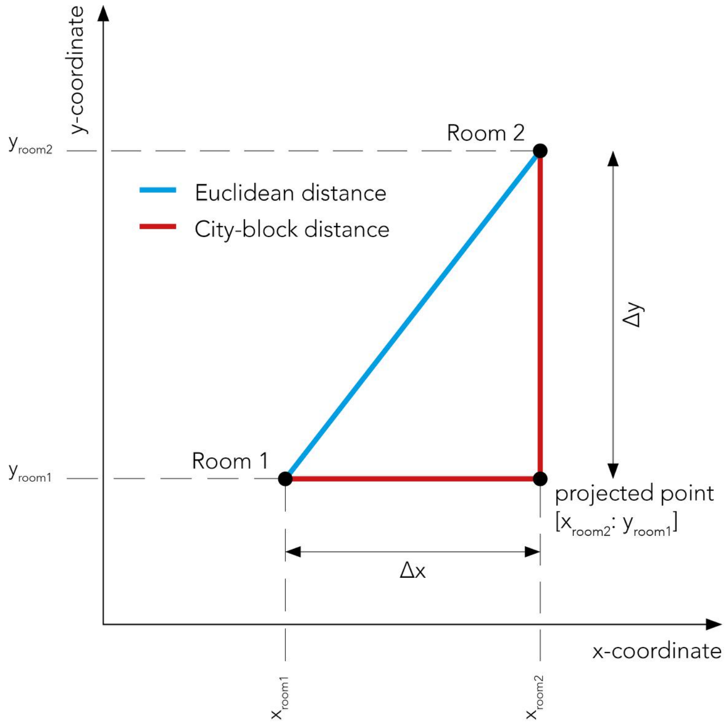

Figure 7: Mathematical data of rooms visualised

Two rooms are introduced in Figure 7, Room 1 and Room 2. These rooms are resembled in a single point. From these two rooms the x- and y-coordinates are resembled on the x- and y-axis. This results in the coordinated for Room 1 and Room 2.

Table 3: Room coordinates

	Coordinates
Room 1	$[x_{room1}, y_{room1}]$
Room 2	$[x_{room2}, y_{room2}]$

To calculate the Euclidian distance, which is the straight line between Room 1 and Room 2, Dynamo has two options. First, it has the imbedded option to automatically calculate the length of the line between two points. Second, it can calculate the distance via a mathematical formula which can be programmed in Dynamo. For this mathematical formula, the Pythagorean theorem can be used. To do so the distance travelled in x-direction and in the y-direction needs to be calculated. Therefore, a projected point is needed, that established a triangle with one corner of 90 degrees. This is done with the projected point. This projected point, is a combination of the coordinates from Room 1 and Room 2. Note that this projected point has two options; the projected point in the bottom-right as it is projected in the figure above; or in the top-left, both points will give identical answers.

Table 4: Room coordinates with projected point

	Coordinates
Room 1	$[x_{room1}, y_{room1}]$
Room 2	$[x_{room2}, y_{room2}]$

Projected point	$[x_{room2}, y_{room1}]$

With the introduction of this projected point the distance between Room 1 and Room 2 in x- and y-direction can be calculated. This distance will be called Δx and Δy, as Δ indicated the difference between two values. To calculate the Δx and Δy the following formulas apply.

$$\boxed{\Delta x} = \boxed{x_{room2}} - \boxed{x_{room1}}$$

Equation 1: Difference in x-axis

$$\boxed{\Delta y} = \boxed{y_{room2}} - \boxed{y_{room1}}$$

Equation 2: Difference in y-axis

To calculate the Euclidean, distance the following formula can be used:

$$\boxed{Distance_{Euclidean}} = \sqrt{\left(\boxed{x_{room2}} - \boxed{x_{room2}}\right)^2 + \left(\boxed{y_{room2}} - \boxed{y_{room2}}\right)^2}$$

Equation 3: Euclidean distance with all values separate.

$$\boxed{Distance_{Euclidean}} = \sqrt{\boxed{\Delta x}^2 + \boxed{\Delta y}^2}$$

Equation 4: Euclidean distance combined with previous equations

This formula serves as the basis on which the Dynamo model can be build up to measure the Euclidean distance.

Furthermore, the city-block distance can be calculated with the help of several previous defined variables. To calculate the city-block distance the distance travelled between Room 1 and Room 2 in both x- and y-direction is summed up. With the help of the previous defined formulas the formula of the city-block distance is defined as follows:

$$\boxed{Distance_{City\text{-}block}} = \left(\boxed{x_{room2}} - \boxed{x_{room2}}\right) + \left(\boxed{y_{room2}} - \boxed{y_{room2}}\right)$$

Equation 5: City-block distance with all values separate

$$\boxed{\text{Distance}_{\text{City-block}}} = \boxed{\Delta x} + \boxed{\Delta y}$$

Equation 6: City-block distance combined with previous equations

With the help of the equation for the Euclidian distance and the city-block distance the mathematical backbone for the framework is set. These equations will be used within the Dynamo model.

5 Walk, Wait, Work

As introduced by Koutamanis et al. (2001) six categories of data are need for route analysis: actors; starting point; destination; path; means of transportation; and activities. Meaning that construction workers walk, or with other modes of transport get from one space to the other and along. Between these point is a certain path that the construction worker has travelled and during this path he can have done different activities. For example, he has executed construction activities or has waited for an elevator. This path analysis can be broken down into three categories: walking; waiting and working. In the next paragraphs, these three categories will be elaborated.

5.1 Walking categories

To get from one point to the next the workers have to travel a certain path. By which means of transport, the worker travels this path can be different along the length of the path. On the construction site of *het Noordgebouw* three means of transport for the construction worker are available. Walking along a horizontal surface; walking through the stairwells; and, travelling vertically by elevator. Deeper understanding of these three means of transport is given in the following paragraphs.

5.1.1 Horizontal walking

As introduced previously this sub-category contains the walking of the construction worker in horizontal sense. Walking on the different floor levels of the building and on the construction site itself. The distance travelled is measured by the city-block method, as introduced in Chapter 4. Together with the average walking speed the total horizontal walking time can be calculated. The walking speed will be later introduced in Chapter 11.

5.1.2 Vertical travel by stairs

Taking the stairs takes a construction worker to a different level of the building and on the construction site itself. Traveling by stairs is similar to walking along a horizontal surface. The difference lies between the calculation of distance travelled and average speed. The calculation of the distance travelled, and the average speed will be further elaborated in Chapter 11.

5.1.3 Vertical travel by elevator.

A construction worker can also get to a different level of the building by taking the elevator. This option may be preferred over the stairs when a large number of levels need to be bridged, (or when a construction worker prefers to retain his or her energy). The average speed of the elevator is used together with the vertical distance travelled to calculate the total time needed to transport the construction worker from point A to point B. The calculation of the average speed of the elevator will be elaborated in Chapter 12.

5.2 Waiting categories

Some points on the construction site produce a certain waiting time. One of these point is for example the elevator, in which the construction has to wait an average time before the elevator is available to use. But this waiting can also be introduced to places like the rest-break areas or the toilets, where the construction worker spends a certain amount of time in a certain place.

The waiting time entails the time the construction worker stays static on a certain point, but does not perform any (semi) value adding activities.

5.3 Working categories

In certain point, or rooms, in the building the construction worker has to perform certain activities that add value to the project. These activities are performed on a certain location and specified within the construction schedule and specifications. The construction workers perform these activities on this location for a certain amount of time on a day. The amount of time the construction worker is working in these locations, or rooms as the can be called, is further elaborated in Chapter 13.

Figure 8: Construction workers waiting on the elevator on the site of *het Noordgebouw*.

6 Defining labour productivity

In this chapter, a general introduction to labour productivity is given, which can be used within this project. Furthermore, the labour productivity is related to the three categories of walking, waiting, and working as introduced in the previous chapter.

6.1 Productivity in general

Contractors at the project site are often interested in labour productivity. Contractors estimate the cumulative productivity under which the work will be carried out. If the work is awarded to the contractor, the need to ensure that the estimated level of productivity is achieved or improved (Thomas et al., 1990). Productivity can simply be illustrated as the association between output and input. Previous studies show two definitions of productivity of productivity. One, productivity is output/input, and two, productivity is input/output (Park, 2005). Productivity is input/output is widely used within the existing literature on productivity in construction (Forbes & Ahmed, 2011; Park, 2005; Poirier et al., 2015; Thomas et al., 1990). To maintain consistency with other research of productivity this is the chosen definition of productivity.

$$\text{productivity} = \frac{\text{input}}{\text{output}}$$

Equation 7: General definition of productivity

On site level, the process of converting the input and output can be complex (Thomas et al., 1990). The system in Figure 9 shows that there are multiple internal and external influences as well as undefined disturbances.

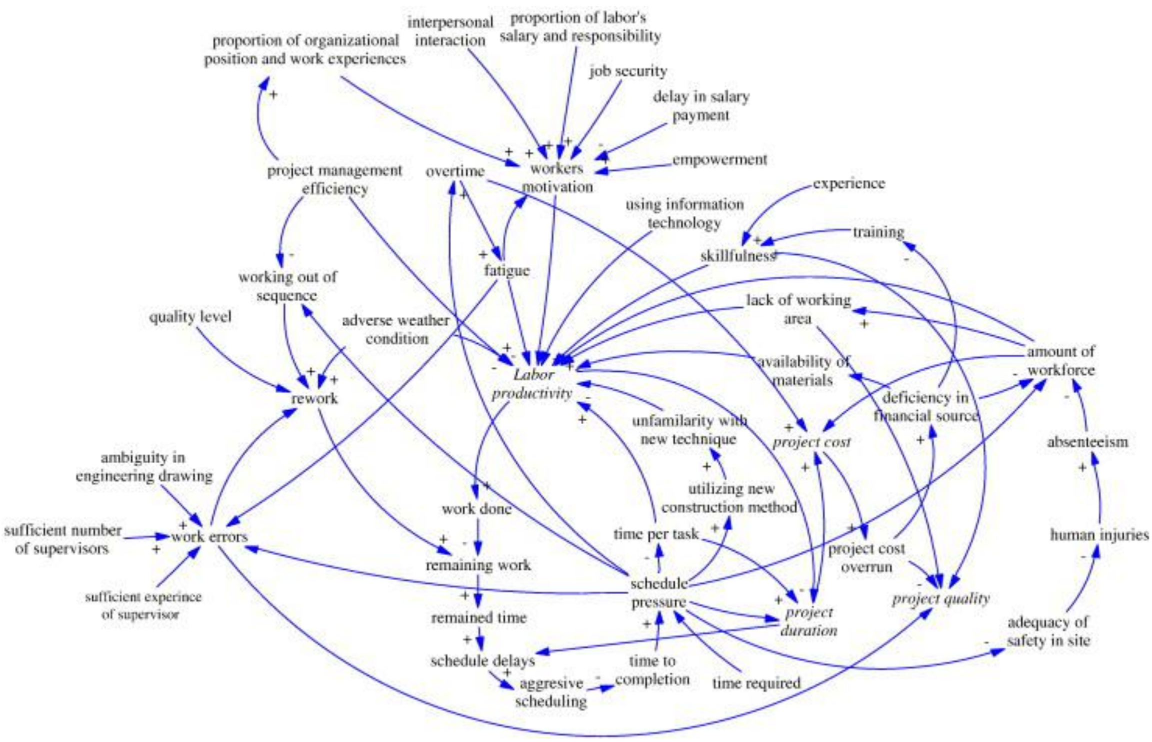

Figure 9: Conceptual model of labour productivity (Nasirzadeh & Nojedehi, 2013)

According to Park (2005), labour productivity is measured in the actual work hours per installed quantity, which is the number of actual work hours required to perform the appropriate units of work. When thus defined, lower productivity values resemble better productivity performance (see equation Equation 8).

$$\text{labour productivity} = \frac{\text{input}}{\text{output}} = \frac{\text{actual work hours}}{\text{installed quantity}}$$

Equation 8: Labour productivity according to Park (2005)

According to Thomas (2015, p. 3) two aspects are important to good labour productivity: "what is produced in a finite period of time / output (quantities and the craft hours over the same period of time need to produces the output/input (WHs)." The most common and recognized measure of labour performance in construction is the unite rate (Thomas, 2015) which is defined in Equation 9.

$$\text{labour productivity} = \frac{\text{input}}{\text{output}} = \frac{\text{working hours}}{\text{units of work}}$$

Equation 9: Labour productivity Thomas (2015)

Comparing the two equations given by Thomas (2015) and Park (2005) they are similar. The two formulas presented are comparing the input, which are the actual working hours; and the output, which are the units of work. This resembles the same, as it is related to the turn out of the construction workers. The definition used within this research is shown in Equation 10.

$$\text{labour productivity} = \frac{\text{input}}{\text{output}} = \frac{\text{total working time}}{\text{productive time}}$$

Equation 10: Definition of labour productivity used within this research

The definition used within this research is shown in the equation above, which is derived from the previous equations. The formulas are basically the same, that the compare the total working hours with the production made by the construction workers. The quantity of work or units of works as defined by Park (2005) and Thomas (2015) is quantified in the productive time. Which resembles the same, as it is related to the turn out of the construction workers.

Productive time is well-connected to output and productivity. If the productive time is known, the output of construction can be calculated. For instance, waiting time is also related to productivity, productivity thereby improves when waiting times are reduced or by reducing the delays, the productive time is increased (Thomas et al., 1990). Reducing waiting time does not inherently mean an increase of productivity in practice. Construction workers work a certain amount of time a day. When reducing the waiting time, this time can be spent on productive activities. Thus, productivity increases since the total working time stays the same.

Furthermore, this definition is used for the measurability of the research. As this research focuses on the modelling of labour and movement of workforce and its ability to increase labour productivity, it is hard to express movements of workforce in term of units of work or installed quantity. However, the movement of workforce can be expressed in terms of time, as movements have a travelled distance and speed for example. Therefore, the definition of labour productivity, as shown in Equation 10 is used within this research.

6.2 Gradations in productivity

In the preceding paragraph the definition of labour productivity within this research is given. As the output is measured as productive time the difference between productive and unproductive time needs to be defined.

As in the manufacturing the waste is 12% of the total amount of time, with the rest being productive time. In the construction industry, this time wasted is between 53-60% (Aziz & Hafez, 2013; El Asmar, 2012; Platform Logistiek in de Bouw, 2014). In general, the waste of production is seen as all activities that directly or indirectly produce costs but do not add value to the product from a client point of view (Aziz & Hafez, 2013). Within this waste is seen as activities that do not add value to the client's end product. More specifically it can be defined into value adding and non-value adding activities. Value adding activities are those, which convert materials and/or information in the search to meet client's requirements. Non-value adding activities, those which are time, resource, or space consuming, but do not add value to the product (Aziz & Hafez, 2013).

El Asmar (2012) present the value-added and non-valued added categories in a typical workday. In Figure 10 the figures are presented, which shows that, only 41% of the work is value adding.

The other part, adding up to 59%, can be seen as waste. This figure gives a more tangible view on activities that contribute to value added and non-value-added activities.

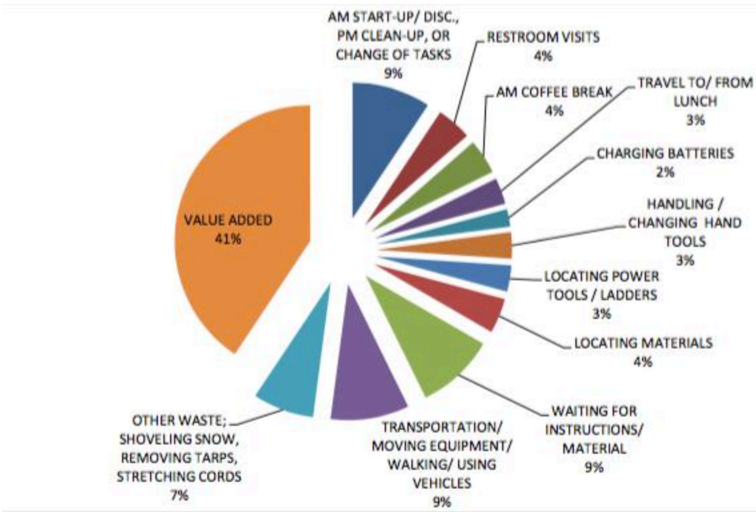

Figure 10: Value-added versus non-value added categories in a typical workday (El Asmar, 2012).

Vrijhoef (2016) and Eaton (2013) show that the activities can be divided into three categories. First, productive time, which is time that adds value to the product. Second, unproductive time, Muda type 1: time that is used for activities that indirectly add value. Third, unproductive time, Muda type 2: not necessary and not value adding. Muda is a Japanese word meaning waste. It is a commonly used definition within lean practices.

According to Aziz and Hafez (2013) integrating lean principles and computer simulation techniques can be useful and workable to streamline the construction process for improved productivity, efficiency and costs effectiveness. Lean is being defined as a framework to design productions systems that minimize the waste of materials, time and energy to deliver the greatest value (Koskela, Howell, Ballard, & Tommelein, 2002). Lean management is dedicated to address shortcomings and improve the entire design and construction process. Therefore lean management does not only apply to the construction phase of the project (Forbes & Ahmed, 2011; Koskela et al., 2002).

Traditionally industry practices have separated the roles of designers and constructors, the Lean Projects Delivery System as a continuum for project management to achieve three fundamental goals (Forbes & Ahmed, 2011). The goals are focused on the improvement of the construction process by deliver the product to customers' demands, maximize value and minimize waste (Forbes & Ahmed, 2011; Koskela et al., 2002).

According to Koskela et al. (2002) there are 11 principles that can be used make lean applicable to the construction industry:

- Reduce the amount of non-value adding activities;
- Increase the output value by systematically considering the wishes of the client;
- Reduce the amount of variation;
- Reduce the run times;
- Simplification by reducing the number of steps, elements and relations;

- Increase the output flexibility;
- Increase of transparency within the process;
- Focus and control on the entire process;
- Constant improvement of the process;
- Balance flow improvement;
- Benchmark and criteria.

Lean suggests that by the use of lean three main problems in the production system will be eliminated. Namely, waste (Muda), instability, and, variation (Mura) (Eaton, 2013). These problems reduce the efficiency of the system with a negative effect on quality, costs and delivery time (Koskela et al., 2002).

Alarcón (1997) presented a division between productive work, contributory work and non-contributory work. Contributory work can be identified as Muda 2, as it related to work that does not directly add value but is necessary to execute the job. Non-contributory work can be identified as Muda 1 as it does not add values. The ratio between these three is shown in Figure 11.

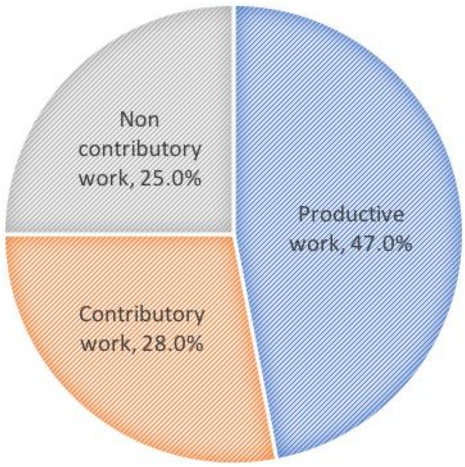

Figure 11: Ratio between the productivity categories adopted from Alarcón (1997)

6.3 Division of productivity categories

Loera et al. (2013) divides the value and non-value adding activities into five categories: productive, preparation, work supplements, unproductive time and administrative aspects. One, productive in includes all activities that give an added value to the product or service, these are all operations in which any work is being performed on materials or parts, such as welding, painting, cutting, etc.

Two, preparation includes all activities necessary to carry out productive work but do not give added value to the final product or service. Such activities include: preparation of the work area, machines or tools. This category also includes security-related activities, such as safety talks or waiting for safety clearance (all these activities pretend to reduce time).

Three, work supplement includes the activities that are related to the recovery of physical activity due to the nature of work, such as, working tirelessly in the sun, drink water or rehydrating beverages or physiological activities; all of these activities within the range time allowable (according to the standards set by the safety area). In general, recovery time due to the nature of the work.

Four, unproductive time includes all activities that do not add value to the final product, in this case downtime is attributable to the operator. These are classified in leisure activities, talking, more time of rest and meal than permitted.

Five, administrative aspects include activities which are related with unproductive time not attributable to the operator like: Inactiveness because of lack of material (poor planning of materials), inactive due to lack of equipment or personnel (poor resource planning), idle by waiting for instructions (poor planning of activities). It is also included transfer activities by item (poor distribution).

The three categories introduced by Eaton (2013); Vrijhoef (2016) to the five categories presented by Loera et al. (2013) are related within the following table.

Vrijhoef (2016)	Loera et al. (2013)
Productive time	Productive
Muda 1; indirectly adding value	Preparation Work supplements Administrative aspects
Muda 2; not adding value	Unproductive time

Table 5: combining activity categories of Vrijhoef (2016) and Loera (2013)

Relating these categories of activities to the definition of labour productivity given in Equation 10 the following figure applies. This figure shows how the different activities of construction workers can be traced back to the definition of labour productivity. As the different activities will add up, productive time and unproductive time will form the total working time.

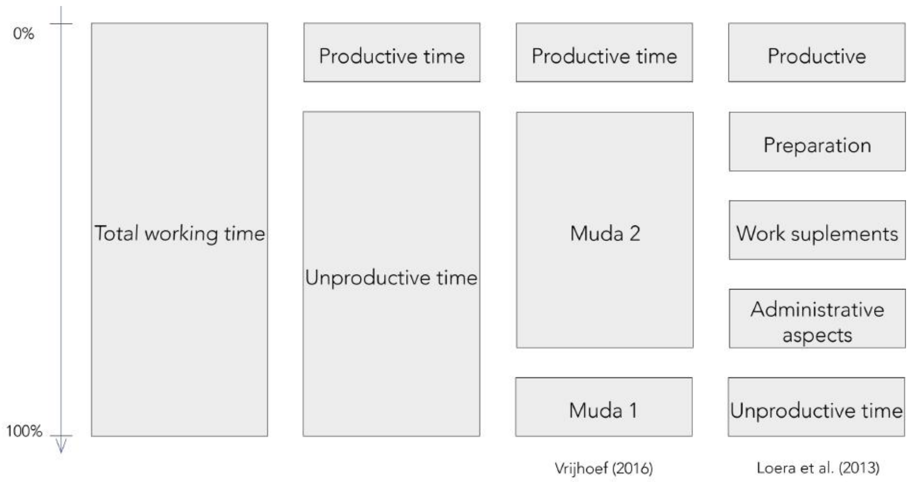

Figure 12: Combining the different categories with the definition of labour productivity (note: not drawn on scale, boxes are only indicative).

The five categories of activities are not weighted. To give insight into the ratio between, productive, Muda 1 and Muda 2 these have to be weighted. This is visualised in Figure 14 and Figure 15 for respectively the figures provided by Alarcón (1997); El Asmar (2012). This shows the ratio between and build-up of the different categories. Appendix 2 shows a more detailed breakdown and the classification of the typical workday presented by El Asmar (2012).

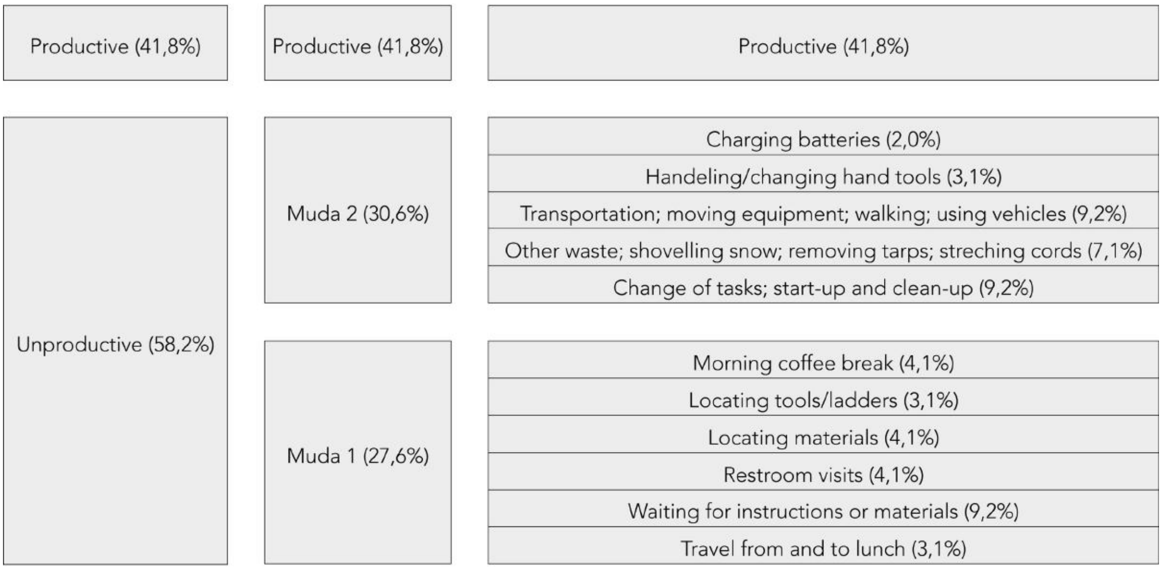

Figure 13: Division of typical workday presented by El Asmar (2012) on three productivity categories

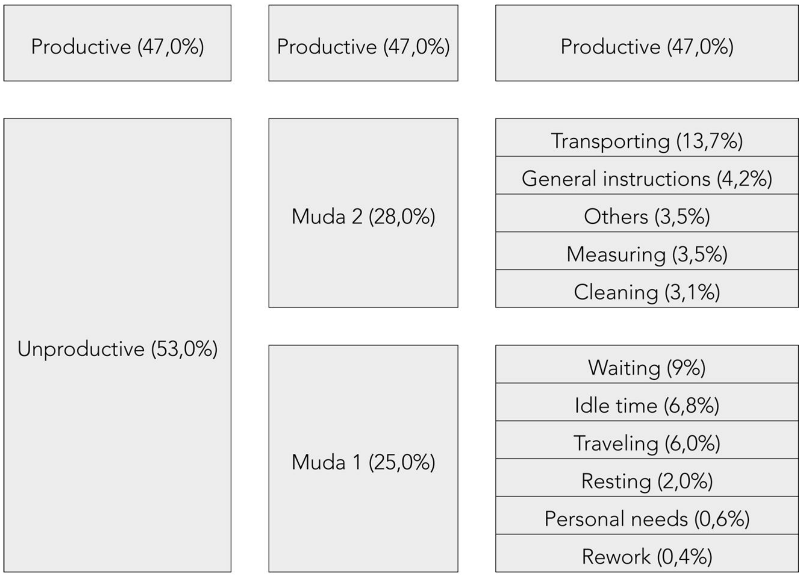

Figure 14: Division of categories of waste presented by Alarcón (1997) on three productivity categories.

6.4 Relating productivity to walk, wait and work

In the previous chapter the categories of walking, waiting and working were introduced. Within the simulations these three categories are used to divide the different movements and activities of the construction worker.

Figure 12 presented the different categories within labour productivity and a subdivision. The following figure is an elaboration on Figure 12. Within the figure the implication of: productive, unproductive time; work supplements; preparation; and administrative aspects; are presented. Within these categories the working, waiting and walking time can be divided. As described in the previous chapters how these times are defined and calculated.

Figure 15: Different categories of labour productivity broken down to measureable factors (note: not drawn on scale, boxes are only indicative)

The categories of preparation and administrative aspects are scaled under Muda 1, and are indirectly adding value. And are not part of the productive time, a change in walking or waiting time will therefore affect the productivity. Since the working time in a room stays constant, because the nature and amount of the work that needs to be executed does not change. But the walking paths or waiting times can be changed, i.e. by changing the layout of the construction site. By keeping the working time constant but changing Muda 1-factors, the total amount of time changes but and therefore the ratio between productive and unproductive, and thus the productivity.

A rearrangement of the broken-down activities, which are elaborated in the previous paragraph, the ration between walking, waiting and workings can be established. This rearrangement is visualised in the following figure. In which the activities are divided between walking, waiting and working. Figure 17 shows the sum of the activities divided between working, waiting and walking. This ratio will help to identify and verify the simulation which are performed in the upcoming part of this research.

The reasoning behind the division of activities into different categories is as follows: all activities that are of stationary nature, thus the workers staying at one specific place, fall under waiting time; activities that involve movements are placed under walking time. Other activities are placed under working time.

	Alarcon (1997)	El Asmar (2012)
Working time	Productive (47,0%)	Productive (41,8%)
	General instructions (4,2%)	Charging batteries (2,0%)
	Others (3,5%)	Handeling/changing hand tools (3,1%)
	Measuring (3,5%)	Other waste; shovelling snow; removing tarps; streching cords (7,1%)
	Cleaning (3,1%)	Change of tasks; start-up and clean-up (9,2%)
	Personal needs (0,6%)	Locating tools/ladders (3,1%)
	Rework (0,4%)	Locating materials (4,1%)
Walking time	Transporting (13,7%)	Transportation; moving equipment; walking; using vehicles (9,2%)
	Traveling (6,0%)	Travel from and to lunch (3,1%)
Waiting time	Waiting (9%)	Morning coffee break (4,1%)
	Idle time (6,8%)	Restroom visits (4,1%)
	Resting (2,0%)	Waiting for instructions or materials (9,2%)

Figure 16: Division on working, walking and waiting

	Alarcon (1997)	El Asmar (2012)
Working time	62,3%	70,4%
Walking time	19,7%	12,3%
Waiting time	17,8%	17,4%

Figure 17: Division on working, walking and waiting

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part III

This part shows the implementation of Dynamo within this research and is divided into two chapter. In the first chapter the modelling backbone is presented. In the second chapter the different steps of the Dynamo model are presented and elaborated.

Implementing Dynamo

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7 Modelling backbone

7.1 Introduction to the modelling backbone

As basis for the final model a backbone is necessary to know which steps have to be taken in which order. In Figure 18 this overview is given, within this overview the flows of information needed, and data generated are elaborated. A full-scale version can be found in Appendix 3.

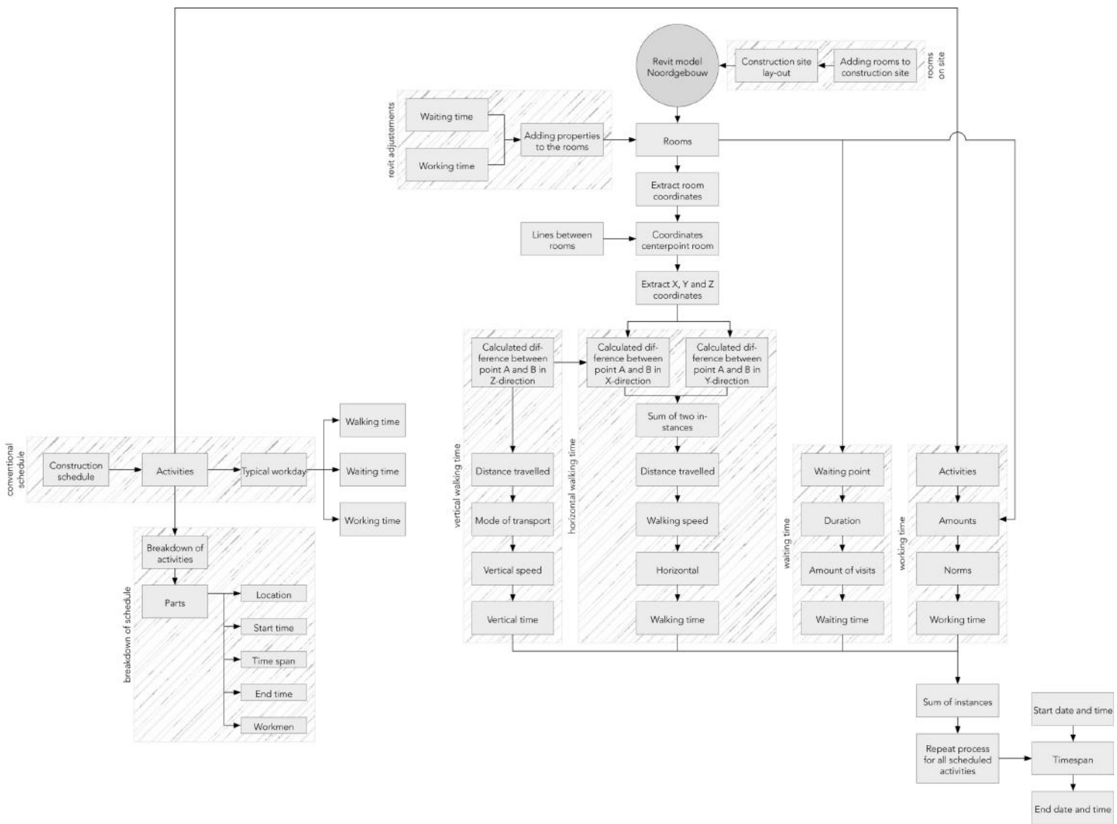

Figure 18: Overview of Dynamo backbone

7.2 Explanation of modelling backbone

The backbone starts with the Revit model. This is the Revit model of the case used within this research *het Noordgebouw*. First, additional information needs to be added to the model, of which the construction site layout is one. Second, is the addition of the waiting and working times of certain rooms.

The next step is to read out the rooms, and the room location, with its coordinates. With the help of the rooms the lines of the travelled path can be drawn. These coordinates of the rooms can be used to calculated different distances. The vertical distance together with the means of transport, and the average speed related to that mean of transport gives the time needed for the vertical travel.

The horizontal walking distances need the addition of the city-block method, for which the X and Y-coordinates are needed. The distance calculated is then used together with average walking speed to calculate the walking time over a horizontal distance.

The waiting time of certain rooms is added to the Revit model. This waiting time is then used with the rooms which are passed by the construction worker and the amount of time he passes these rooms. Adding up these individual waiting times the total waiting time is calculated.

The working time is also added to the room. This resembles the norm and the amount of work that needs to be executed within the rooms. And gives the amount of time needed to execute the activities in a certain room.

The rooms that the construction workers visits are resembled in the typical workday. This typical workday is derived from the construction schedule. To which the activities are elaborated with the location and amount of people.

Adding up the walking, working and waiting times gives the total amount of time the construction worker spends on a day in total and trough the three categories. From these calculation different simulations can be compared among different the different levels of the building and categories.

8 Basic model

The following paragraphs will be a guidance through the Dynamo model. The different steps taken in the programming will be elaborated. The software used at the project of *het Noordgebouw* to produce the Building Information Model is Revit. This Revit model is used together with Dynamo to interchange information. The following paragraphs will describe the different steps of the basic model, which are presented in the modelling backbone. An overview of this model can be found in Appendix 7.

8.1 Extracting information

One of the standard function within Revit is the ability to grant a room to a certain space. This room function of Revit is commonly used within the building industry. One of the functions of Dynamo is its ability to extract certain information from the Revit model. Dynamo has the ability to directly read out the rooms generated in Revit. With the help of the functions in this first part the Rooms are listed. Then several lists are created with different functions of Dynamo. One list is created with all the room numbers, room names and room locations. These three lists form the output for this first section.

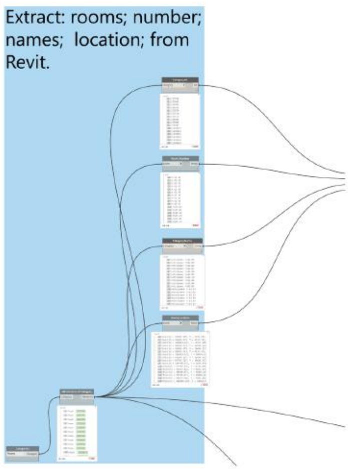

Figure 19: Dynamo, extract rooms

8.2 Exporting room list and importing room list

Within this paragraph the function of exporting and importing the rooms is getting elaborated. In this first section the list of rooms is exported to Microsoft Excel. This list of rooms in Excel can be used to order the rooms manually in the desired arrangement. This arrangement corresponds to the typical workday of one of the construction workers and in which order it addresses the different rooms. This makes it possible to visit one room multiple times during a certain workday.

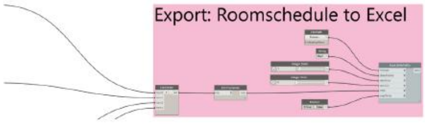

Figure 20: Dynamo: Create Excel-file with rooms

15	1239881	H.03.14	hotelkamer	Point(X = 96696.073, Y = 20464.815, Z = 9870.000)
16	1239902	H.03.05	hotelkamer	Point(X = 89673.766, Y = 7045.882, Z = 9870.000)
17	1240555	H.03.15	hotelkamer	Point(X = 100303.927, Y = 20464.815, Z = 9870.000)
18	1240640	H.03.13	hotelkamer	Point(X = 92503.927, Y = 20464.815, Z = 9870.000)
19	1240724	H.03.11	hotelkamer	Point(X = 84703.927, Y = 20464.815, Z = 9870.000)
20	1401290	H.03.06	hotelkamer	Point(X = 83594.814, Y = 6911.221, Z = 9870.000)
21	1401296	H.03.18	gang H.03.	Point(X = 93489.294, Y = 15391.313, Z = 9870.000)
22	1401302	H.03.23	linnenkam	Point(X = 86832.891, Y = 12458.336, Z = 9870.000)
23	1401305	H.03.21	gang H.03.	Point(X = 91284.361, Y = 12333.528, Z = 9870.000)
24	1519832	H.01.09	kleedruimt	Point(X = 82813.434, Y = 18780.361, Z = 3870.000)
25	1564876	H.00.18	voorr. H.0(	Point(X = 83312.235, Y = 18454.945, Z = 0.000)
26	1564885	H.00.19	tr. H.00.19	Point(X = 81886.430, Y = 20767.129, Z = 0.000)
27	1566049	H.00.08	back office	Point(X = 107786.856, Y = 19196.912, Z = 0.000)
28	1643597	H.11.12	lift 1 H.11.	Point(X = 99049.973, Y = 12262.161, Z = 33870.000)
29	4845317	H.03.04	hotelkamer	Point(X = 91347.402, Y = 7122.830, Z = 9870.000)
30	4849119	H.10.10	hotelkamer	Point(X = 76983.210, Y = 20526.576, Z = 30870.000)
31	5787989	H.05.05	hotelkamer	Point(X = 92503.927, Y = 4135.185, Z = 15870.000)
32	5788002	H.05.04	hotelkamer	Point(X = 96696.073, Y = 4135.185, Z = 15870.000)
33	5788023	H.05.03	hotelkamer	Point(X = 100303.927, Y = 4135.185, Z = 15870.000)
34	5788042	H.05.13	hotelkamer	Point(X = 88896.073, Y = 20464.815, Z = 15870.000)
35	5788061	H.05.15	hotelkamer	Point(X = 96696.073, Y = 20464.815, Z = 15870.000)

Figure 21: Created Excel-file with rooms

When the list is arranged in the desired configuration, it needs to be imported within the Dynamo model to be ready to be worked with, this is done in the following step. The excel-file is selected with the help of the file path. Next the list is read out and transposed. The transpose-function enables the model to generate two lists; one with the room numbers, and one with the room names. Now the rooms are imported in the model in the right order.

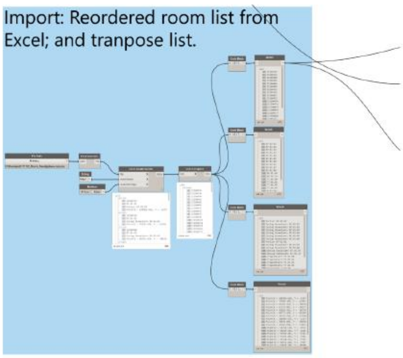

Figure 22: Importing reorder Excel-file with rooms

8.3 Filter and reorder lists

Because in the last step the rooms are imported from an external database a link needs to be established between the rooms imported from Excel and the Revit model. This is done by comparing the room list generated by Revit with the Excel-file. Whenever a room in the list generated by Revit can also be found in the Excel-list the value true is given, if not the value false is given. This Boolean-mask that gives the true and false values does appear to not be a standard function of Dynamo. Therefore, a script is written in Python and used. Then with a Boolean filter only the True values filtered out. Now the rooms from the Excel list are relinked with the rooms from the Revit model.

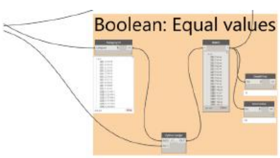

Figure 23: Boolean of imported and Revit room list

Next the specified order presented in the Excel-list, which represents the walking path of the construction worker, has to established. This is done with the help of another Python script which reorders the lists in the right order and keeps double values as well. Now the List of rooms is generated in the right order.

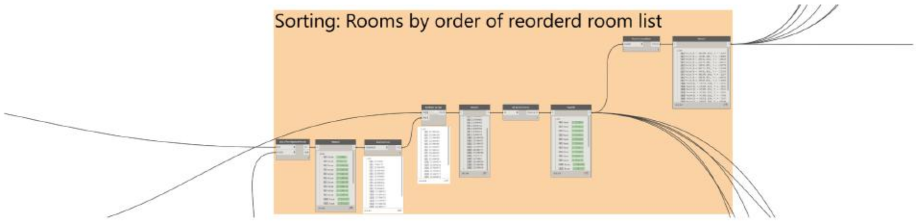

Figure 24: Reordering of rooms

8.4 Calculating Euclidean distance by Dynamo

This rearranged list of rooms, and the location of the designated rooms are now extracted from the model. The next step is to calculate the rooms. Since the location of the rooms is indicted by the center-point of the room tag, this point will be used to measure the distance. Within the following section the room points are used to generate a polyline. This polyline is then measured, this results in a certain length, which is generated by Dynamo.

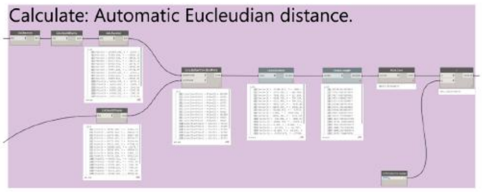

Figure 25: Automatic generation of Euclidean distance

8.5 Calculating Euclidean distance mathematically

With the formulas presented in the mathematical backbone, the distances of the lines through the different center-points of the rooms can be calculated. The first step that had to be taken in the mathematical backbone is to extract the x- and y-coordinates of the point separately. This is done for the x- and y-coordinates of the room. Followed by generating two lists. For one of the lists the first value is removed an in the second list the last value is removed. Doing so results in an equal number of values in both list, so the difference in values can be calculated, this is illustrated in Table 6. Next the values indicated as Δx and Δy in the mathematical backbone can be calculated. This simply done by a function of subtraction which is embedded in Dynamo. This results in two separate list, one of them resembles the Δx and the other Δy.

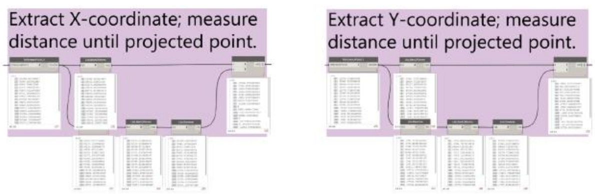

Figure 26: Extraction of X- and Y-coordinates from rooms

Table 6: Rearrangement of list visualised

	~~X0~~	
X0	X1	Δ(X1-X0)
X1	X2	Δ(X2-X1)
X2	X3	Δ(X3-X2)
X3	X4	Δ(X4-X3)
X4	X5	Δ(X5-X4)
X5	X6	Δ(X6-X5)
X6	X7	Δ(X7-X6)
X7	X8	Δ(X8-X7)
X8	X9	Δ(X9-X8)
~~X9~~		

In the following step the Euclidean distance is calculated on the hand of the Pythagorean theorem. The following formula is presented in the mathematical backbone:

$$\boxed{\text{Distance}_{\text{Euclidean}}} = \sqrt{\boxed{\Delta x}^2 + \boxed{\Delta y}^2}$$

Equation 11: Euclidean distance combined with previous equations

This formula is used with the distances Δx and Δy generated in the previous list. The sum of these individual values gives the length of the Euclidean distances between the rooms.

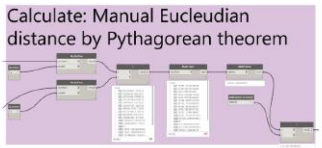

Figure 27: Manual calculation of Euclidean distance

8.6 Calculating city-block distance mathematically

Again, the mathematical backbone provides us with the formula's and values needed to perform the calculations for the city-block distance. The following formula is used:

$$\boxed{\text{Distance}_{\text{City-block}}} = \boxed{\Delta x} + \boxed{\Delta y}$$

Equation 12: City-block distance combined with previous equations

In the previous section the calculations to get the distances Δx and Δy are already performed, and these can be used again. In the following step these values are used again. Because it is possible that the x- or y-coordinate of point 1 is larger than point two, errors in the outcome would inevitable. This would result in certain negative values of distance, while a construction worker cannot lose a certain distance to get from point 1 to point 2. Therefore, it is important that the distances Δx and Δy are made absolute, due to this step the minus values become positive. With the sum of all distances travelled in x-direction and y-direction the total city-block distance is calculated.

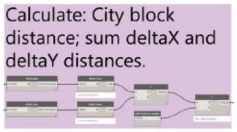

Figure 28: Calculation city-block distance

8.7 Calculating City-block distance by Dynamo

The city-block distance can also be calculated automatically by the length of the lines, as shown at the Euclidean distance. First, the coordinates of the points need to be established, this contains the points of the rooms and the projected points. Then these points need to be ordered in the right order, being [PointA; ProjectedPointAB; Point B; ProjectedPoint BC: Point C: and so forth]. Next a line can be drawn between these points and length of the lines can be calculated.

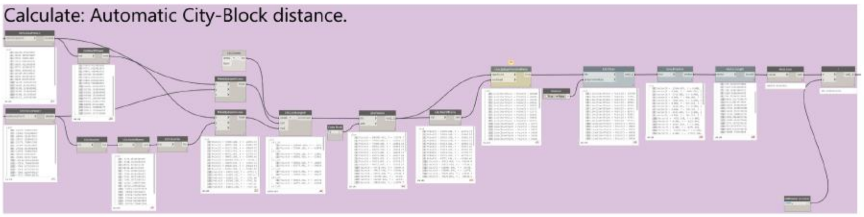

Figure 29: Automatic generation of city-block distance

8.8 Calculating vertical travel distance

Within the construction site there are two means of vertical transport the elevator and the stairs. Within the total vertical distance, the absolute values in z-direction are calculated. This is then summed up and results in the total vertical travel distance.

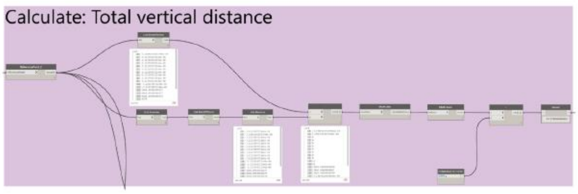

Figure 30: Calculate vertical travel distance

The vertical elevator or stair travel distance can also be calculated. This calculation is similar to the total vertical distance calculation. The difference is found in first filtering out the two means of transport. Which results in two lists, one of distances travelled by stair and the other containing distances travelled by elevator.

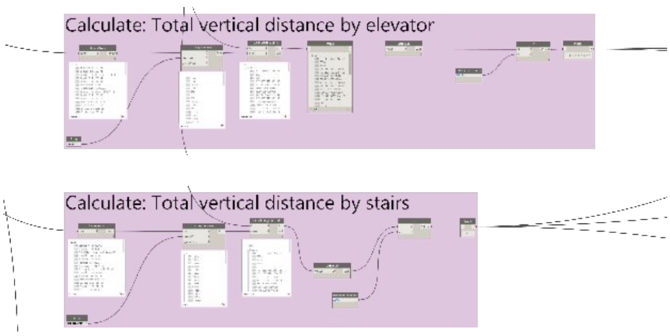

Figure 31: Calculate vertical travel distance by elevator or stair

8.9 Equality-check

To validate this formula and mathematical approach an equality check is performed. In this equality check the distance generated automatically by Dynamo is compared with the mathematical approach as presented above. When the outcome of this equality check is true the value is equal and therefore valid. This is done as well for the vertical distances.

It has to be noted that the equality check of the Euclidian distance is only true if the points measured are on a single horizontal pane. Because the manual calculation only takes into account the x- and y-values and the automatically calculated distance includes the z-values as well.

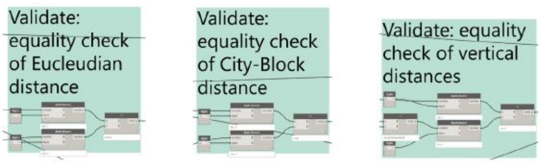

Figure 32: Equality checks

8.10 Waiting time

As previously explained the waiting time at a certain location is added to the parameters of this location. This is done so by adding the parameter waiting time to the rooms. To visualize the amount of waiting time at different points Dynamo offers a solution. Comparable with the way the Rooms are extracted, the waiting time can be extracted as well. The difference is that this waiting time parameter is not standard to Revit, therefor the extraction asked for a different approach. It has to be noted that the waiting times are grouped per rooms and added up. This resembles that if the worker passes one point 10 times the waiting time increases with 10 times as well.

Similar to the extraction of the rooms, first a list of rooms is created. Second, the parameter of the waiting time if filtered from these rooms. This limits the list to only the waiting time. With this waiting time and the location of the rooms centre point a sphere can be created. This sphere resembles the waiting, time, the larger the waiting, the larger the sphere becomes.

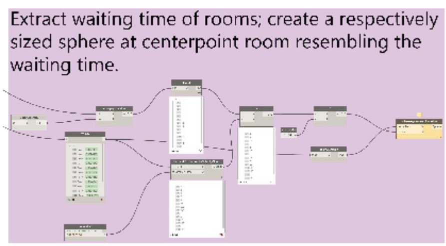

Figure 33: Visualising waiting times by spheres

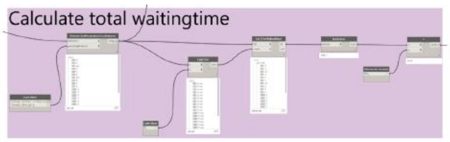

Figure 34: Calculation of total waiting time

8.11 Working time

Comparable with the previous visualisation and calculation of waiting time the working time is presented. The working time is filtered from the Revit model and a cube is drawn at the centerpoint of each room representing the working time. The size of the cube represents the working time. The difference between working and waiting time is that the working times is counted one time, even when the construction worker is visiting the room with the working time multiple times.

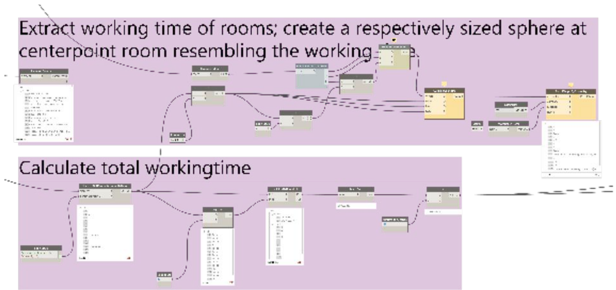

Figure 35: Calculation and visualisation of working time

8.12 Calculating time

In the previous steps only distances are measured. For the research the distances have to be translated into time, by using distances and speeds the time can be calculated. For this multiple speeds are necessary, which is shown in Figure 36.

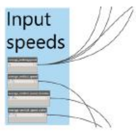

Figure 36: Input of speeds used for the calculations

The speeds giving in the input above are used to calculate the walking time. With the average walking speed and the travelled distance, the walking time can be calculated with the following formula.

Equation 13: Time by distance and speed

$$\text{time} = \frac{\text{distance}}{\text{speed}}$$

This formula is implemented in the Dynamo model. In which the travelled distances of the different measurement systems: Automatic Euclidean, Manual Euclidean, Automatic City-Block and Manual City-Block; are divided by the average walking speed. Which gives the elapsed time for this round.

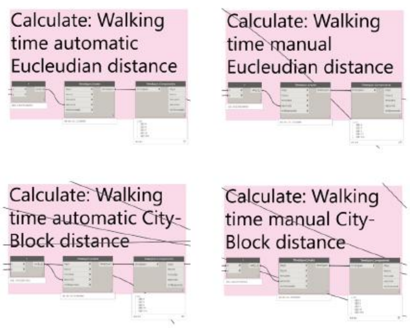

Figure 37: Calculation of walking times

The same is done for the vertical travel times. The only difference is that for the walking speed only one value was used. For the vertical walking time, three different speeds are used. The average vertical elevator speed, the average vertical stair speed and the combination of the before which is the average vertical travel speed.

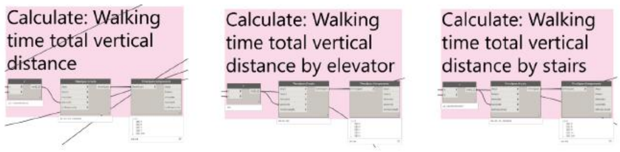

Figure 38: Calculation of vertical travel times

As the waiting time read from the Revit model is already given in time the only step is to add up the different times. Which gives the total waiting time.

Figure 39: Calculation waiting time

The last step is to add up all the separate times to get the total time. Given that the City-block distance is resembling the real-life situation the most, this one is used. And the separate vertical times are used; the total vertical travel time by elevator and by stairs.

Figure 40: Calculation of total time

8.13 Assembling and exporting results

In the last step of the model the results are combined in an overview. All figures are presented in this overview. These figures are then assembled into a single list which can be exported to a spreadsheet of choice.

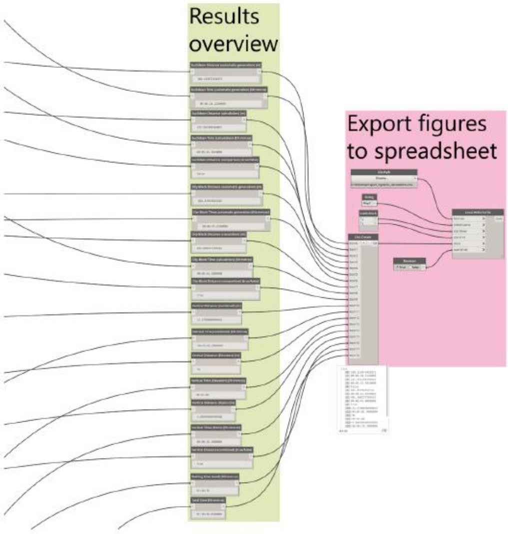

Figure 41: Results overview and export

part IV

This part gives insight in the data used within the Dynamo model presented in the previous part. This consists out of five chapter. The first chapter elaborates on the preparation in Revit. The second chapter elaborates on the typical workday. The third chapter presents the different walking speeds. The fourth chapter presents the different waiting times. The fifth chapter elaborates on the working times used within this research.

Behind Dynamo

9 Preparing Revit

The Building Information Model needs to contain all the necessary information to be able to perform the walking path analysis, and the information needs to be of a certain quality to be used. In order to perform the analysis information needs to be added to the model, the following paragraph elaborates on the necessary information.

9.1 Adding rooms

One of the embedded functions in Revit is the capability to make rooms. According to Autodesk (2017) a room is a subdivision of space within a building model, based on elements such as wall, floors, roofs an ceilings. These elements are defined as room-bounding. When computing the perimeter, area and volume of a room Revit appeals to these room-bounding elements. To these rooms properties can be added like: name, number, occupancy and more. Which will be revered to later on in this chapter.

9.2 Providing site-layout

One of the preparation that has to be taken to perform walking path measurements on the construction site is the introduction of the site-layout to the BIM, as introduced in paragraph 4.2. The site-layout contains a lot of information on elements and the properties of these elements. In general, all places that the construction worker can visit need to be added to the model. In practice, this means that all construction sheds, amenities, stair wells, elevators, gates and other significant elements need to be added.

In the previous paragraph the principle of the room function in Revit was introduced. The elements added to the model which are part of the site-layout need to be equipped with rooms. The rooms also need to be enriched with additional data like, name, number and department.

Furthermore, to be able to distinct the travelled path in vertical orientation, just the base of an elevator or stairwell modelled is not sufficient. With these resources of vertical movement, at each stop at a certain level a room needs to be defined. Otherwise the vertical movement cannot be analysed properly, because of inaccurately walking paths.

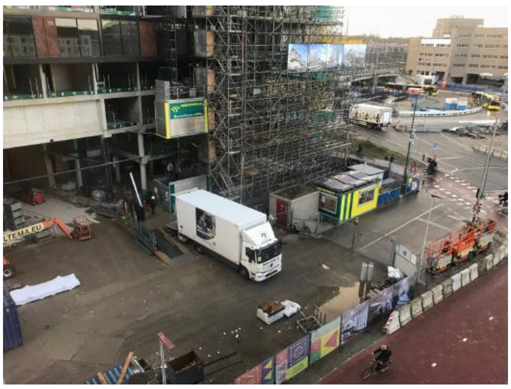

Figure 42: Small overview of elements on construction site

9.3 Adding waiting and working time

One of the functions need to analyse the working day of is to know the amount of time a worker stays in a certain place, the waiting or working time. This can for example be because there is a waiting time until the elevator is ready for use, because he is using the amenities, having his lunchbreak or doing work in a certain place.

Paragraph 9.1 refers to the rooms and the properties of rooms within a BIM. Revit has the ability to add parameters to certain elements, for instance rooms. One of the parameters that needs to be added to the model is the working time. The amount of time a certain worker spent in a certain room. This working time is the time the worker needs to execute just the activities he needs do in this rooms. The waiting time is added to rooms where the workers has to spend time without doing activities, for example waiting on the elevator or the time spend on the toilet itself. The following figure shows the added parameters to the properties of a certain room. The working time and waiting time can be entered per room.

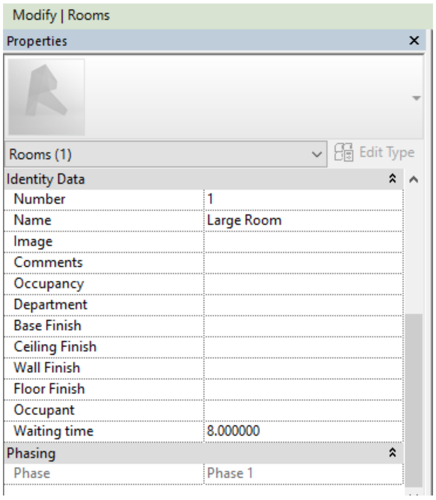

Figure 43: Properties in Revit

10 Typical workday

Each worker on the job site performs different tasks and different tasks along the working days. This research is focusing on the activities of the metal-stud contractor. For the simulation of walking path of this actor the typical workday needs to be drawn. This typical workday is a resemblance of the general activities and breakdown of a workday.

In Figure 45 and Figure 46 the typical breakdown and activities of the metal stud contractor is schematised. The information of Figure 46 is collected with an interview. This interview is held with Robin Workel, who is the project leader of the metal stud contractor Eissink on the project of *het Noordgebouw*. A full transcript of this interview can be found in Appendix 4.

The activities of the typical workday of the metal stud contractor can be found in Figure 45. This typical workday shows the general point of actions and related times of the construction workers schedule. Furthermore, this can be linked to the construction schedule and the overview of task that the builder has to execute, which is schematised in Figure 46. Together with the construction schedule the location of the activities is known.

These activities of the metal stud contractor can be broken down into three crew. All working separately on different jobs. Each crew consists out of two people and the crews are interchangeable. Meaning that each crew member is able to all jobs specified. Which is visualised in Figure 44.

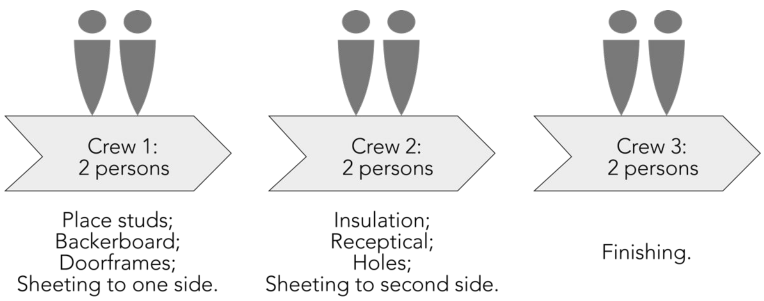

Figure 44: Breakdown activities of crews

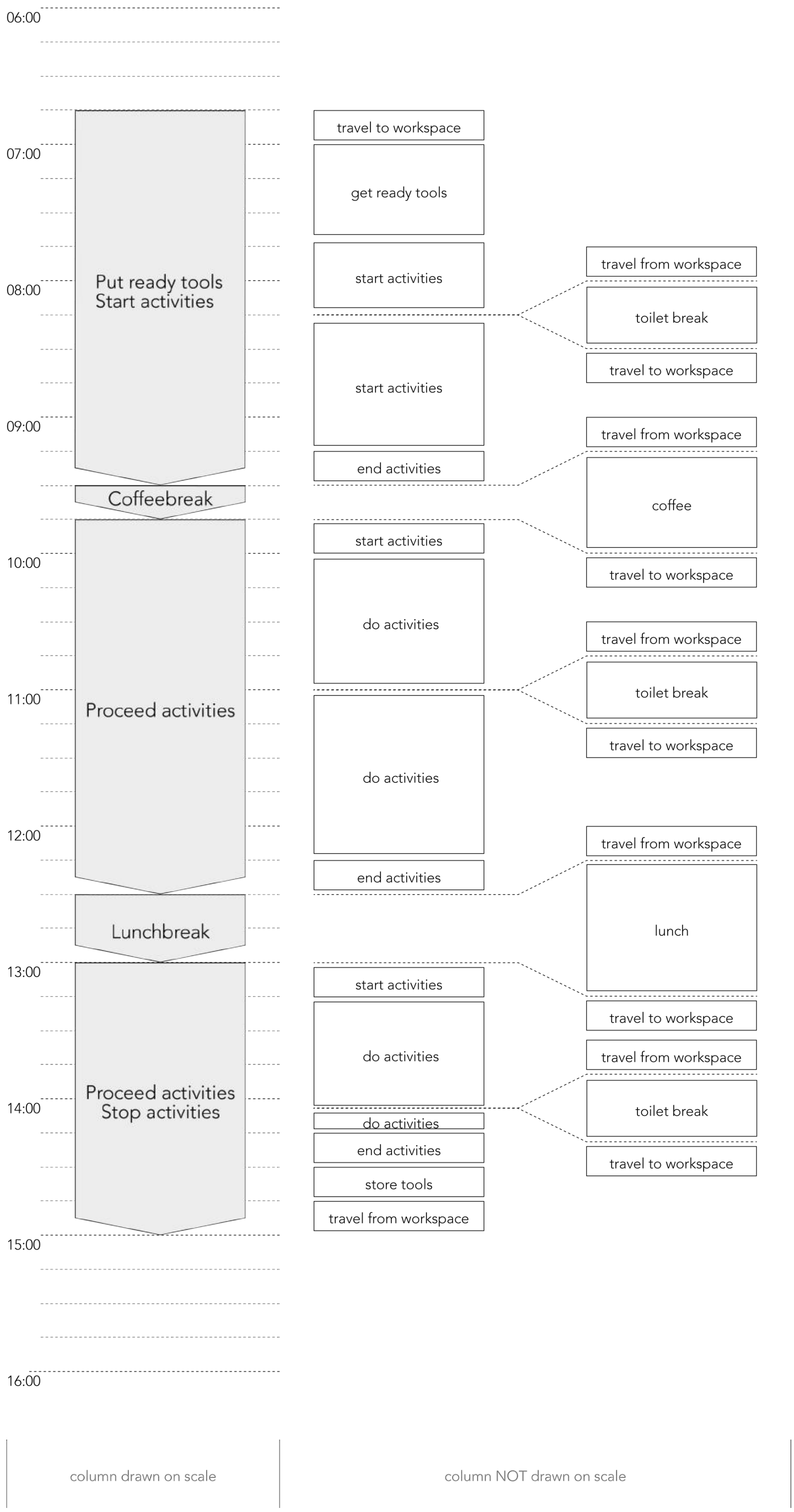

Figure 45: Typical workday of metal-stud contractor

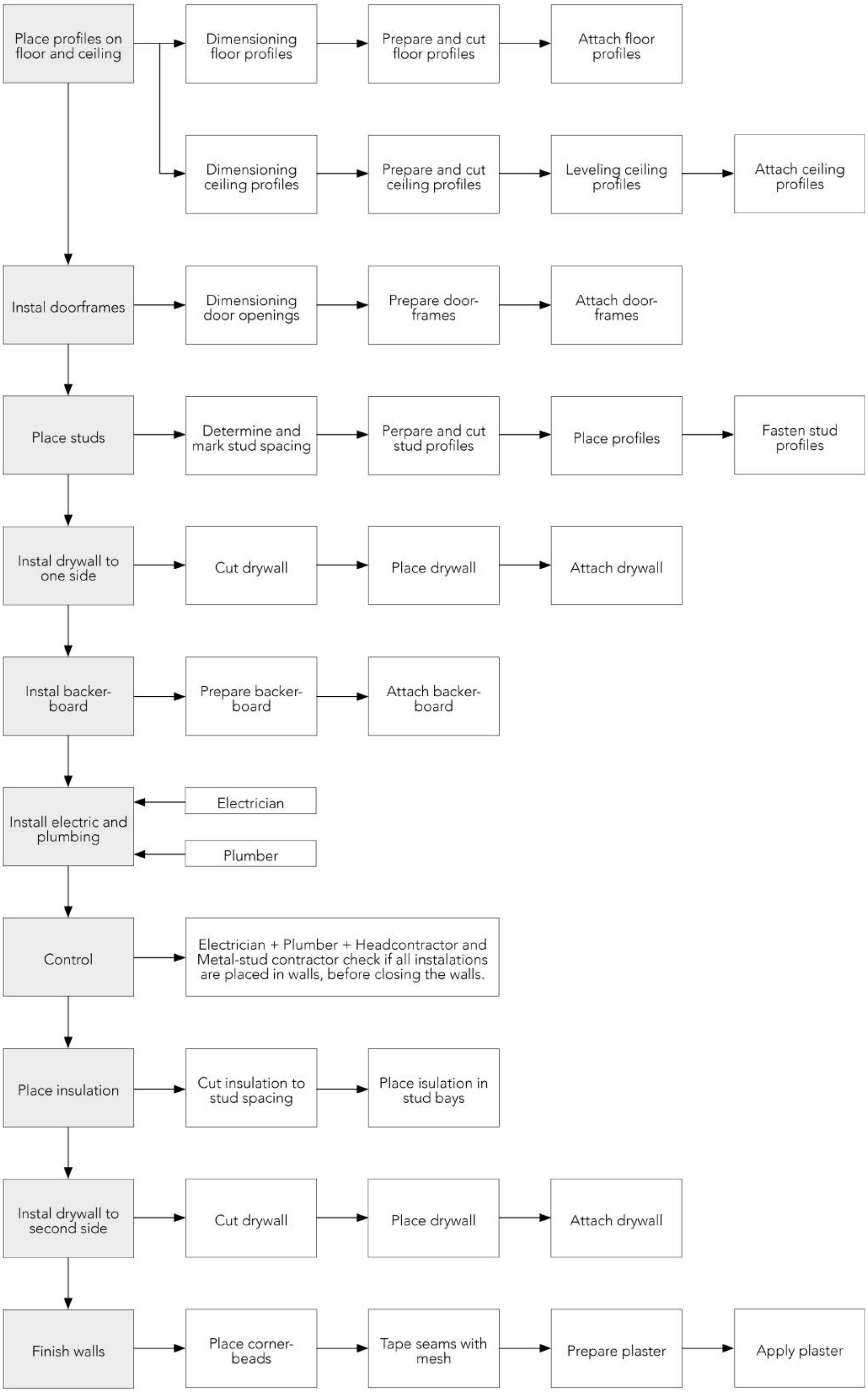

Figure 46: Chronological activities of metal-stud contractor

11 Walking speed

One of the figures needed to be able to calculate the time related to the distance construction workers have travelled is the speed. In the next paragraphs the average walking speed on stairs and on flat surfaces will be discussed.

11.1 Horizontal walking speed

The walking speed on flat ground of persons is broadly addressed in literature. A sample of 15 people, of which 7 male and 8 female, with an average age of 34,5 the normal walking speed on a horizontal surface was found to be 140 cm/s. An average fast walking speed was measured of 184 cm/s (Fujiyama & Tyler, 2004). In the research of Bohannon (1997) a group with a age between 20-79 years was measured on their walking speed. The normal walking speed found in this measurement in the different age groups is shown below (Bohannon, 1997).

Table 7: Average normal walking speed (Bohannon, 1997)

Sex/Decade	[cm/s]
Men	
20s	139.3
30s	145.8
40s	146.2
50s	139.3
60s	135.9
70s	133.0
Women	
20s	140.7
30s	141.5
40s	139.1
50s	139.5
60s	129.6
70s	127.2

So as the figure above show the difference in walking speed does vary along the sex and age of the sample. For the simulation of the walking paths of construction workers the average walking speed is needed. To find the average walking speed the literature above does not conceal a clear answer. This walking speed is measured in a straight path without any obstacles. In the real-world a construction works average walking speed might differ as the worker has to walk around corners or wait for a passing colleague. Within this research this is not taken into account.

As this average walking speeds is quite divers among the different age groups the average walking speeds are compared with the age groups and sexes to give the average walking speed. This average walking speeds should represent de demographics of the construction site in the Netherlands.

Table 8: Combination of walking speeds, age and sex on Dutch construction sites.

	Amount of people working in construction in the Netherlands (CBS, 2016e)		Average normal walking speed (Bohannon, 1997)	
	People (x1.000)		Speed (centimetre/second)	
Age group	Male	Female	Male	Female
15-25	25	0	139,3	140,7
25-35	54	1	145,8	141,5
35-45	66	1	146,2	139,1
45-55	67	2	139,3	139,5
55-65	40	1	135,9	129,6
65-75	8	0	133	127,2
Average walking speed		**144,3**	**centimetre/second**	

With the help of Table 8 the average walking speed could be calculated on Dutch construction sites. Taken into account where the average speed per age-group and sex, this was compared with the demographic of the Dutch construction industry. This results in an average horizontal walking speed of 144,3 centimetre per second, that will be used for the simulations.

11.2 Walking speed on stairs

Different literature exists on the walking speed of people on stairs. Fujiyama and Tyler (2004) conducted a study in which the walking speed of pedestrians on stairs was measured. Within this study the following definitions of walking speeds on stairs where used: Horizontal walking speed; Vertical walking speed and inclined walking speed. The Figure 47 gives a schematic representation of these walking speeds.

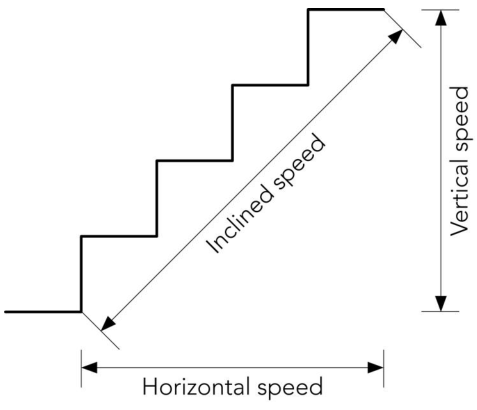

Figure 47: Definition of speeds (Fujiyama & Tyler, 2004)

The study of Fujiyama and Tyler (2004) showed the results of walking speeds on stairs of two different groups. An elderly group with an average age of 71.0 consisting of 6 males and 7 females, and a young group with an average age of 34.5 consisting of 7 males and 8 females. From these groups, the average walking speeds were measured.

Table 9: Average stair walking speeds adopted from Fujiyama and Tyler (2004)

<table>
<tr><th></th><th></th><th colspan="2">Inclined speed</th><th colspan="2">Vertical speed</th></tr>
<tr><th></th><th></th><th>Elderly</th><th>Young</th><th>Elderly</th><th>Young</th></tr>
<tr><td rowspan="2">Ascending</td><td>Male</td><td>0.601</td><td>0.668</td><td rowspan="2">0.30 - 0.35</td><td rowspan="2">0.35 – 0.4</td></tr>
<tr><td>Female</td><td>0.475</td><td>0.511</td></tr>
<tr><td rowspan="2">Descending</td><td>Male</td><td>0.596</td><td>0.811</td><td></td><td></td></tr>
<tr><td>Female</td><td>0.565</td><td>0.631</td><td></td><td></td></tr>
</table>

On the construction site of the case, *het Noordgebouw*, an action research is performed which measured the vertical speed of the construction workers on stairs. Within this measurement a total of 30 instances are measured. The results of these measurements can be found in Appendix 5. Within this measurement the time of the construction workers is measured and compared with the travelled levels of the building. The start of this measurement is the moment that the worker enters the stair well. The end of the measurement is the moment the worker exits the stair well. The time between these moment is compared with the travelled vertical distances. Because the height of levels is different among different levels, this has to be taken in to consideration. The final measurement results in a vertical speed in meters per second. The measurements include ascending and descending workers with 62 levels descended and 48 levels ascended, in which a total vertical distance of 338.79 meter is travelled.

The minimum vertical walking speed measured was 0.21 meter per second, the maximal vertical walking speed 0.51 meters per second. The average vertical speed on stairs is 0.30 meters per second and a standard deviation of 0.07 meter per second.

The average vertical speed measured is comparable with the average vertical found in the research of Fujiyama and Tyler (2004). The average speed found in the research for elderly was between 0.30 and 0.35 meter per second, which is equal to the speed found in the measurement of 0.30 meter.

12 Waiting times

As the shown by El Asmar (2012) on a typical workday 8% of the time is spend on waiting for instructions and materials. More information is needed about this non-value adding time, as waiting time occurs in different setting, for example a waiting time applies for the use of an elevator.

12.1 Elevators

Previous research has found that construction workers tend to use the elevator when more than five stories need to be travelled. The author noted that this depends on the person and of the goods that the construction worker is taking with him. During the start of the workday there is a high demand of ascending workers. When the lunch and sanitary facilities are placed a ground level, before and after lunch break the demand of descending and ascending workers grows. At the end of the working day there is a trend of descending workers (Muskens, 2010).

The author performed a measurement on the waiting time at the elevator a certain project. The measurement performed gave a minimum waiting time of 20 seconds and a maximum waiting time of 9 minutes 32 seconds. The average waiting time was calculated at 5 minutes 13 seconds. The waiting time was defined as the time between the moment a workers placed a call for the elevator until the worker embarked the elevator (Muskens, 2010).

On the project of *het Noordgebouw* two elevators of different types are being used. The following types of elevators for people and freight are used: one Stross NOV1230 elevator and one Raxtar RX2040 elevator. For these elevators, the following properties apply:

Table 10: Elevator capacity

	Capacity		Cage dimensions	Lifting speed
Stross NOV 1230	1200 kg	15 persons	3.000 x 1.300 x 2.700 mm	36 m/min
Raxtar RX 2040	2000 kg	24 persons	3.950 x 1.380 x 2.480 mm	42 m/min

The elevators of the type Raxtar have an approximated delay of 4 seconds between the moment the button of departure is pressed and the moment that the elevator has reached its constant speed. On previous project Dura Vermeer has executed measurements on the waiting time of the elevators. The following figures from these measurements can be used. The average amount of people transported by the elevator is 3,6 persons per movement and the average waiting time is 6 minutes and 35 seconds. The characteristics of the project are similar to the characteristics of *het Noordgebouw*.

On the project of *het Noordgebouw* another action research was performed. Within this action research measurement where performed, these showed the lifting speed of the Raxtar RX2040. Within the measurement the time between the start and end moment of the elevator movement was measured This was compared with the levels travelled. The start of the measurement is the moment that the door of the elevator is opened. The end of the measurement is when the elevator has reached its level of destination and the door is closed. The floor height of *het Noordgebouw* is in general is 3.0 meter, except from the first and last floor. This is taken into consideration with the translation of the levels to the actual height of the level. From this the average vertical travel speed of construction works with elevators is measured.

A total of 50 instances where measured. Within these instanced 97 levels where descended and 147 levels where ascended, which results in a total of 246 levels travelled or 773,67 meters travelled. The minimum vertical travel speed measured is 0,06 meters per second and the maximum travel speed measured was 0,46 meters per second. The average vertical travel speed measured is 0,24 meters per second with a standard deviation of 0,11 meters per second. These results can be found in appendix 6.

To be able to introduce the waiting time into the final model the average waiting time of the elevator is known form previous research. The average waiting times from both jobs were 5 minutes and 13 second; and 6 minutes and 35 seconds. The average waiting time of these two jobs combined is 5 minutes and 54 seconds.

Known is that the construction worker is traveling from place A to place B. In the case of the elevator this is the starting point of the elevator, which is in this example level 0. The end point of the elevator is level 3. The average elevator waiting time of the construction can be schematically be divided into two elements, knowing that the worker passes the start point and the end point.

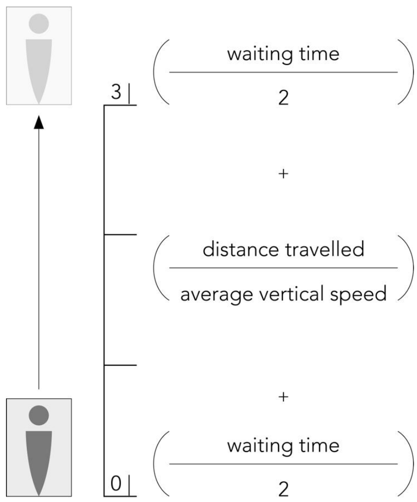

Figure 48: Schematisation average waiting time

This schematization is helpful for the modelling of the waiting time of elevators. In the final model the construction worker passes two points, the start and endpoint. Each of these points contains half of the average waiting time. As schematized in Figure 48 the total time needed to travel by elevator, which is the sum of half the waiting time, the time needed to travel the vertical distance and half the waiting time. Dividing the waiting time in half, the waiting time at each stop of the elevator is set at 2 minutes and 57 minutes.

13 Working time

Within the conceptual model three elements where defined: waiting time walking time; and working time. In the previous two chapters the walking and waiting times are discussed. Within this chapter the section of working time is elaborated.

13.1 Determining working time

The previous chapters elaborated the determination of the waiting and walking time, this paragraph starts with the determination of the working time. The working time is based on different norms that derive from previous research. Within this previous research the activities that the metal stud contractor executes are broken down per step.

This previous research conducted by Brokelman and Balk (2010), who has broken down the steps taken by the construction worker who builds the metal stud walls. This data is divided into: the preparation of the location; the transport of materials and equipment to the site; and all the different steps to build the walls: dimensioning and placing metal frames; placing insulation; sheeting the frames; and finishing the walls. These different steps will be further broken down in the following paragraph to be able to define the working time. Under which are activities like resting due to the physical nature of the activity. The data also supplies figures for an approximate ceiling height of 5 meter. This data is not taken into account because the ceiling height of *het Noordgebouw* is 3 meters, therefore the data given for a height of circa 2.5 meters applies.

13.1.1 Time norms for metal frames

The first step is to layout all dimensions of the wall, this can be done with laser projections of with chalk lines. Next, the ceiling and floor profiles have to be mounted and at last the studs of the walls have to be mounted. The following tables present figures that represent the time needed to execute these different tasks width different implements.

Table 11: Time norms of installing metal stud adopted from Brokelman and Balk (2010).

Dimensioning	
Method with laser projection	1.70 man-min / wall
Method with chalk line	3.14 + 0.25 x L man-min / m^1 wall length
Install floor and ceiling profiles	
Floor profile	1.1883 x L man-min / m^1 wall length
Ceiling profile height ca 2.60 with ladder	1.4068 x L man-min / m^1 wall length
Ceiling profile height ca 2.60 with stilts	1.2113 x L man-min / m^1 wall length
Ceiling profile height ca 4.00 with scaffold	1.4051 x L man-min / m^1 wall length
Ceiling profile height with aerial work platform	1.4491 x L man-min / m^1 wall length
Install studs	
Studs height ca 2.60 with ladder	1.0465 man-min / stud
Studs height ca 2.60 with stilts	0.9665 man-min / stud
Studs height ca 4.00 with scaffold	1.3585 man-min / stud
Studs height with aerial work platform	2.1945 man-min / stud

The steps described in the previous table can be translated to norms of man-hour per square meter. This is presented in Table 10 and 11. In Table 10 the dimensioning with the help of chalk lines is used and different implements as stairs, stilts or scaffolds are named. In Table 11 the same is done, only the dimensioning is done with the help of laser projections.

Table 12: Netto-construction time in man-hour per m2 of mount the metal frames excluding backer board and insulation with chalk line dimensioning adopted from Brokelman and Balk (2010).

Construction with ladder (chalk line)					
Height of wall			2.50 meter		
Length of wall	1.00m	2.00m	4.00m	8.00m	10.00m
Total in man-hour / m^2 c.t.c. 0.40m	0.0917	0.0623	0.0494	0.0429	0.0416
Total in man-hour / m^2 c.t.c. 0.60m	0.0847	0.0588	0.0441	0.0377	0.0360
Construction with stilts (chalk line)					
Height of wall			2.50 meter		
Length of wall	1.00m	2.00m	4.00m	8.00m	10.00m
Total in man-hour / m^2 c.t.c. 0.40m	0.0882	0.0594	0.0466	0.0402	0.0389
Total in man-hour / m^2 c.t.c. 0.60m	0.0818	0.0561	0.0418	0.0354	0.0338
Construction with scaffold (chalk line)					
Height of wall			2.50 meter		
Length of wall	1.00m	2.00m	4.00m	8.00m	10.00m
Total in man-hour / m^2 c.t.c. 0.40m	0.1000	0.0685	0.0551	0.0373	0.0470
Total in man-hour / m^2 c.t.c. 0.60m	0.0909	0.0640	0.0483	0.0416	0.0398

Table 13: Netto-construction time in man-hour per m2 of mount the metal frames excluding backer board and insulation with laser dimensioning adopted from Brokelman and Balk (2010).

Construction with ladder (laser)					
Height of wall			2.50 meter		
Length of wall	1.00m	2.00m	4.00m	8.00m	10.00m
Total in man-hour / m^2 c.t.c. 0.40m	x	x	0.0453	0.0400	0.0389
Total in man-hour / m^2 c.t.c. 0.60m	x	x	0.0400	0.0348	0.0333
Construction with stilts (laser)					
Height of wall			2.50 meter		
Length of wall	1.00m	2.00m	4.00m	8.00m	10.00m
Total in man-hour / m^2 c.t.c. 0.40m	x	x	0.0425	0.0373	0.0362
Total in man-hour / m^2 c.t.c. 0.60m	x	x	0.0337	0.0325	0.0311
Construction with scaffold (laser)					
Height of wall			2.50 meter		
Length of wall	1.00m	2.00m	4.00m	8.00m	10.00m
Total in man-hour / m^2 c.t.c. 0.40m	x	x	0.0510	0.0455	0.0443
Total in man-hour / m^2 c.t.c. 0.60m	x	x	0.0442	0.0387	0.0371

13.1.2 Time norms for backer board and doorframes

For the purpose of a solid installation of for example sanitary or cupboards a backer board is mounted between the studs. This backer board normally consists out of a piece of plywood. According to Brokelman and Balk (2010) the man-hour per piece of installing back board is 0.035. This includes that the backer board is pre-cut to size.

Doorframes are placed within the metal stud frames. For the frame, extra studs or horizontal profiles need to be added to which the frames are mounted. With this additional action extra time is spend. For the placement of an extra stud 1.3585 man-min per stud is needed. For the montage of an extra horizontal profile 1.4051 man-min per m^1 is needed. In total this would be 2,7631 man-min per doorframes, or 0.05 man-hour per doorframes (Brokelman & Balk, 2010).

13.1.3 Applying insulation

Insulation materials like glass wool and stone wool are comely used in because of thermal or acoustic properties in walls and ceilings. Stone wool is delivered in sheets and glass wool is delivered as rolled up blankets and are excellent sound absorbers for light room dividing walls.

The application of insulation consists out of multiple steps: the application of the insulation itself; the application of a membrane; indirect activities, like protective clothing; rest and personal care; run-up and run-off. The total application time of insulation is 1.56 man-min per m^2 or 0.026 man-hour per m^2 (Brokelman & Balk, 2010).

13.1.4 Applying drywall

One of the steps in the process is applying the drywall to the metal frames. In the project of *het Noordgebouw* all metal stud walls in the hotel area are double plated. That's why the figures of walls which are single plated are not presented below. The following figure give a man-hour per square meter norm for applying double layered drywall to one side of the metal frames.

Table 14: Netto-construcion time of applying double layered drywall to the metal stud on one side in man-hour per m2, excluding openings etc. adopted from Brokelman and Balk (2010).

Wall height	Wall length	Width of drywall in mm: 600	900	900	1200
		Center to center distance of studs in mm: 600	450	600	400
2.50	1.00	0.0875	0.0875	0.0511	0.0584
	2.00	0.0722	0.0653	0.0511	0.0584
	4.00	0.0611	0.0542	0.435	0.0508
	8.00	0.0590	0.0521	0.0379	0.0452
	10.00	0.0572	0.0503	0.0375	0.0448

Additional activities which are applicable to the application of drywall give the following workload. This are activities like drilling holes for plumbing or electrical pipes, make hole in the wall for receptacles. The figures are presented in Table 13.

Table 15: Additional activities to drywall adopted from Brokelman and Balk (2010).

Hole for piping	0.04 man-hour per hole
Cut-out receptacles	0.06 man-hour per cut-out
Cut-out doorframes	0.103 man-hour per opening
Apply elastic caulking	0.7 man-hour per meter

13.1.5 Finishing of wall

The last step is finishing the walls with a drywall compound. The times norms different in type of drywall used; the finishing class that needs to be achieved; and the width of the drywall sheets. These activities include: taping the joint; filling the joints and screw holes; preparing the filler; and cleaning the sheets.

Table 16: Netto-construction time of finishing the walls in man-hour per m2 adopted from Brokelman and Balk (2010).

	Sheet width 1.20 m	Sheet width 0.60 m
Finishing class-D		
Gipskartonplaat	0.0342	0.0553
Gipsvezelplaat	0.0402	0.0614
Finishing class-C		
Gipskartonplaat	0.0473	0.0779

Gipsvezelplaat	0.0533	0.0829
Finishing class-B		
Gipskartonplaat	0.0500	0.0818
Gipsvezelplaat	0.0560	0.0878
Finishing class-A		
Gipskartonplaat	0.1050	1.368
Gipsvezelplaat	0.1110	0.1428

Adding up all these norms the working time can be calculated for the different rooms that are within the hotel area. The BIM can be used to extract the amounts of walls that need to be placed. If modelled correctly even the holes for plumbing or electrical pipes, and receptacles could be calculated. Within this study an approximation per room is made to define the working time for these activities.

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part V

This part will perform simulations with the model and input presented in the previous parts. This part consists out of seven chapters. The first chapter presents the input used within the simulation. The second chapter represents the benchmark simulation. The third to sixth chapter present the simulation of the different interventions made. The seventh chapter provides and overview and elaboration on the simulation performed.

Simulations

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14 Input of the model

In the previous chapters the basics behind the model are presented and elaborated. In this chapter, the input variables used within the simulation are presented in an overview and are elaborated in part IV.

14.1 Rooms used within the simulations

The simulations are performed on the model of *het Noordgebouw*. As previously mentioned, this building compiles different functions. The hotel section within the building is chosen for the simulation, due to the repetitive nature of this section with the generally repeated floor plan on different levels. Furthermore, the construction of this section progressed the most. This enhances the availability of detailed information about the building.

For the simulation, two hotel rooms are used. This type of hotel room, *Kamertype 1*, is repeated from level 2 up to and including level 10. This type of room is repeated among these levels and within the same grid marks, and is therefore used within the simulation. The following numbers apply to the room. These rooms can be found on the floorplans of the building which are shown in Appendix 11.

Table 17: Rooms used in the simulation with numbers and levels

Room number Hotel	Room number Revit	Level
2.14	H.02.08	2nd level
2.15	H.02.09	
3.14	H.03.13	3rd level
3.15	H.03.14	
4.14	H.04.14	4th level
4.15	H.04.15	
5.14	H.05.14	5th level
5.15	H.05.15	
6.14	H.06.14	6th level
6.15	H.06.15	
7.14	H.07.14	7th level
7.15	H.07.15	
8.14	H.08.14	8th level
8.15	H.08.15	
9.14	H.09.14	9th level
9.15	H.09.15	
10.14	H.10.14	10th level
10.15	H.10.15	

14.2 Working time

In Chapter 10, the activities for the drywall-contractor are set out in different steps. The different steps of the drywall contractor are set out in the norms which show a certain time needed per m^2 to perform the tasks according the specifications. The specifications are related to size, composition of walls, height, etc. With the information gathered from the BIM model and drawings provided by the drywall-contractor, the specifications of the walls and quantities are set. With the norms, specification and quantities the total working time can be calculated. This is done in the calculations which are provided in Appendix 10. A rough breakdown is presented below.

Furthermore, the interview with the drywall-contractor showed that the work is performed in three different crews, or so-called trains. Which perform consecutive activities to build the metal-stud walls. These crews consist out of two people, and all crews have the same level of expertise. When setting out the work performed by each crew the working time can be calculated per team.

Table 18: Calculated working time for hotel room

Total man-hour per room per step for all crews		**Total man-hour per room per crew**		
Studs	2.5211 man-hour per room	Crew 1	Crew 2	Crew 3
Insulation	0.2184 man-hour per room	Studs; backer board; doorframes; sheeting one side.	Insulation; receptacles; holes; sheeting second side.	Finishing.
Drywall	1.9079 man-hour per room			
Finishing	0.9331 man-hour per room			
Additional factors	1.0750 man-hour per room			
Total	**6.656 man-hour per room**	**3.840 man-hour per room**	**1.882 man-hour per room**	**0.933 man-hour per room**

The previous table shows the different working times of drywall-contractors. The drywall-contractor works in three crews. These three crews perform consecutive activities in consecutive order. Due to the project scope of the drywall-contractor the working time of crew 1 is applicable. Since the drywall-contractor is not only responsible for the construction of the metal-stud walls but is responsible for the construction of the ceilings as well. Within crew 2 and 3 the ceiling is constructed as well, as in crew 1 only the activities of the metal-stud walls are performed. Therefore, the working time of crew 2 and 3 is not applicable. Therefore, only the working time of crew 1 is taken into account in the simulation.

14.3 Waiting times used within simulations

The waiting time is split up into different categories that are used in the model. This parameter of waiting time is added to the Revit model elaborated in Chapter 0. In the model, the following waiting times are used:

- Elevator to shed; 1.0 min
- Elevator on site; 2.95 min
- Storage on site; 10.0 min
- Gateman; 5.0 min
- Shed, day-start; 10.0 min
- Shed, coffee-break; 15.0 min
- Shed, lunchbreak; 30.0 min
- Shed, day-end; 10.0 min
- Tourniquet; 2.0 min
- Stairwell; 0.5 min
- Site toilet; 5.0 min

14.4 Walking times used within simulations

As previously mentioned walking time can be divided into two categories: the horizontal walking time, and vertical walking time. Both are the product of a travelled distance and speed. The travelled distance is calculated within the model, as mentioned in Chapter 4. In Chapter 11, the walking speeds for the horizontal and vertical displacement of construction workers is defined and used in the model.

14.5 Typical workday

The preceding steps are input for the simulations of the model. These simulations are performed for the previously specified levels and two rooms. These two rooms relate to the schedule of the drywall-contractor who planned to work on two rooms a day, which resembles a typical workday of the drywall-contractor.

The typical workday is imported in the model and can differ among the different simulations as changes are made. The typical workday represents the path of the construction-worker, which is set out into the different rooms. This results in a list in chronological order of rooms, which lie along the path of the construction worker.

There is one important aspect within this path: the means of vertical transport. According to the policy of the head-contractor Dura Vermeer, the construction worker is only allowed to take the elevator if he or she travels more than four levels or is carrying tools or materials. This policy is resembled in the typical workday, whether or not the construction worker takes the stairs or the elevator along its path.

14.6 Simulations performed

A total of five simulations are performed within this research. The characteristics of the simulation and the results will be presented in the upcoming paragraphs. These five simulations can be divided into two groups: the benchmark, and the interventions. In total, four interventions are done: extra elevator, toilets on levels, elevator to corner, and elevator near work. The visualisation of these simulation can be found in the appendices, Appendix 14, 15, 16, 17 and 18 respectively.

Table 19: Overview of performed simulations

Simulation 1	Benchmark
Simulation 2	Intervention 1: Extra elevator
Simulation 3	Intervention 2: Toilets on levels
Simulation 4	Intervention 3: Elevator to corner
Simulation 5	Intervention 4: Elevator near work

15 Benchmark

15.1 Characteristics

The first simulation performed is the Benchmark. Within this simulation, the current layout and way of working on the construction site are simulated. The data described in Chapter 0 is entered into Dynamo to perform this simulation. The list of rooms describing the travelled path can be found in Appendix 8.

In general, the following steps, derived from the typical workday, of the construction worker apply: worker enters the work shed for day start; worker enters construction site; gathers tools from storage and go to the first work space on a specific floor; worker goes to toilet on construction site; worker goes back to the first work space on specific floor; worker goes back to work shed for coffee break; worker goes to the second workspace; worker goes to work shed for lunch break; construction worker goes back to second workspace; worker goes to toilet on construction site; worker goes back to second workspace; workers places tools back in storage and leaves the site; and, worker goes to work shed and leaves. A visualisation of this simulation can be found in Appendix 14, which shows the walking lines, waiting time as red spheres and working times as blue cubes.

15.2 Results time calculations

With the input and characteristics mentioned in the previous paragraphs, a simulation is performed as Benchmark. Figure 49 shows the results of the benchmark simulations per level. On the horizontal axis, the different levels on which the simulations are performed are shown. The different lines show the different categories of time, which are part of the total time of a typical workday. The total time is the sum of all separate categories; and resembles the total time of a workday for one construction worker who does two rooms a day and no separation per crew.

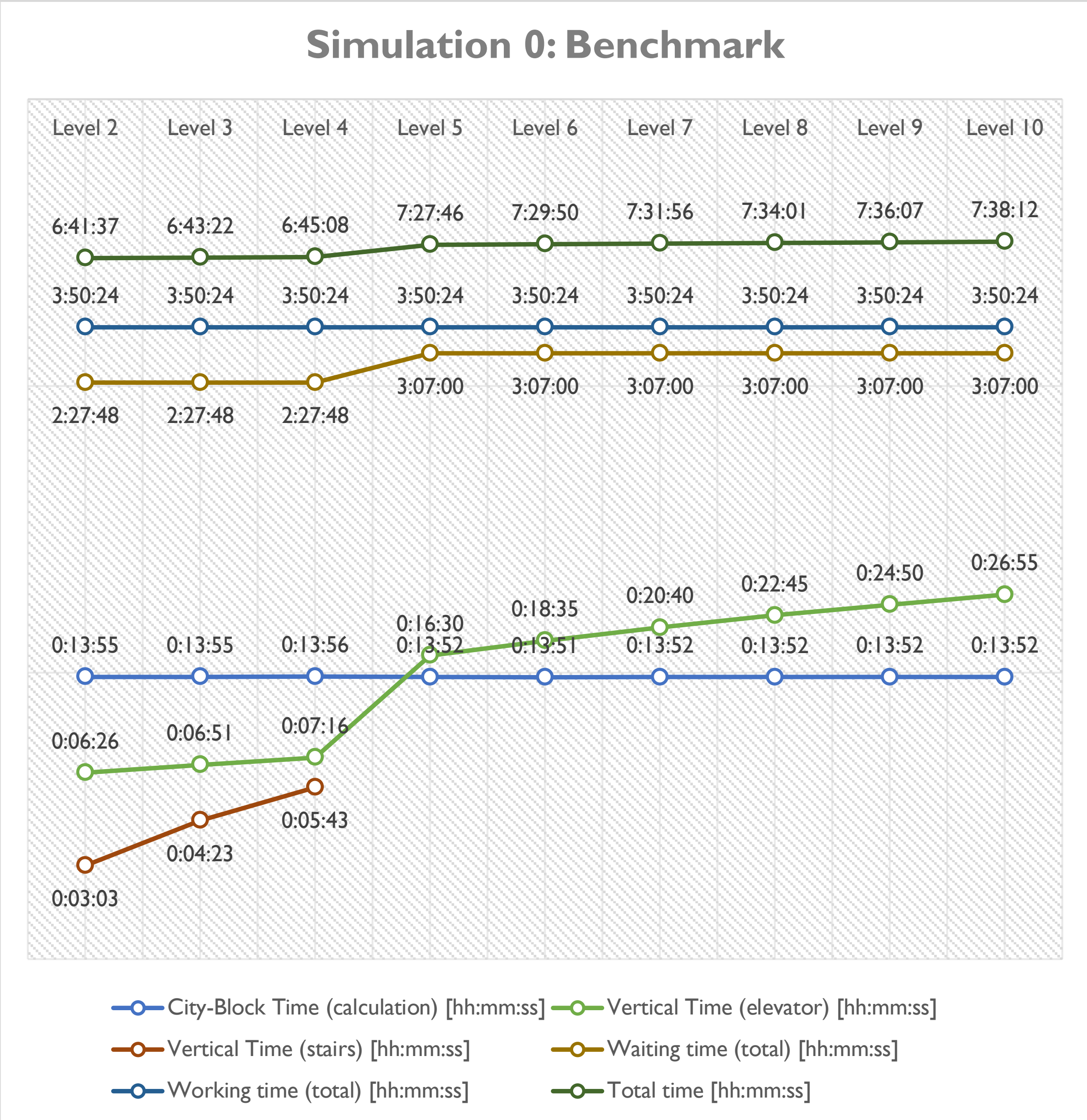


Figure 49: Results Benchmark simulation in terms of time

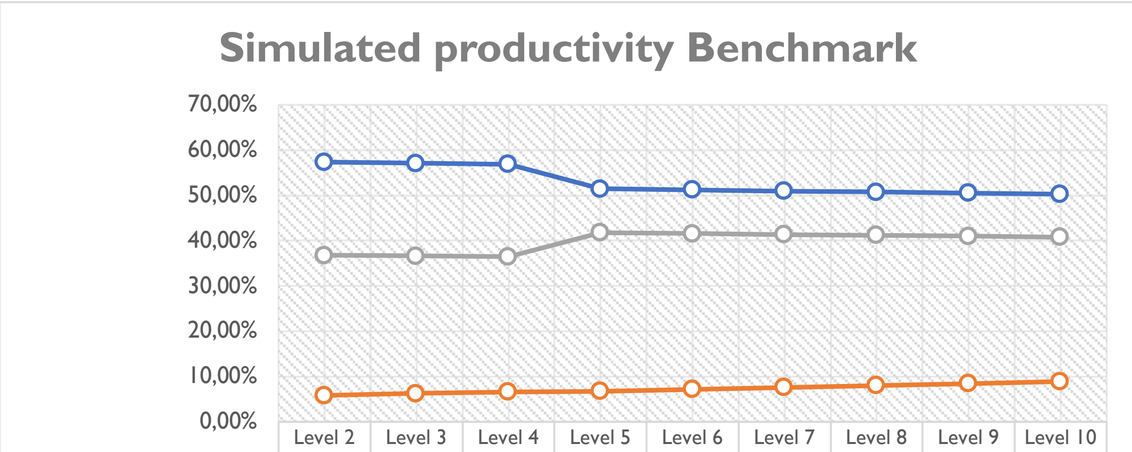
The figure shows that the total working time starts at 6 hours, 41 minutes and 37 second for level 2; up to 7 hours, 38 minutes and 12 second for level 10. As the work that needs to be carried out in the specified rooms does not change, the working time remains equal among all levels. Between level 4 and 5 the figure shows a stop in the vertical time by stairs and a strong increase in the vertical time by elevator. This can be explained by the policy of the head-contractor that when more than four level are passed the elevator can be used. Therefore, the construction workers change from means of vertical transport; from stair to elevator between level 4 and 5. This strong increase is also reflected in the waiting time; as the elevator is used more often during the day the waiting times increases as well.

15.3 Results simulated productivity

As defined in Chapter 6, the productivity in this research is defined as the ratio between working time and total time. As the productivity is defined as the ratio between the total time and working time, which is represented as the crew 1 – working in the figure below. Furthermore, the ratio of the waiting time and walking time to the total time is presented.

All three items of productivity show a decrease in productivity between level 4 and 5. This can be explained by the previously mentioned policy that construction workers are only allowed to take the elevator when more than 4 levels are passed. This significantly increases the waiting time on the workday and therefore changes the ratio between the working time and waiting time.

This shows that the productivity of the total working time differs between the 57.4% and 50.3% between level 2 and level 10. As productivity in terms of working decreases as the levels increase. Due to the increase of total time, and the working time remaining equal between all levels. The walking time's ratio increase slight with the increase of the levels. This is due to the decrease of walking distances by eliminating the stairs after the 4th floor and the increase of the total time.



	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9	Level 10
Crew 1 - Working	57,37%	57,12%	56,87%	51,46%	51,22%	50,98%	50,75%	50,51%	50,28%
Crew 1 - Walking	5,83%	6,24%	6,65%	6,78%	7,21%	7,64%	8,06%	8,49%	8,90%
Crew 1 - Waiting	36,80%	36,64%	36,48%	41,76%	41,57%	41,38%	41,19%	41,00%	40,81%

Figure 50: Results Benchmark simulation in term of productivity

16 Intervention 1: Extra elevator

16.1 Characteristics

This second simulation resembles the first intervention made to the construction site. For this first intervention, the elevator capacity is increased. Doubling the lift capacity means that not just one elevator is placed on site, but two. This second elevator is placed next to the first elevator. This intervention only changes one aspect of the simulation input, compared to the benchmark. For the elevator on site the waiting time is halved. With the availability of two elevators, the chances of one not being occupied or being closer to the starting point assumed is that the waiting time will be halved. The vertical travel speed of the elevator does not change, because the same type of elevator is used within this simulation. The list of rooms, which describes the travelled path can be found in Appendix 8. The steps shown in the simulation of the benchmark, which resemble the path followed by the construction worker, are equal in both simulations. A visualisation of this simulation can be found in Appendix 15, which represents the walking lines, waiting time as red spheres and working times as blue cubes.

16.2 Results time calculations

Figure 51 shows the results from the first intervention simulations per level. The horizontal axis shows the different levels on which the simulations are performed. The different lines show the different categories of time of which the total time of the typical workday is made of. The total time is the sum of all separate categories; and resembled the total time of a workday for one construction worker who does two rooms a day for crew 1.

The total time of these simulations differs from 6 hours, 35 minutes and 43 seconds at level 2 up to 7 hours, 8 minutes and 42 seconds at level 10. Since the time of the benchmark was 6 hours, 41 minutes and 37 second for level 2; up to 7 hours, 38 minutes and 12 second for level 10, this is lower. As the working time is calculated by the work that needs to be executed in the different rooms this stays equal between all levels and all simulations.

As mentioned in the benchmark simulation, the construction works are generally only allowed to take the elevator when more than four levels need to be passed. This implication resembles a significant increase in waiting time and vertical travel by elevator time; and an elimination of vertical travel time by stairs between level 4 and 5.

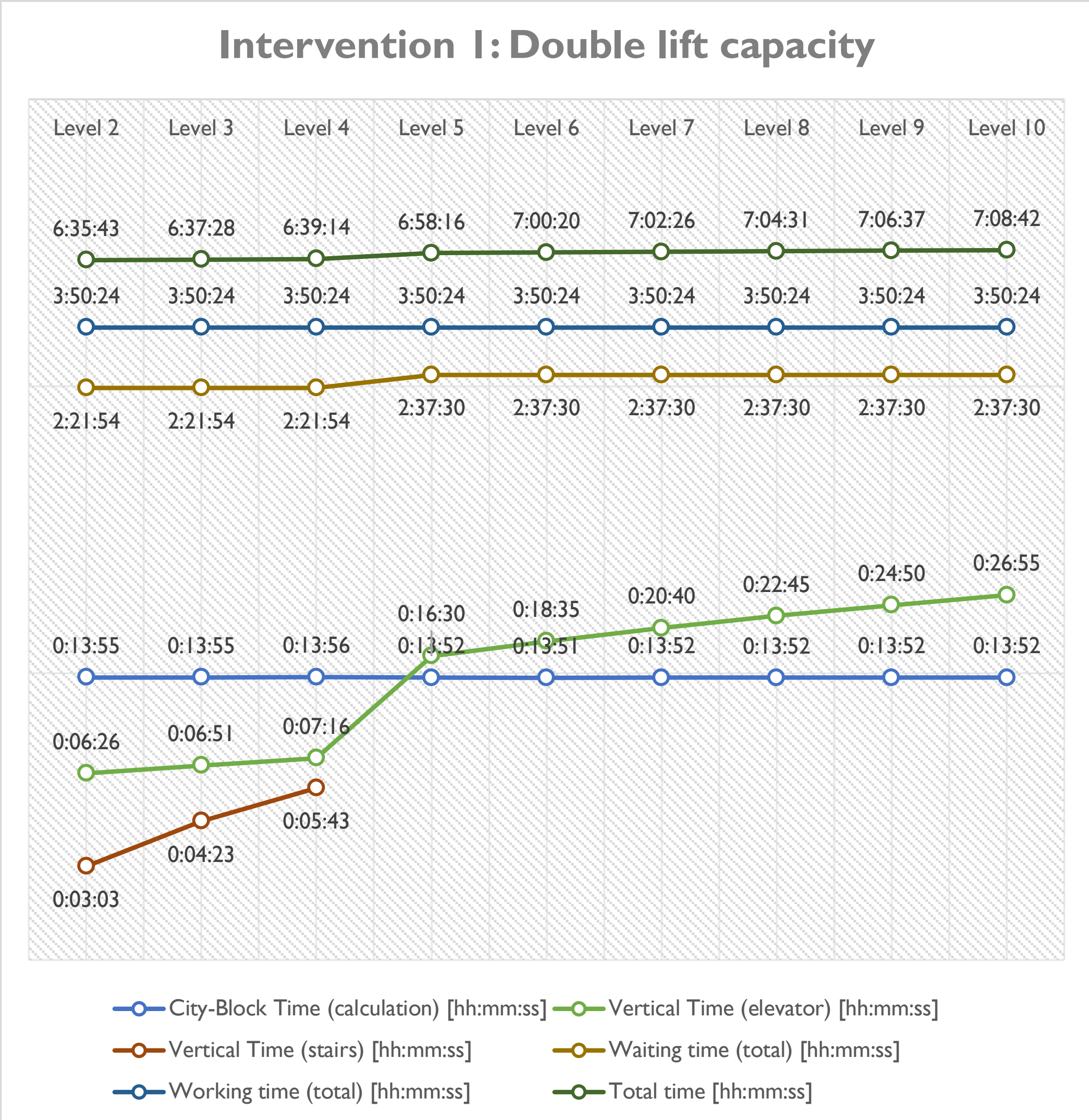


Figure 51: Results simulation Intervention 1 in terms of time.

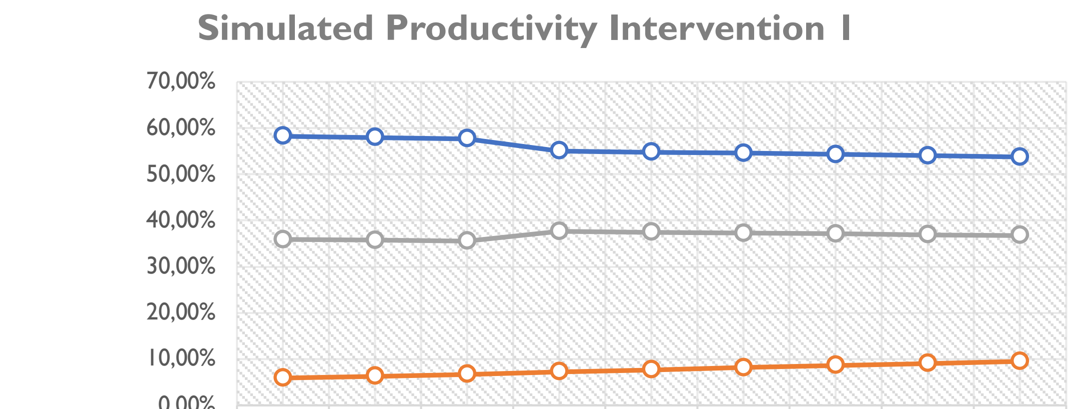
16.3 Results simulated productivity

The productivity of the first intervention simulation is visualised in Figure 52, and the difference in productivity between the intervention and benchmark is visualised in Figure 53. This shows that the productivity of the total working time differs between the 58.2% and 53.7% between level 2 and level 10; which is higher than the benchmark as shown in Figure 53.

All three items of productivity show a change in productivity between level 4 and 5. A decrease in productivity can be found between level 4 and 5, as a result of the head-contractors elevator policy. With the intervention of an extra elevator this instance shows a large change in productivity, in sense of increased productivity.

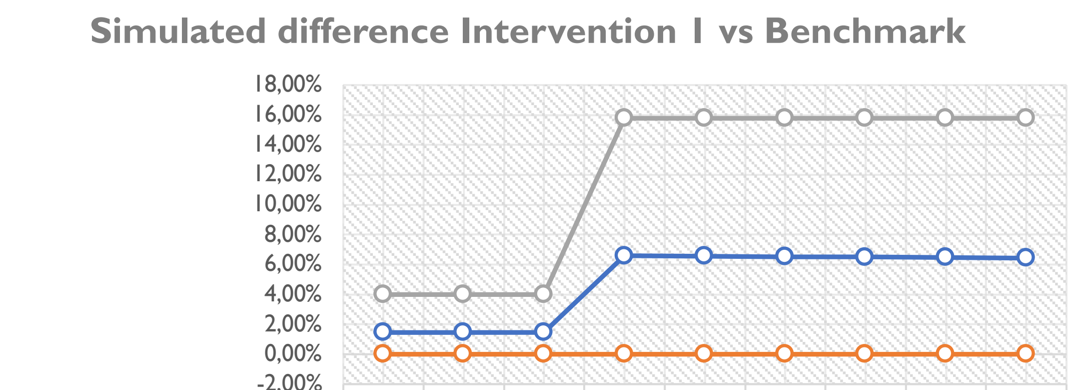
Furthermore, the increase in productivity between the benchmark and first intervention (see Figure 53) is related to the head-contractor's elevator policy as well. The increase in productivity remains equal between the level 2 to 4 and between the level 5 to 10. This can be clarified by the changes in waiting time. As the number of elevators used does only changes between level 4 and 5, this is the only change in total amount of waiting times for the elevator.

Figure 53 shows that the highest increase can be described by the waiting time. As the working time stays equals between the different simulations (see Figure 51) the increase in productivity can only be caused by a change in waiting or walking time. Within Intervention 1, the waiting time has had the biggest difference compares to the benchmark (see Figure 53), and thus the biggest influence on the increase of productivity.



	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9	Level 10
Crew 1 - Working	58,22%	57,97%	57,71%	55,08%	54,81%	54,54%	54,27%	54,01%	53,74%
Crew 1 - Walking	5,92%	6,33%	6,75%	7,26%	7,72%	8,18%	8,63%	9,07%	9,52%
Crew 1 - Waiting	35,86%	35,70%	35,54%	37,66%	37,47%	37,28%	37,10%	36,92%	36,74%

Figure 52: Results simulation Intervention 1 in terms of productivity



	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9	Level 10
Crew 1 - Working (difference)	1,47%	1,46%	1,46%	6,59%	6,56%	6,53%	6,50%	6,47%	6,44%
Crew 1 - Walking (difference)	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Crew 1 - Waiting (difference)	3,99%	3,99%	3,99%	15,78%	15,78%	15,78%	15,78%	15,78%	15,78%

Figure 53: Difference in productivity between Intervention 1 and Benchmark

17 Intervention 2: Toilets on levels

17.1 Characteristic

The second intervention is to place the toilets on each level of the building. This eliminates two vertical travel rounds to the ground level, where the toilets in the benchmark are placed. The typical workday showed that the construction worker visited the toilets on site two times a day. Within this intervention, 9 extra toilets are placed on the construction site. These 9 toilets are placed on the scaffolding outside the building. This is done from level two to 10.

The path followed by the construction worker along his or her day is shown in Appendix 9. Different from the previous two simulations is that the worker does not visit the toilet on the ground level, but visits a different toilet placed on every level. A visualisation of this simulation can be found in Appendix 16, which shows the walking lines, waiting time as red spheres and working times as blue cubes.

17.2 Results time calculations

Within Figure 54 the results in terms of time per category is visualised. On the horizontal axis, the different levels on which the simulations are performed are shown. The different lines show the different time categories that make up the total time of the typical workday. The total time is the sum of all separate categories and resembles the total time of a workday for one construction worker who does two rooms a day for crew 1.

The total time differs from 6 hours, 24 minutes and 30 second on level 2 up to 6 hours, 54 minutes and 44 second on level 10. Which is the lowest compared to the previous two simulations. As mentioned in the previous two simulations the working time is equal to the previous two simulations as the specifications of the work that needs to be carries out does not change.

Again, the head-contractors elevator policy shows a strong increase in vertical travel time by elevator and elimination of the vertical travel time by stairs.

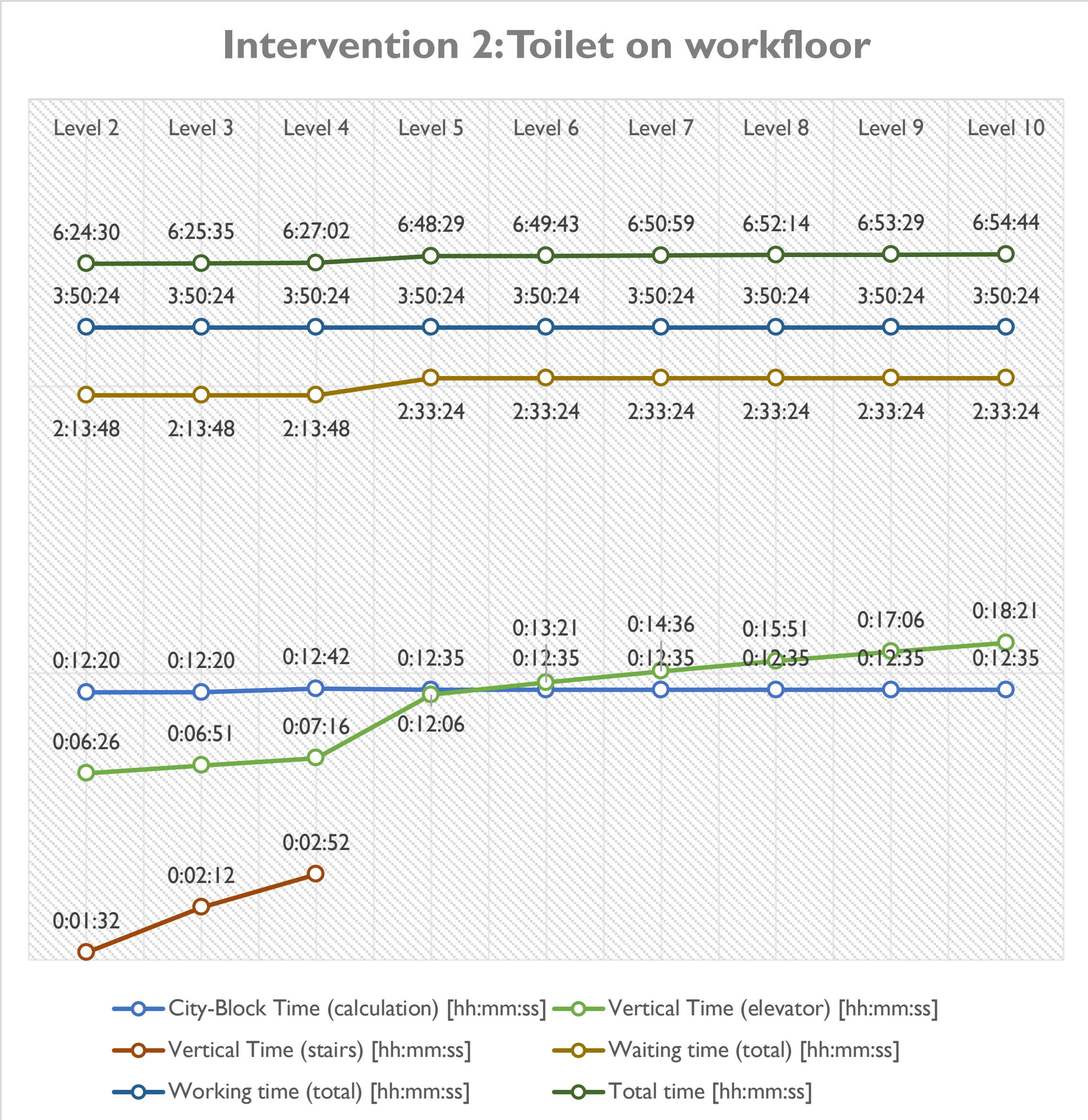


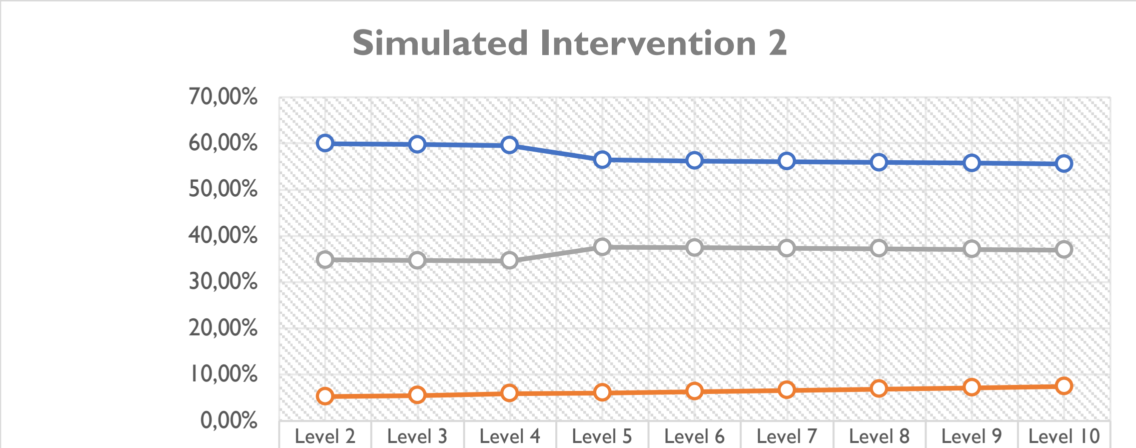
Figure 54: Results simulation Intervention 2 in terms of time.

17.3 Results simulated productivity

The productivity that relates to this second interventions is visualised in Figure 54: the difference in productivity between this second intervention and the benchmark is visualised in Figure 56. This shows that the productivity of the total working time, all crews combined, is between 59.9% at level 2 and 55.6% at level 10. This is the highest productivity of all simulations performed.

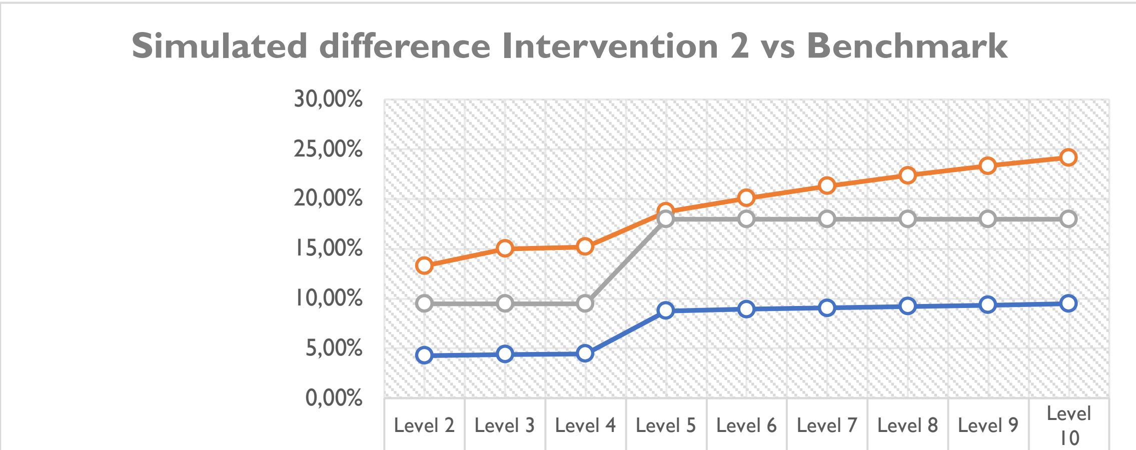
Within Figure 55, the increase in productivity between the benchmark and the second interventions is shown. The decrease in productivity decreases among the different levels, with the strongest decrease between level 4 and 5 resulting from the head-contractors elevator policy. That the productivityincreases among the different level and does not stay equal between level 2-4 and level 5-10 as in intervention1 can be explained by elevator travel time and waiting time. In the previous intervention, only the waiting time of the elevator had influence on the productivity. In this second intervention, the waiting and the vertical travel time by elevator is influenced since the amount of vertical movements is decreased.

The increase in waiting and working time significantly contributes to the productivity as is indicated in Figure 56. The intervention results in a decrease of walking and waiting time as vertical movements are decreased. This both decreased the waiting times and the walking time compared to the benchmark.



	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9	Level 10
Crew 1 - Working	59,92%	59,75%	59,53%	56,40%	56,23%	56,06%	55,89%	55,72%	55,55%
Crew 1 - Walking	5,28%	5,55%	5,90%	6,04%	6,33%	6,61%	6,90%	7,18%	7,46%
Crew 1 - Waiting	34,80%	34,70%	34,57%	37,55%	37,44%	37,33%	37,21%	37,10%	36,99%

Figure 55: Results simulation Intervention 2 in terms of productivity



	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9	Level 10
Crew 1 - Working (difference)	4,26%	4,41%	4,47%	8,77%	8,92%	9,06%	9,20%	9,35%	9,49%
Crew 1 - Walking (difference)	13,28%	15,01%	15,20%	18,72%	20,09%	21,31%	22,36%	23,32%	24,17%
Crew 1 - Waiting (difference)	9,47%	9,47%	9,47%	17,97%	17,97%	17,97%	17,97%	17,97%	17,97%

Figure 56: Difference in productivity between Intervention 2 and Benchmark

18 Intervention 3: Elevator to corner

18.1 Characteristics

For this fourth simulation and third intervention, the placement of the elevator on site and the stairwell on site is questioned. In the benchmark, the elevator and stairwell were placed within the centre of the hotel building, connected to the scaffolding. The new location of the elevator and stairwell is placed more towards one corner of the hotel building. This corner is closer to the toilets and closer to the site entrance that is mostly used by the workers in the benchmark.

The path followed by the construction workers, broken down into the different rooms, is shown in Appendix 8. The difference between the benchmark and the first intervention is that the rooms are equal: only the location of the elevator and stairwell is changed. This results in different coordinates. A visualisation of this simulation can be found in Appendix 17, which shows the walking lines, waiting time as red spheres and working times as blue cubes.

18.2 Results time calculations

The results of the simulations, which show the times of the different categories, are presented in Figure 57. The different lines represent the different categories of time that collectively make up the total of time of the typical workday of a construction worker who works on two rooms a day for crew 1.

The total time of the workday in this simulation differs from 6 hours, 41 minutes and 33 second on level 2 to 7 hours, 38 minutes and 12 seconds on level 10. These times are comparable with the benchmark as the difference is minimal. This is due to the fact that the only change in the simulation is the location of the elevator, and therefore only the city-block distance or walking distance is the only one that differs. With changes the placement of the elevator on site, the construction workers distance to the elevator on ground level is decreased, but to the work area is increased.

Comparable with the previous simulation, is the strong difference between level 4 and 5 for different categories. These strong changes can be related back to the elevator policy of the construction worker. As explained in the simulation of the benchmark.

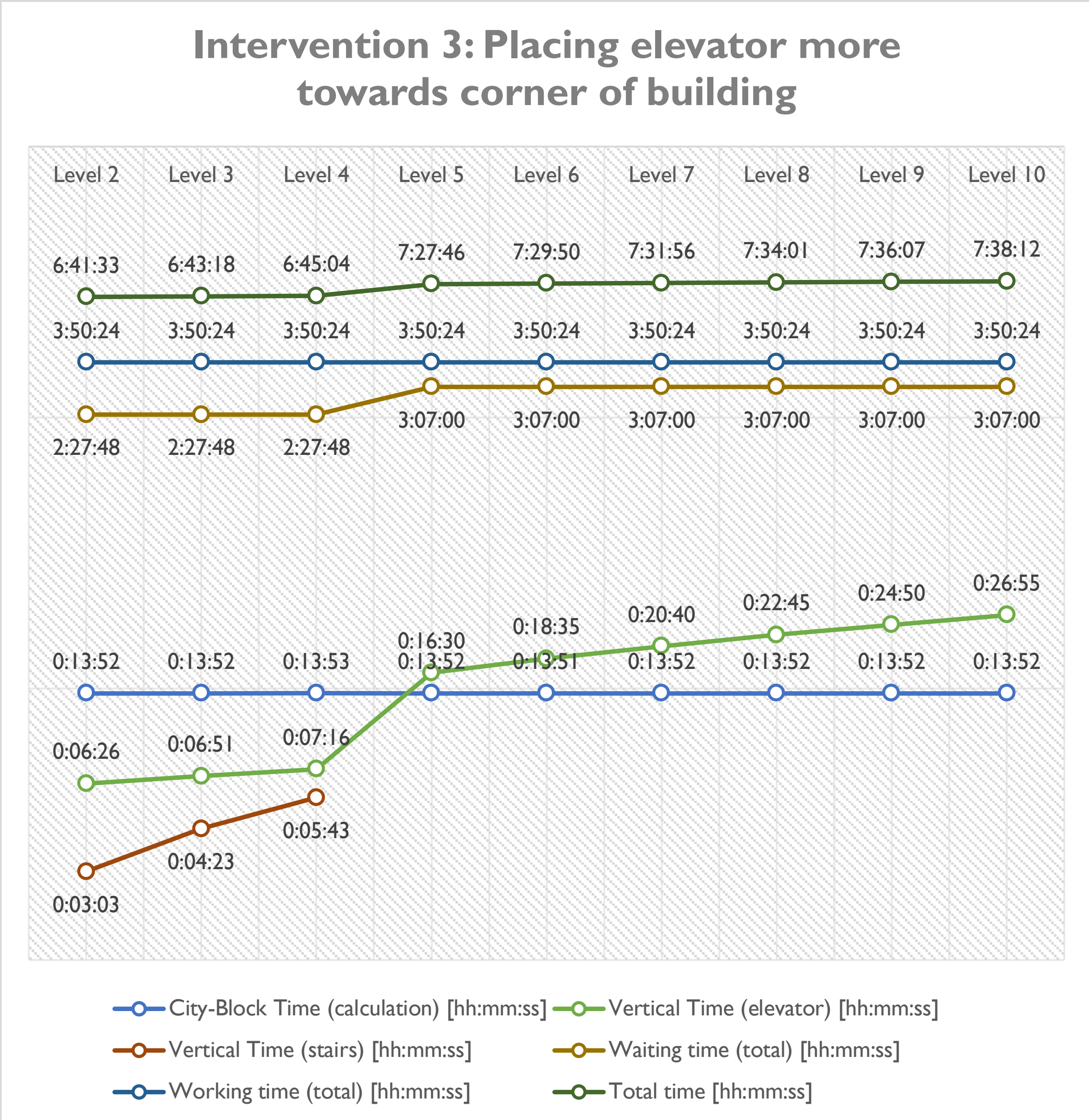
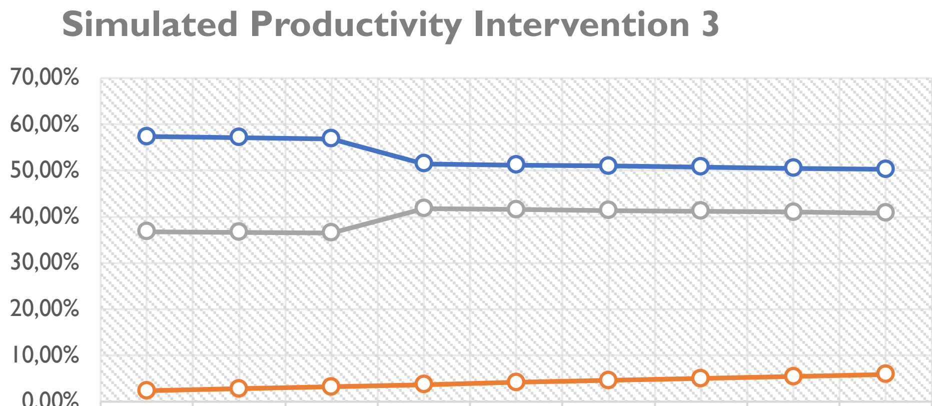


Figure 57: Results simulation Intervention 3 in terms of time.

18.3 Results simulated productivity

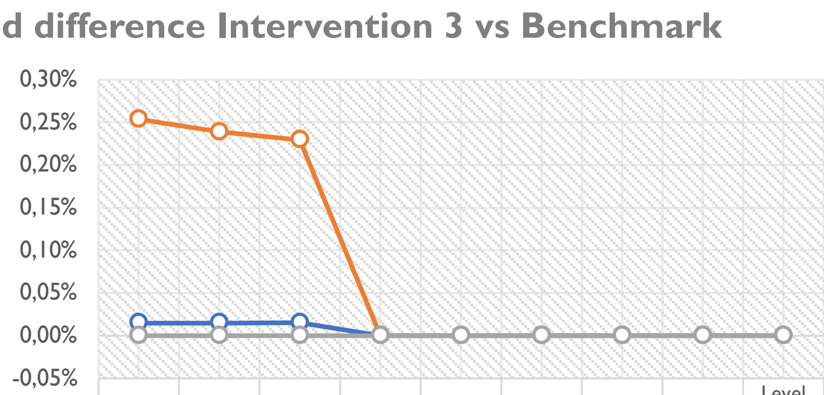
The productivity of Intervention 3 is shown in Figure 58 and the changes in productivity are shown in Figure 59. Figure 59 shows the results that the difference in productivity, between this intervention and the benchmark, is almost zero. Therefore, the impact of this intervention on the productivity can be neglected.

Furthermore, the figures show equal results to the previous simulations, where a change in productivity is found between level 4 and 5. Which, once more, refers back to the elevator policy of the head-contractor.



	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9	Level 10
Crew 1 - Working	57,38%	57,13%	56,88%	51,46%	51,22%	50,98%	50,75%	50,51%	50,28%
Crew 1 - Walking	2,36%	2,79%	3,21%	3,69%	4,13%	4,57%	5,01%	5,45%	5,88%
Crew 1 - Waiting	36,81%	36,65%	36,49%	41,76%	41,57%	41,38%	41,19%	41,00%	40,81%

Figure 58: Results simulation Intervention 3 in terms of productivity



	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9	Level 10
Crew 1 - Working (difference)	0,01%	0,01%	0,02%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Crew 1 - Walking (difference)	0,25%	0,24%	0,23%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Crew 1 - Waiting (difference)	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%

Figure 59: Difference in productivity between Intervention 3 and Benchmark

19 Intervention 4: Elevator near work

19.1 Characteristics

The fifth and last simulation performed is the fourth intervention presented. In this intervention, comparable to Intervention 3, the placement of the elevator is questioned. As in the benchmark, the elevator was placed in the centre of the building next to the scaffolding, and in Intervention 3 the elevator is placed toward a corner in the building. Within this fourth intervention, the elevator and stairwell are placed near the workspace where the rooms in which the construction worker has to perform construction work is located.

As the rooms chosen within the simulations are on the opposite side of the building compared to the original placement of the elevator and stairwell, the elevator and stairwell are placed to the backside of the building. This shortens the horizontal distance between the elevator and workspace on the different levels of the building, but it increases the horizontal distance that has to be travelled on the ground level of the construction site.

The path followed by the construction workers, broken down into the different rooms, is shown in Appendix 8. The difference between the benchmark, the first, and third intervention is the location of the elevator and stairwell. This results in different coordinates. A visualisation of this simulation can be found in Appendix 18, in which the walking lines, waiting time as red spheres and working times as blue cubes are shown.

19.2 Results time calculations

The times of the different categories resulting from the simulation, are presented in Figure 60. As before, the different lines show the different categories of time that make up the total time of the typical workday. The total time is the sum of all separate categories; and resembles the total time of a workday for one construction worker who does two rooms a day from crew 1.

The total time of the workday in this simulation differs from 6 hours, 42 minutes and 36 second on level two to 7 hours, 39 minutes and 14 seconds on level 10. These times are, with 1 minute and 1 second at level 2 and 1 minute and 2 second difference, slightly longer than the times simulated in the benchmark.

As the location of the elevator and stairwell is the only thing that is changed compared to the benchmark, only the horizontal distances differ. This results in a higher city-block time than in the previous simulations. Therefore, the difference with the benchmark is the city-block time.

As a result of the head-contractor's elevator policy, as previously explained, different categories show a large difference between level 4 and 5.

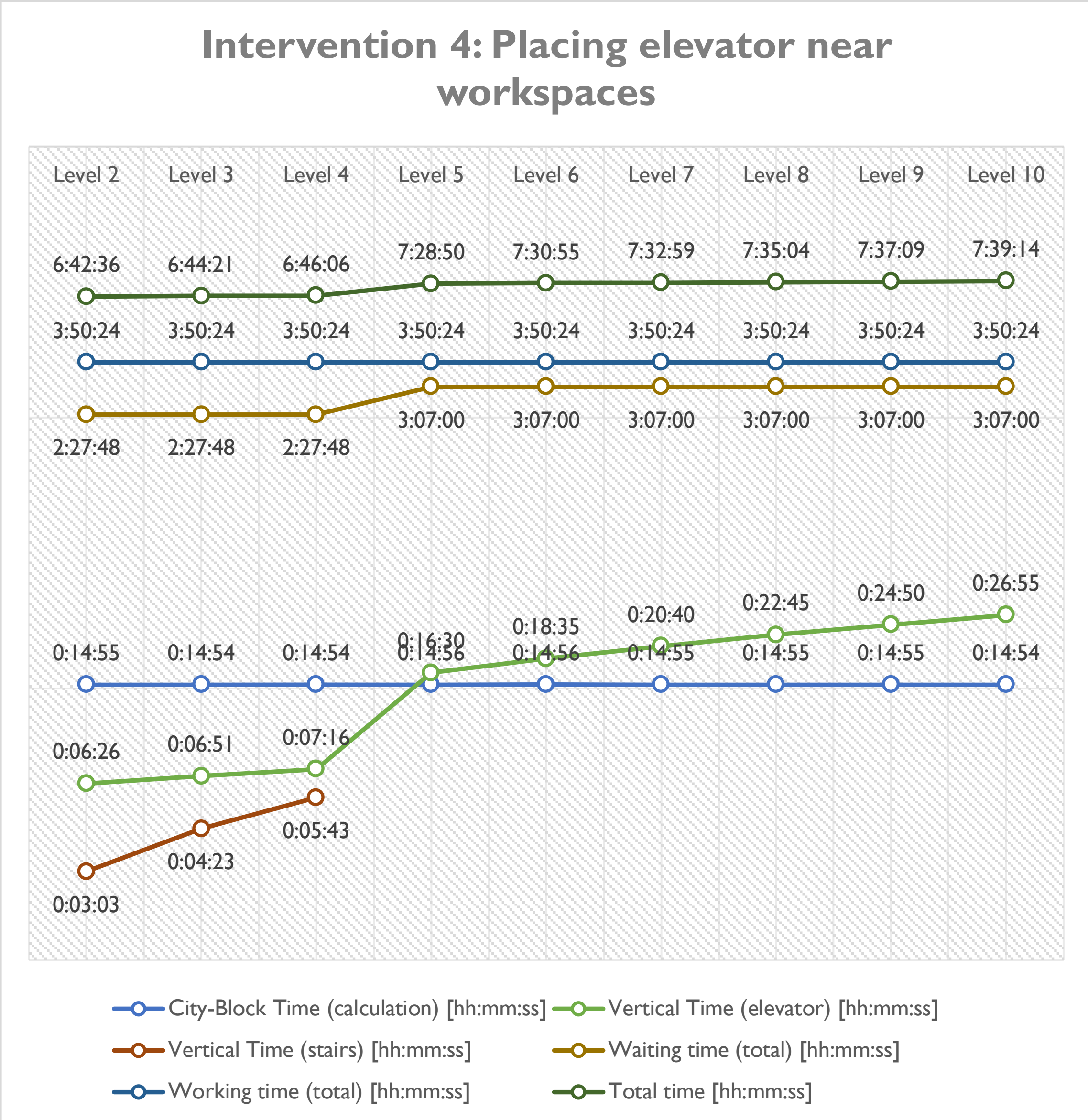


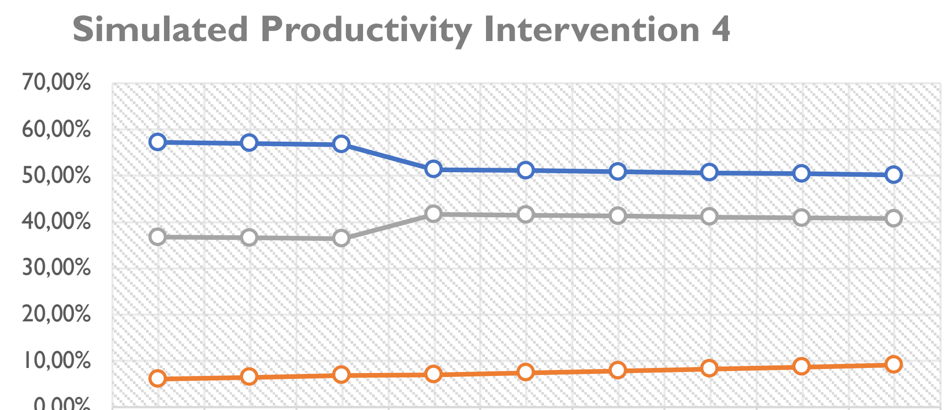
Figure 60: Results simulation Intervention 4 in terms of time.

19.3 Results simulated productivity

Figure 60 shows the productivity of intervention 4 per level. Within Figure 61, the difference between Intervention 4 and the benchmark is visualised. Once more the productivity figures show a large difference between level 4 and 5, which can be related back to the head-contractor's elevator policy.

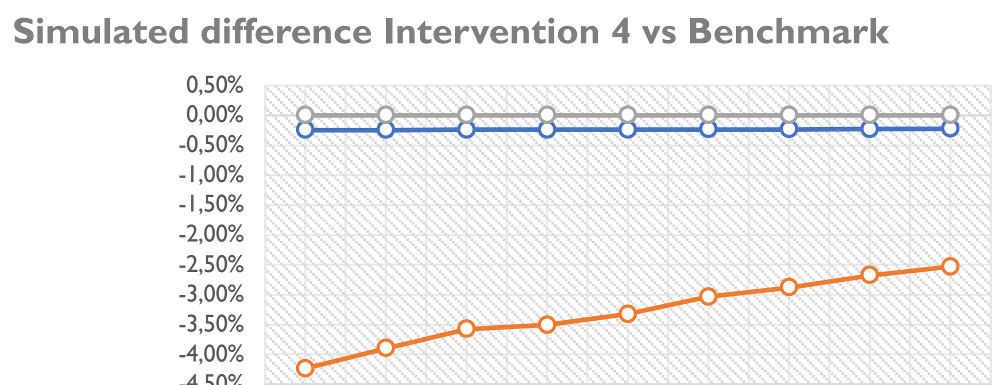
Total productivity for the intervention lies between 57.23% at level 2, and 50.17% at level 10. This is slightly lower compared than the benchmark. Thus, this intervention has a negative effect on the productivity compared to the benchmark. This is due to the larger walked distances in horizontal sense in the intervention.

As indicated this decrease is primarily caused by the increase of walking time. As the walking time increases the total time increases and the productivity decreases. The decrease in productivity is only small between 0.25% and 0.23%



	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9	Level 10
Crew 1 - Working	57,23%	56,98%	56,74%	51,33%	51,10%	50,86%	50,63%	50,40%	50,17%
Crew 1 - Walking	6,06%	6,47%	6,87%	7,00%	7,43%	7,86%	8,28%	8,69%	9,11%
Crew 1 - Waiting	36,71%	36,55%	36,40%	41,66%	41,47%	41,28%	41,09%	40,91%	40,72%

Figure 61: Results simulation Intervention 4 in terms of productivity



	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level 9	Level 10
Crew 1 - Working (difference)	-0,25%	-0,24%	-0,24%	-0,24%	-0,24%	-0,23%	-0,23%	-0,23%	-0,23%
Crew 1 - Walking (difference)	-4,23%	-3,90%	-3,58%	-3,51%	-3,33%	-3,04%	-2,88%	-2,67%	-2,53%
Crew 1 - Waiting (difference)	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%

Figure 62: Difference in productivity between Intervention 4 and Benchmark

20 Results

20.1 Overview of simulations performed

Within Figure 63, the average times per categories are shown. The walking time is the sum of the city-clock time; vertical time (elevator); and, vertical time (stairs). The total time is the sum of the city-block time; vertical time (elevator); vertical time (stairs); waiting time; and working time. Within this average, each level has the same weight. The vertical time by stairs is not visible in Figure 63, due to its respectively low values compared with the other categories.

This shows that the working time is set as constant in the total time and remains the same along each intervention. Furthermore, its shows that the Intervention 3 and 4 are quite similar to the total time calculated in the Benchmark, with differences of 1 second and 1minute and 2 seconds respectively. Total time of intervention 2 differs most with the benchmark. This can be explained by the nature of the intervention: in which two rounds of vertical movements were eliminated, through which the waiting time reduced, as well as the vertical travel time by stairs and elevators.

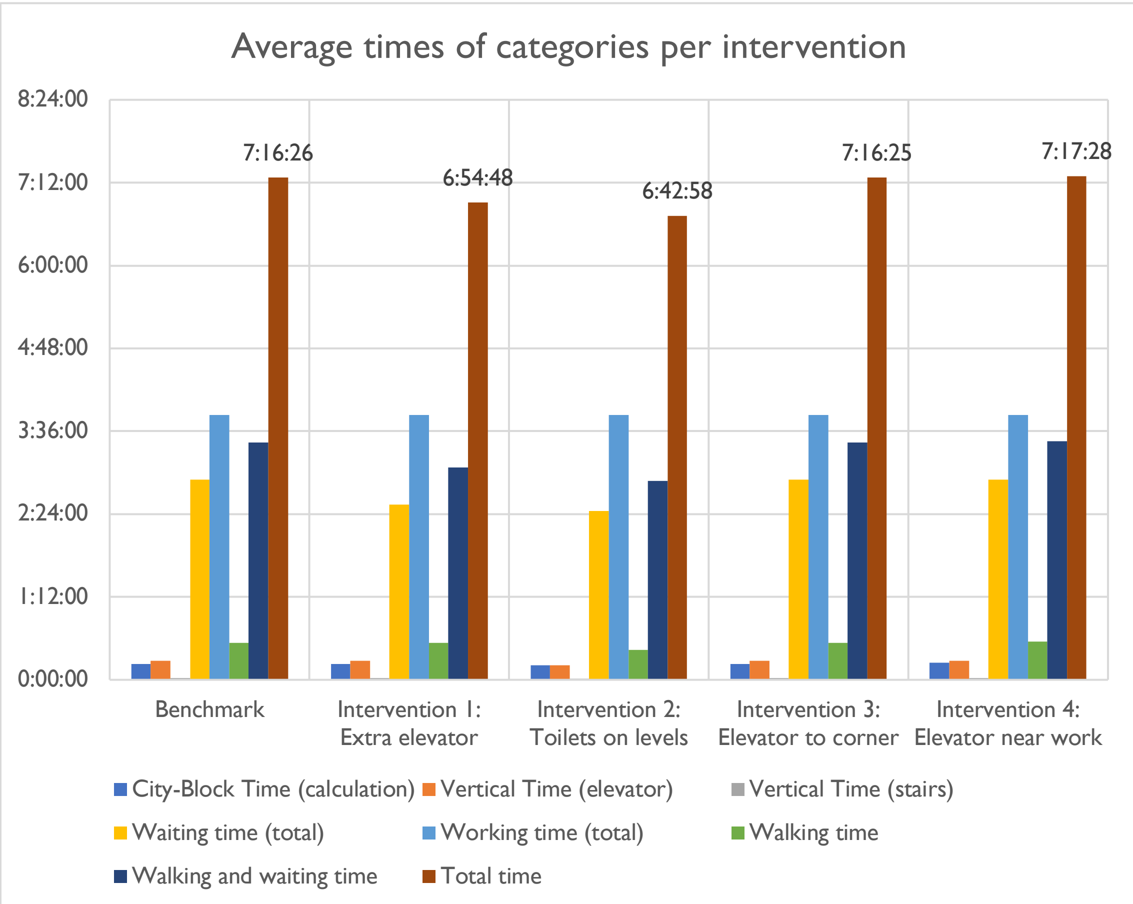


Figure 63: Average times of all simulations per category

20.2 Walking

The following paragraph is broken down in two parts. In the first part, the horizontal walking times of all five simulations are analysed. In the second part, the combination of horizontal and vertical travel time is investigated.

20.2.1 Horizontal walking times

As previously mentioned, the horizontal walking time is defined as the city-block time, which is the distance travelled on the ground level of the construction site or within the different building levels. The results of the city-block time are visualised in Figure 64.

The city-block times is consistent among the different levels. Comparing the city-block time of each intervention among the different levels, and therefore the horizontal walking distance, remains almost equal among all levels. At the utmost, it differs a few seconds from other levels.

Furthermore, it is notable that from the highest and the lowest city-block time the difference is 2 minutes and 25 seconds on average. This is the average difference between levels of Intervention 2 and Intervention 4.

When comparing the city-block times with the benchmark the following applies. Between the benchmark and the intervention of an extra elevator, no difference is made in city-block time. Between the benchmark and the intervention in which the toilets are placed on the building levels, the city-block time lowers by 1 minute and 21 second. Between the benchmark and the third intervention of placing the elevator toward the corner of the building, the improvement is only 1 second. Between the benchmark and the fourth intervention of placing, the elevators near the workspace the city-block time is enlarged with 1 minute and 2 second. These improvements are an average per level, with each level weighted equally. This shows that the difference made within this case and these interventions is having a maximum of 1minute and 21 second. When relating this to the workday, which varies approximately between 9,5 and 10 hours on average of all levels, the impact of the city-block time is minimal as improvement of 1 minute and 21 second is only a very small percentage of the total time.

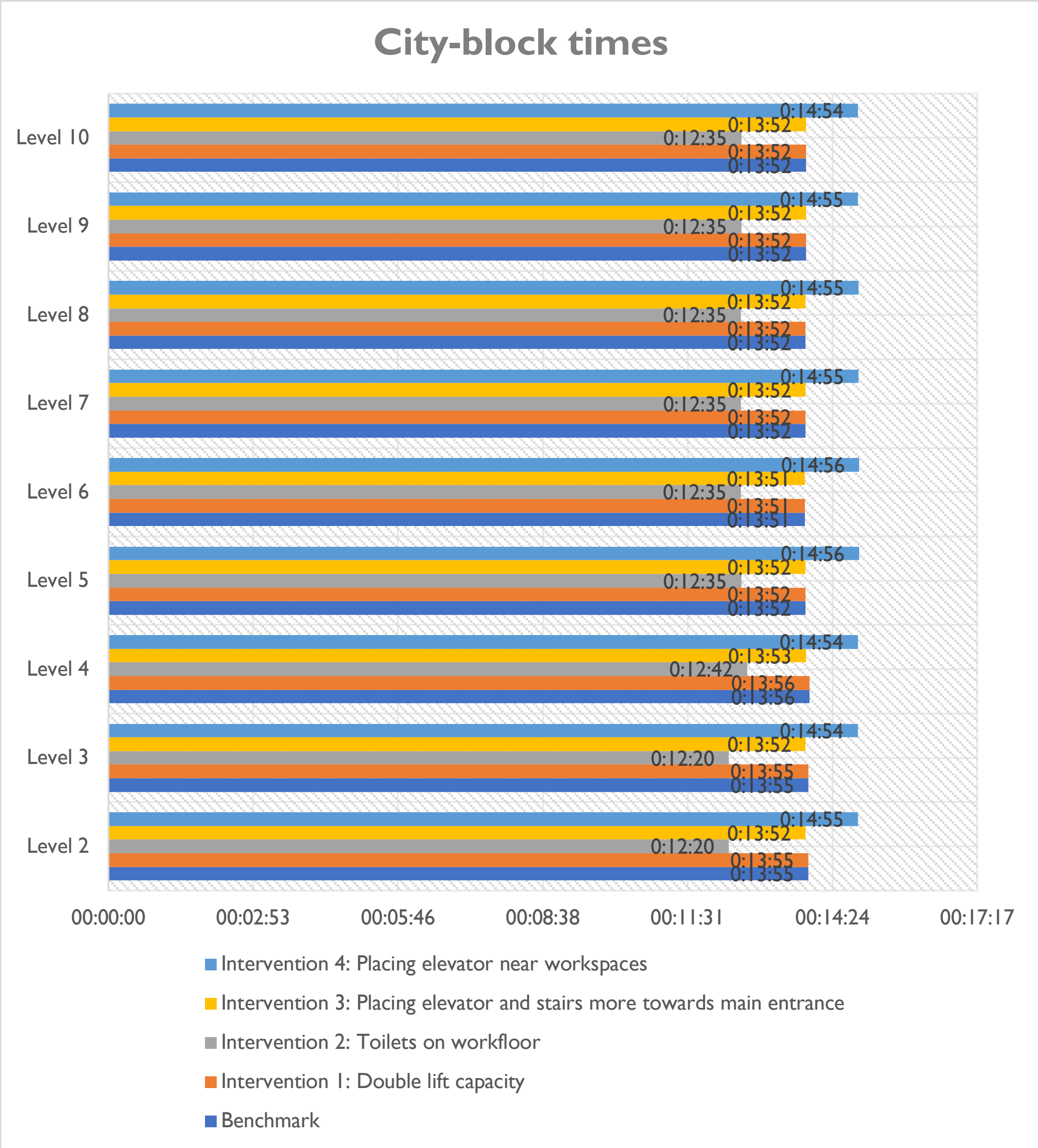


Figure 64: Horizontal walking times of all simulation per level

20.2.2 Vertical time by elevator

The vertical time by elevator entails all vertical travel by the elevator and the time it takes the elevator to travel from one level to the other level (see Figure 65). Remarkable in is that from level 2 to level 4 the results equal between all simulations. This is related that due to the head-contractor's elevator policy, where workers have to take the stairs when traveling less than 5 levels. The only use of elevators is to bring to and remove equipment from these levels. Therefore, this does not change during any interventions.

Furthermore, from level 5 up to 10, the benchmark, interventions 1, 3 and 4 have all the same elevator time on each level, while intervention 2 differs. This can be explained by the nature of Intervention 2. In intervention 2 the vertical travel time by elevator is minimised trough eliminating two up and down movements.

Contrary to the city-block time the vertical time by elevator proves to have a bigger time optimisation, as the differences between the benchmark and interventions are bigger. As previously mentioned, only Intervention 2 causes a change in vertical time by elevator. The average improvement between all 9 levels, weighing each level equally, is an average improvement of 4 minutes and 20 seconds.

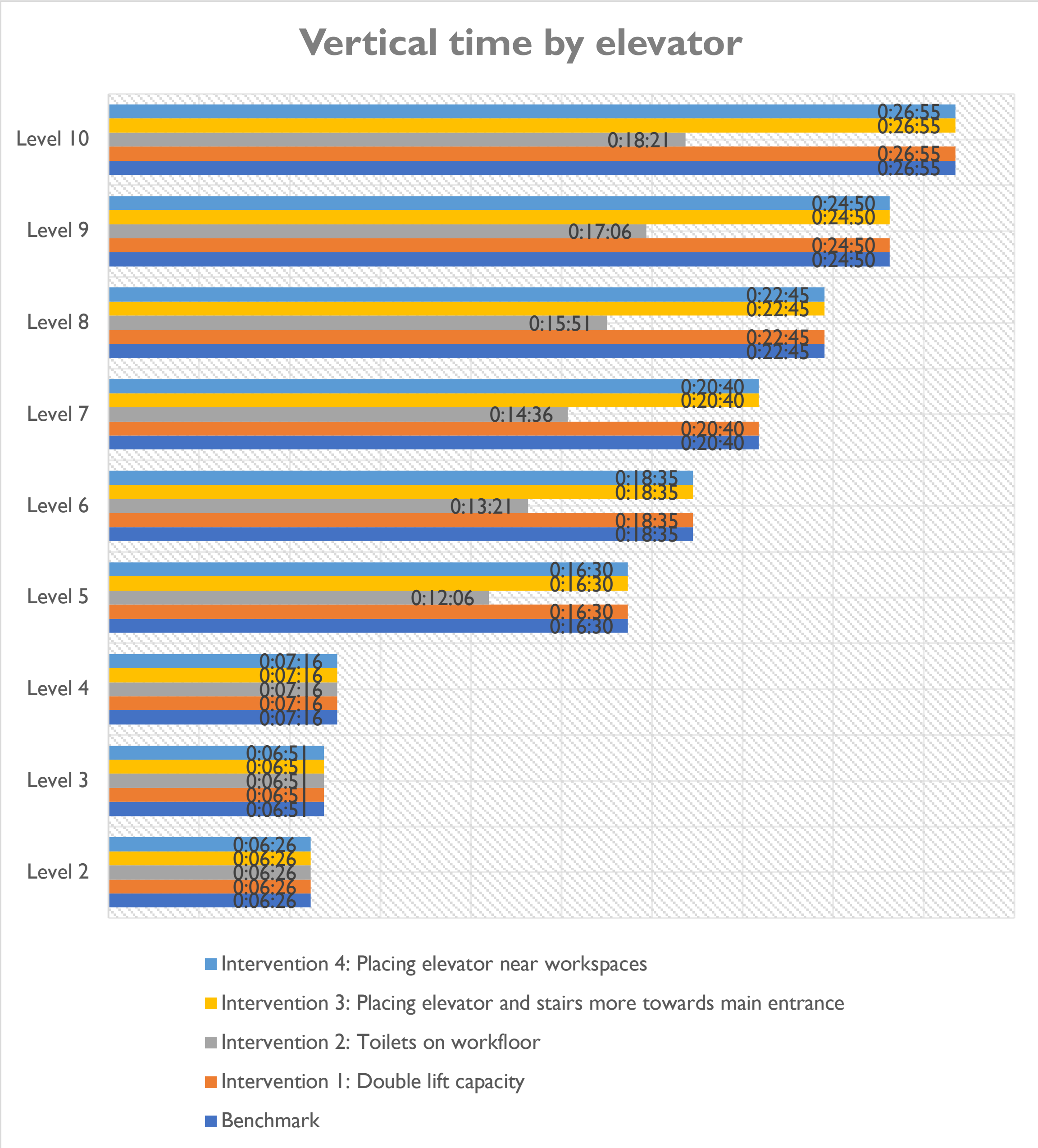


Figure 65: Vertical travel time by elevator

20.2.3 Vertical time by stairs

As mentioned before, the elevator is only tolerated when more than 4 levels are travelled. Therefore, in this simulation the use of stairs above level 4 is eliminated. Therefore, only level 2, 3 and 4 are presented in Figure 66, which resembles the vertical travel times by stairs.

As mentioned in the previous paragraph the only interventions that has impact on the amount of vertical movements of the construction workers is interventions 2. Therefore, the figures show that only an improvement in vertical travel time by stairs is related to the second intervention. Therefore, the vertical travel time by stair for the other simulations remains equal. Intervention 2 has an improvement of 44 second on average for each level, with each level weighted equally. The impact of the vertical time by stair improvement are therefore comparable with the city-block time.

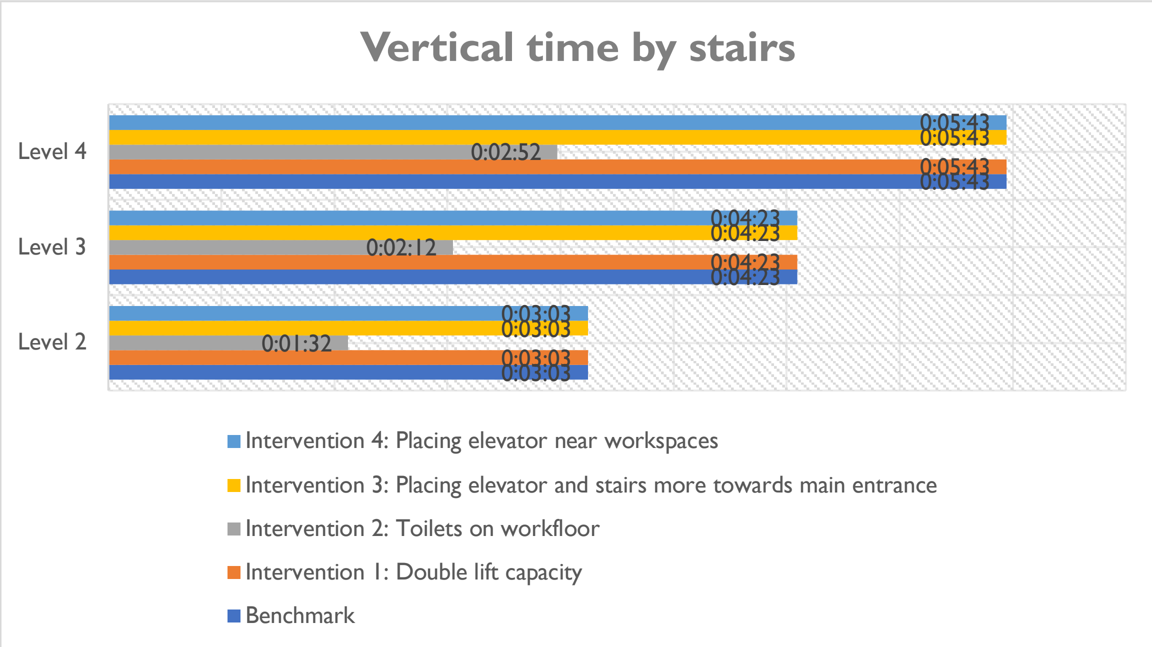


Figure 66: Vertical travel time by stairs

20.2.4 Horizontal and vertical walking times

Within Figure 67 the three categories which form the traveling time: City-block time; vertical time by elevator; and, vertical time by stairs are presented. This shows the average impact of each category per simulation. The average is calculated with all levels weighted equally. This shows that the benchmark, Intervention 1 and 3 are about equal for all three categories. And that Intervention 4 is slightly higher, due to the longer city-block times. Intervention 2 has the biggest improvement from the benchmark. And has improved for both the vertical time by elevators and stairs.

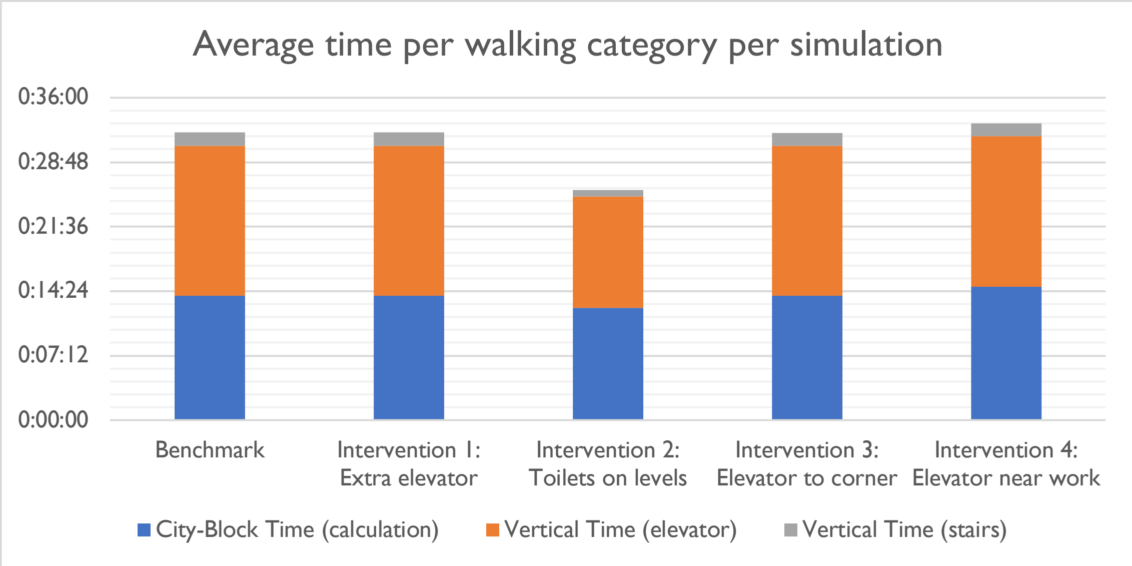


Figure 67: Breakdown average walking times between all simulations

Figure 68 shows all three categories collectively, compared to the 9 levels on which the simulations are performed. In this figure, a couple of remarkable features can be pointed out.

First, all simulations show a progressive growth when the levels increase. This can be explained by the fact that the higher the level the more vertical travel needs to be done by the construction workers. Therefore, the vertical travel time gradually increases as the levels increase.

Second, while the benchmark, Intervention 1 and 3 are approximately equal among each level. Intervention 2. This difference is due to the nature of Intervention 2: the amount of vertical travels and the horizontal movements was decreased in this intervention. Therefore, the impact of Intervention 2 on traveling time is the biggest of all.

The traveling time of Intervention 4 is slightly longer than the benchmark among each level, which can be explained by the nature of this interventions: as the intervention only changes the city-block time and does not change one of the vertical travel time categories, it only affects one of the three categories. And the impact on this category is relatively low as it is a relatively small factor on the total time, as explained in paragraph 20.2.1.

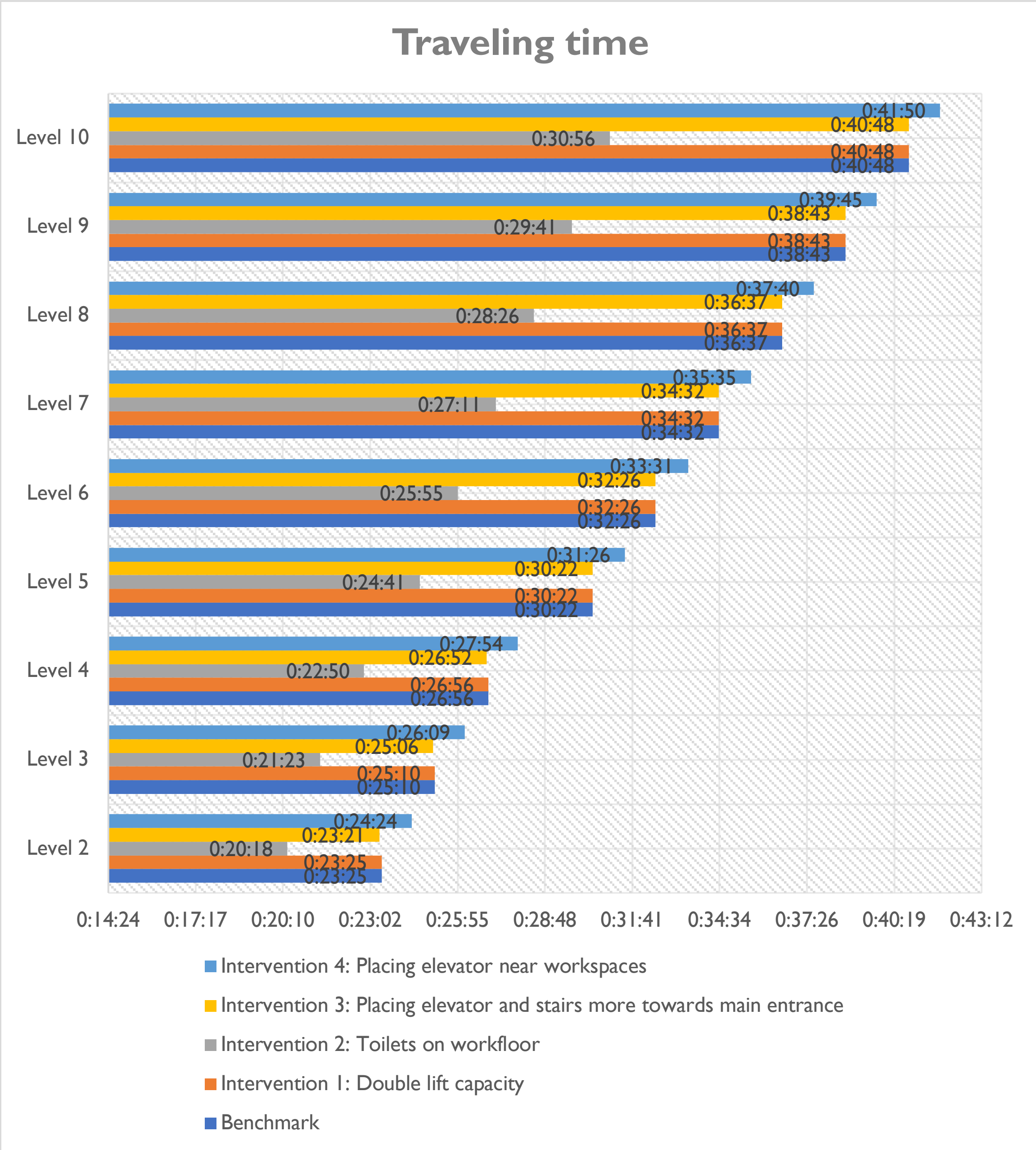


Figure 68: Traveling time, sum of city-block time and vertical time by stairs and elevators.

20.3 Waiting

The waiting time is the sum of all waiting times of all rooms passed along the constructions worker's path in a typical workday. When rooms are passed multiple times a day, the waiting time is multiplied with the number of visits. The total waiting time is presented in Figure 69. A couple of remarkable points about this figure are dicusssed.

First, the waiting time is not defined per level. As the construction workers path travels along different rooms on different levels, the only difference is that the rooms are situated on a different level. The waiting time of this room does not change per level.

Second, the results show that the benchmark, intervention 3 and 4 have equal values. This can be explained by the nature of the interventions. Intervention 3 and 4 both have one kind of adjustment in the construction site layout: and that is the placement of the elevator, which changes the horizontal city-block distance, but not the waiting times.

For Intervention 1, the waiting time is the only category affected by this intervention. Due to the nature of this intervention of placing an extra elevator on site, the assumption is made that the waiting time of the elevators is halved. Therefore, the waiting time, which applies to the elevators, causes the waiting time of Intervention 1 to be lower than the benchmark. An improvement of 21 minutes and 38 seconds is made on waiting time.

For Intervention 2, the waiting time is even lower, with an improvement of 27 minutes and 4 seconds. This is caused by the elimination of vertical movements, because of the toilet places on the building levels. Therefore, the waiting time is reduced, due to less use of the elevator, which reduces the amount of times that the elevator's waiting time is counted.

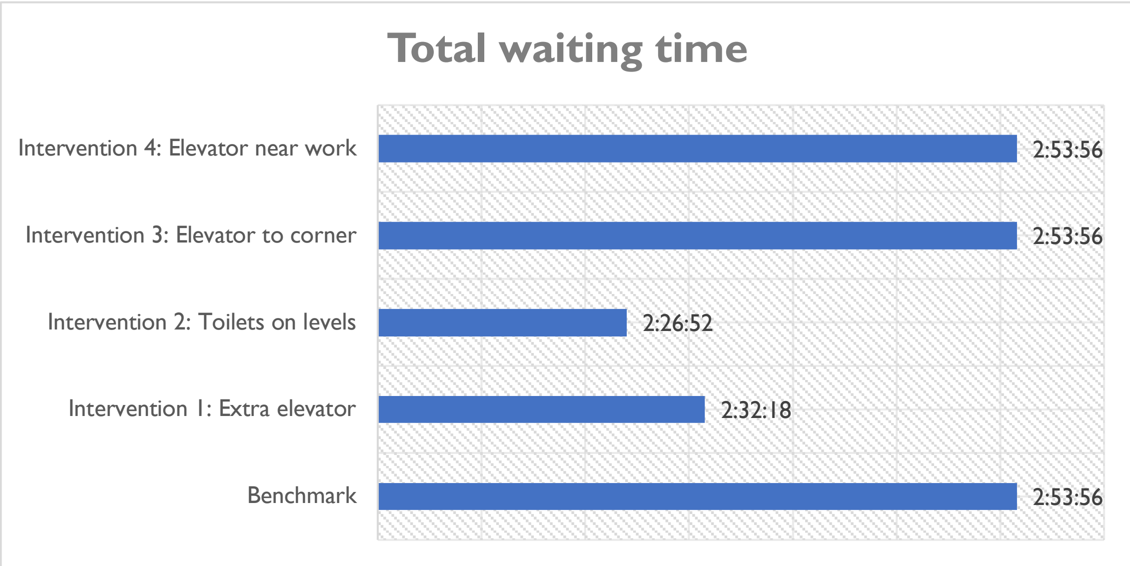


Figure 69: Total waiting time per level and simulation

20.4 Total traveling time

The working time stays constant among all categories, but the other categories do changes during the simulation. The sum of the other categories (sum of city-block time; vertical time by elevator; vertical time by stairs and waiting time) is presented in Figure 70. This figure shows the results of all changeable categories during simulations per level.

From Figure 70, the following trends can be noted. First, for all simulations a large difference appears between level 4 and level 5. Which as previous explained is the result of the head-contractor's elevator policy.

Second, the increase of time per simulation rises when the level increases. This is the results of previously mentioned reasoning, that with a higher level the vertical travel time increases. Due to the fact that the travel time is a product of vertical height.

Third, comparing the different interventions with the benchmark, this results in the following ranking. First, Intervention 4 is the only intervention that is longer than the benchmark, with 1 minutes and 2 second on average per level. Second, Intervention 3, that is only slightly shorter than the benchmark, with an average improvement of 1 second per level. Third, is Intervention 1, has a shorter total travel time than the previous two interventions, of 21 minutes and 38 second on average per level. Fourth, the largest improvement from the benchmark is made in Intervention 2. This intervention has in average improvement of 33 minutes and 28 seconds per level.

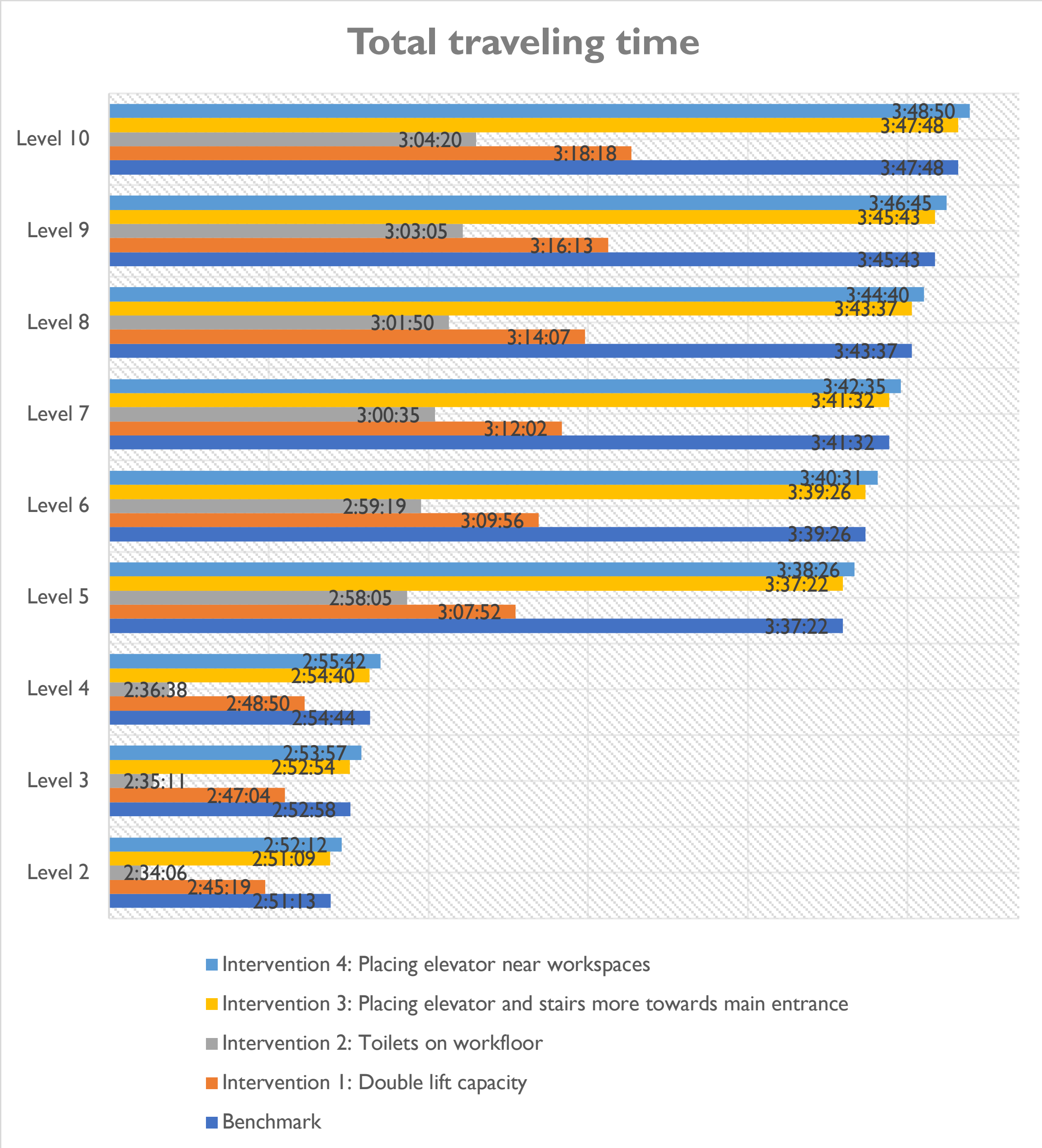


Figure 70: Total traveling time (sum of city-block time; vertical time by elevator; vertical time by stairs and waiting time)

20.5 Changes in productivity

In Chapter 6 the ratio between walking working and waiting was defined. This showed that with this categorization the productivity is between 62,3% and 70,4%. Looking at the Benchmark figures in Figure 71, it shows that in total the productivity is 53.0%. Nevertheless, when comparing the activities performed by the dry-wall contractor and the crew it is not comparable with the productivity figures found in Chapter 6.

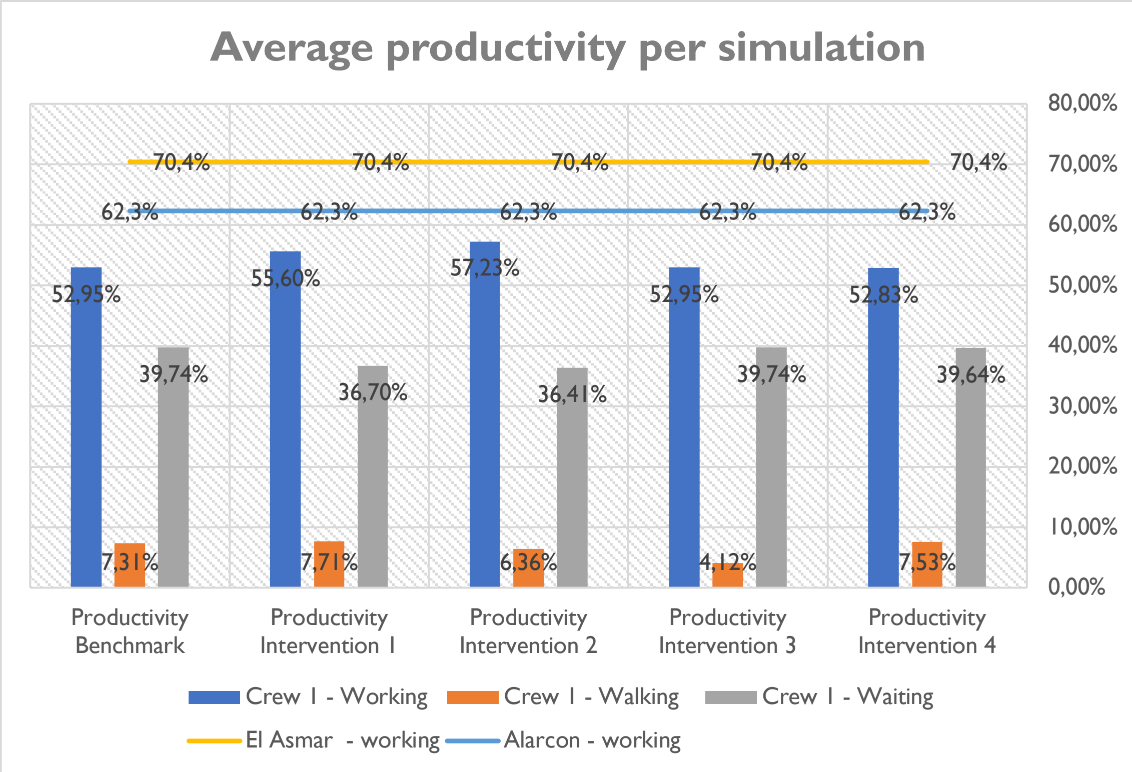


Figure 71: Average productivity per simulation

Figure 72 shows the difference in productivity between the different simulations. This shows that the Intervention 4 is the least effective in improving the productivity among. It even lowers the productivity slightly. Second, is the Intervention 3 which improves the productivity just a hair, it is almost equal to the benchmark.

Third, is Intervention 1 which shows the second-best improvement of productivity. For the total time the improvement in productivity is approximately 2,7%. This can be related back to paragraph 20.4 which showed that this intervention had the second-largest difference from the benchmark.

Fourth, the best improvement in productivity is made in Intervention 2. An improvement of approximately 4.3% in productivity is made. This as well can be related to paragraph 20.4, in which Intervention 2 had the largest difference with the benchmark. This becomes clear when looking at the formula of productivity in which the working time is divided by the total time. The working time remains constant during all simulations. The total time is a product of the different categories, and therefore the intervention that lowers the total time the most will give the largest improvement in productivity.

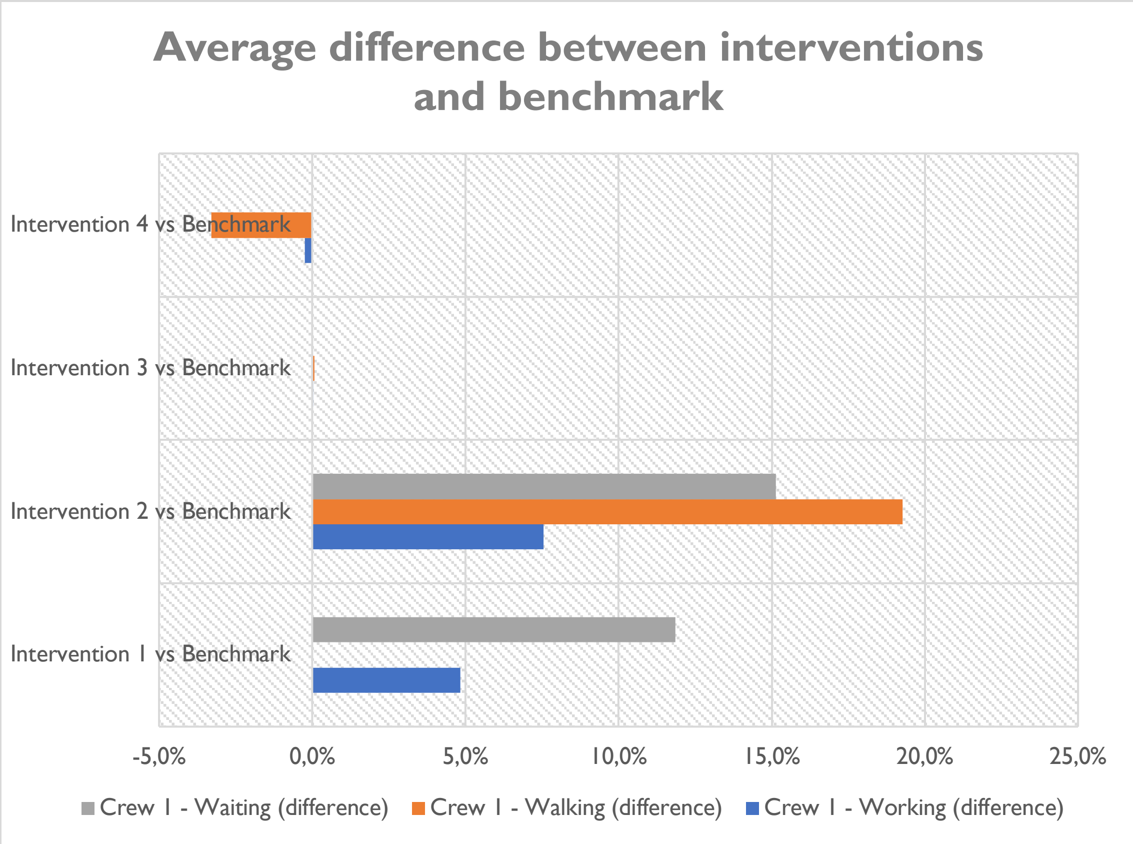


Figure 72: Difference in productivity between interventions and benchmark

21 Expert panel

21.1 Panel introduction

The model and results presented within this research are submitted to and provided with feedback by an expert panel. The first panel was held with employees of Dura Vermeer who on a daily basis work on the implementation of BIM within construction industry. The first panel was a Dura Vermeer panel that consisted out of the following people: Arjen de Feijter (Dura Vermeer); Gert-Jan Ditsel (Dura Vermeer); Sanne Kroon (Dura Vermeer); Sander de Zee (Dura Vermeer); Emiel Ham (Dura Vermeer); and, Bahtiyar Memik (Dura Vermeer).

The second panel consisted of Dura Vermeer employees who work on the realization of *het Noordgebouw, researcher of TU Delft* and with a BIM-consultant of an external company (HFB). The panelmember of this second panel were: Arjen de Feijter (Dura Vermeer); Ruben Vrijhoef (TU Delft); Ronald IJzerman (HFB); Arend Baan (Dura Vermeer); Bjorn Hartman (Dura Vermeer); Frank Benerink (Dura Vermeer); and, Ron Norbart (Dura Vermeer).

The panels resulted in several points of interest concerning the model and results, which are set out within the following paragraphs. Within the simulation paragraph, the model and inputs will be discussed. In the paragraph of productivity, the results will be discussed on the basis of the realistic productivity.

21.2 Panel on simulation

According to the panel the problem lies in that at the moment the General Site Costs calculated one elevator. But for a building of 20 stories, it might be better to place one elevator for materials and one elevator for persons on site. Only one elevator is placed on site, to have committed to the sub-contractors that vertical transport is facilitated. With more than one elevator, the offer would be higher than the market price. This model could make people conscious about the waste and offer a foundation to make decisions, which is different from deciding the site-layout based on experience and gut-feeling, as is the standard right now.

Furthermore, the panel discussed at which moment in the construction process the simulations should be introduced. According to one of the panel members, one of the basics of the model, the rooms from which the typical workday and coordinates are derived, should be available early in the process as the architect is making its first sketch models. In relation to this is the question of how much time is needed to set-up the model and simulation. In general, the models input in terms of speeds is fed for this project. It is questionable is whether or not these values apply to other projects as well, as the panel points out a large database is needed to make implementation quick and reliable. The time and sensitivity are connected to model of the construction site and the built up of the typical workdays.

Next, the panels point out the influence of the building phase. For example, the difference between the structural construction and the finish construction. In the structural construction, less construction workers are on site. This could lead to the decision to start with one elevator and during construction add a second elevator. According to the panel members, it becomes more interesting when several different (sub-)contractors are working on site, which is different from the current model where only one subcontractor's activity is simulated. Also interesting according to the panel is the order of operations: is there an effect on working in a specific order or not?

Even more interesting are dependencies between the different parties on site. This followed by the connection of the model with the times and schedules. As one of the panel member point out a returning problem is found on the dependencies of subcontractors. For example, the ceiling contractors is planned to construct the ceiling, but the electrician or plumber is not finished. This could help to indicate and visualise whether or not the subcontractor could be ready, or that because of all movement he was not able to execute the work in a certain time span.

Another aspect pointed out by the panel are the dependencies of the projects size and shape. Examples are named of a long project of about 300 meters or a very large project with a floor area of 62,000 m^2. What is the influence of these aspects on the walking lines and distances by the construction workers? Furthermore, the panel points out that the current input of the walking speed of 1.4 m/s, which is about 5,0 km/h, seems quite high. More certain when the construction workers are carrying equipment or materials. One of the panel members points out that and average speed of 1.0 m/s looks more realistic.

Moreover, the waiting times of the elevator are different per project. The panel points out that this is more certain the case on the project of *het Noordgebouw*. As the input for the waiting time on the elevator is related to traditional projects and on the project of *het Noordgebouw* is made use of smart building logistics. Which in practice among others means that materials are supplied after construction hours. Which decreases the demand on elevators during construction hours and therefore lowers the waiting times.

Furthermore, the panel points out the difference between construction workers. As an example, it was pointed out that one well experienced and motivated worker does the same work in the same amount of time as two less experienced and motived workers. Thus, there may be a difference between kind of construction workers. There can also be a difference between construction workers is made by the activities the worker has to execute. For example, a worker who works on a small item on a lot of locations a day, probably has a higher waiting time than others. This is questioned by some panel members in terms of toilet use. The two times a day in the typical workday looks often to some panel members, others contradict this.

21.3 Panel on productivity

As mentioned before the panel points out that the productivity Figures presented in this research are set for traditional projects. The project of *het Noordgebouw* uses smart construction logistics, which should increase the productivity on site. One of the panel member points out, that taking one of the items out of the scope of the construction worker does not means it does not exist. It still has to be done, but by another actor.

One of the panel members points out that nobody wants to work eight hours straight on a day. Increasing the productivity does not mean that with the time gained by this increase is spend in a value adding sense. For example, he starts smoking instead of doing value adding activities. Furthermore, is pointed out that eliminating all breaks from work could not be motivating for the worker. Giving the worker the ability to leave the workspace a couple time during the day is necessary to keep the worker motivated and content.

As suggestions, the panel members pointed out several new interventions which could have an effect on the productivity. A few of the examples give is to place the coffee break-room; equipment storage container; saw-shed; or lunchbreak-room on the levels that the construction workers are working.

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part VI

This part presents the discussion and conclusions of this research and is divided into four chapters. First, the discussion and limitations of the research are presented. Second, the conclusions of this research are presented for the model and productivity. Third, the recommendation for future research and practice are presented. Fourth, a personal reflection of the research and process is given.

Discussion and conclusion

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22 Discussion and limitations

This chapter gives an overview of the point of discussion and the limitations within this research, divided in two parts: the model, and the productivity.

22.1 Discussion and limitation of the model

22.1.1 Typical workday

Within this research, the typical workday is used to set out the path and activities performed by the construction worker on a general workday. The result is a list of rooms that are visited by the construction worker in consecutive order. The order in which these rooms are placed is discussable, because of two contradictory reasons.

First, the model presented within this research is designed to be used in the early stages of a project. Within the early stages, it is generally hard to tell which sub-contractor is going to execute the job and what the operational process is going to be. Furthermore, the process can be influenced by other actors on site, which could change the typical workday initially used.

Second, the typical workday is the general representation of the path and activities performed by the construction workers of a certain actor. During the early stages of the construction process, uncertainty is high (Winch, 2010). From the start, the knowledge of the typical workday and the use of this knowledge in 4D-BIM can help make decisions in i.e. the construction site layout, which helps reduce the uncertainty in early stages. By indicating potentials and visualising path, waiting and working times on the construction site.

22.1.2 Elevator

Intervention 1 presented to place an extra elevator on the construction site. It is assumed that by doubling the capacity of the elevator, the waiting time is reduced by half. It can be discussed whether or not this reduction is right since both elevators are in use more often during peak hours, the reduction may be even higher during peak hours.

Furthermore, the vertical travel speed of the elevator is measured from the point that the doors of the elevator are opened until the moment the doors are closed and the elevator is available for use again, and this along the different stops. This means that with an increase in the number of elevators, the number of stops will lower, and the vertical travel speed might rise.

22.1.3 Waiting times

As discussed by the expert panel, waiting times differ per project. Within this research, the waiting time used is set by the average of two previous projects with similar characteristics. Traditional building logistics have been used within these previous projects. In the case of *het Noordgebouw* smart construction logistics are used. This means among others, that a specialised company delivers the materials on the construction site after the normal working hours of construction workers. This supply of materials after work hours should decreases the demand of elevators during workhours and has other benefits. Therefore, the waiting times for the elevators used within this research are relatively higher compared to traditional projects, according the expert panel.

22.1.4 Walking lines

Within the model presented in this research, the horizontal walking lines are drawn on the ground level or on the different levels of the building. These lines show the path taken by the construction worker between the different rooms. The amount of walking lines produced within this model can be questioned, because the construction workers make more horizontal movements. Excluded from the current model are the walking lines on the building levels, to i.e. the place where the materials are stored, or where waste is collected. This increases the walking distances of the construction worker and makes this category of the model more prominent.

22.1.5 Necessity of working times

One of the goals of this research is to provide a model that can create insight and potentials for the construction site layout. This can help to make informed decisions on the layout of the construction site and thus increase productivity. Within this research, the working time, which is set as a constant, is used to gain productivity numbers that can show this productivity increase. The interventions are compared to the benchmark. The necessity of the working time can be questioned since this introduces two constants: the benchmark and the working time. Without the working time, the different simulations can be compared with each other to show which construction site layout is the most productive, since the model focusses on the decrease of time spent on non-value adding activities.

Nevertheless, the importance of the working time can be explained when different projects are compared. Since the working time is formed by quantities and norms, it is related to the value adding activities. Without the working time, no productivity figures can be presented, and it becomes hard to compare different projects.

22.2 Discussion and limitation of the productivity

22.2.1 Ratio between walking, working and waiting time

Figure 13 and Figure 14 of this research presented the categorisation of the different items in walking, waiting and working time. Further on in this research, this ratio is compared to the results of the simulations with the data found in literature. The rightness of this categorisation can be questioned. During the expert panel, for example, it was discussed wheter a tiling contractor is placing a line on a wall for the placement of the tiles is this directly adding value, indirect adding value, or not adding value. This discussion also appears when looking at the categorisation. Items categorised are for example 'locating tools/ladders' or 'locating materials', which are categorised under working time. It can be questioned if this does not belong to walking time, which would make walking time increase by 7,2%.

22.2.2 Smart construction logistics

Smart construction logistics are introduced within the project of *het Noordgebouw*. Due to this introduction, the head contractor tends to reduce the waiting times on the elevators or the amount of transportation movement to and from the construction site among others, by implementing a hub. The numbers presented in **Fout! Verwijzingsbron niet gevonden.**, derived from literature and used within this research to compare to the simulated productivity, are numbers from projects with traditional construction logistics. It is unsure if the figures used to compare the simulation results of *het Noordgebouw* are representative.

22.2.3 Different crews

As shown in the simulation the work of the dry-wall contractor is executed in three crews. The working time per crew is calculated for the hotel rooms. Nevertheless, crew 2 and 3 are doing more that the calculated activities on that same working day, which is not calculated. The working time of the dry-wall application is only calculated for crew 2 and 3, but these crews are applying the ceilings as well. This makes that crew 2 and 3 unsuitable to give a real indication of the working time on a typical workday. Furthermore, the total time of all crew does not represent the working time on the typical workday as well. Therefore, only the working time of crew 1 is used for the comparison of productivity figures.

23 Conclusions

The conclusion is divided into three parts: first, the model, second, the productivity and third, answers to the main research question.

23.1 Model

Within the model paragraph, the conclusion is drawn about the model on the hand of the research question regarding the model.

23.1.1 Data requirement

The research question answered is: *which data is needed from all parties to be integrated into a 4D-BIMI?* This paragraph can be divided into several parts: construction site layout, walking, waiting, working and typical workday.

23.1.1.1 Construction site layout

The primary site-layout of the construction project has to be known, and the position of elements on site. Furthermore, these elements need to be modelled in BIM and contain several parameters. Which are the standard parameters as centre points and the coordinates of these centre points. Additional parameters need to be added to the model, as waiting times and/or working times.

23.1.1.2 Walking

Data for walking can be split into three parts: the horizontal walking time, vertical time by stairs and vertical time by elevators. The data needed for the horizontal walking distance is the average walking speed of the construction worker and the distance travelled by the construction worker. The walking speed derived from literature and is 1.44 m/s. Together, the speed and distance results in the horizontal walking time.

To obtain vertical travel time by stairs or elevator, vertical distance travelled and the average speed of the construction worker on this vertical distance by both means of transport is needed. For the average speed, observation of the vertical speed of the construction workers on stairs is performed and the average vertical speed is calculated at 0.30 m/s. This is comparable with results found in previous research. For the average vertical time speed of the elevator observation where performed as well, which established an average speed of 0.24 m/s.

23.1.1.3 Waiting

On construction site, the elevators are not always readily available. When construction workers spend time standing still while the elevator gets to their level, this is considered as waiting time. The waiting is different per object and location. It is necessary to know the waiting time for every location for accurate determination. The waiting time is an average time the construction workers spend on a location to perform non-value adding or indirect value adding activities.

23.1.1.4 Working

To be able to determine the working time of the construction worker, three items are needed: the kind of activity, the norms related to the activity, and the amount of activities that need to be performed. The kind of activity relates to the nature of the work. As in this research the drywall-contractor was used as an example, the activities of this construction worker can be broken down into i.e. placing metal stud, applying drywall sheeting, setting doorframe, etc. From these activities, the amount of time per sub-activities is needed. This norm indicates a time per unit of work for each sub-activity. Together with the last item, the amount of activities, which relates back to (quantities of work that have to be performed) the amount of working time can be established.

23.1.1.5 Typical workday
The last data set that is needed is the typical workday of the construction workers. There may be differences in the typical workday between workers on site, but it provides an overview of all activities the construction workers apply to on a workday. It is a step-by-step breakdown of the step and places the workers visits on a workday.

23.1.2 Accurate model
This second paragraph answers to the second research question regarding the model: *how to accurately model the data into a 4D-BIM with labour and movements of workforce?*

23.1.2.1 Walking
As discussed previously, walking time is divided into horizontal walking time, vertical walking by stairs and vertical walking time by elevator. The horizontal walking time is calculated with the help of the horizontal walking distance and the average walking speed. The average walking distance is calculated with the help of the city-block method. The city-block method is the sum of the distance travelled between each room in x-direction plus the distance between each room in y-direction. The sum of these is the total city-block distance. The city-block distance is preferred over the Euclidian distance since is gives a better representation of the actual walking distance since construction workers are often not able to walk in a straight line from point A to B.

The vertical time by elevator or stairs is calculated by the average speed of each mean of transport and the distance travelled. The distance travelled is calculated by difference in height between two consecutive points. The sum of these distances is the total vertical distance.

23.1.2.2 Waiting
To be able to accurately model, the waiting time has to be added to the BIM. By adding the waiting time as an additional parameter for the rooms. Within the Dynamo model the waiting time of a room is multiplied with the amount of times that the construction workers visit this room and summed up.

23.1.2.3 Working
The working time has to be added as additional parameter to the rooms in the BIM. The waiting time is used within the Dynamo model and per rooms counted as one. The result is the sum of all rooms with a working time.

23.1.3 Visualisation
The following question refers to the visualisation possibilities in the model: *What are the possibilities of visualising the data into a 4D-BIM with labour and movements of workforce?*

As shown in Part 5 of this report, multiple possibilities of visualisation are shown. First, is the representation of the different categories of time presented in terms of graphs. These graphs visualise the different times, or combination of times per level or the average per level. From this graph, a representation between the different interventions can be given.

Second, the representation of working and waiting times. With the model, the working times are visualised as cubes. The size of these cubes visualises the time, the bigger the cubes the longer the time. The same principle applies to the waiting time, but the waiting time is visualised by spheres. The bigger the spheres, the longer the waiting time at a certain place.

Third is the visualisation of walking lines. The walking lines are presented as lines between the different rooms visited by the construction worker on his or her typical workday. These lines show the paths travelled by the construction worker.

23.1.4 Modelling interventions

The last question regarding the mode is: *how to model interventions into a 4D Building Information Model with labour and movements of workforce?* The answer to this question, the three following points are important.

First, a total of 4 interventions where modelled from the benchmark in this study. Interventions can be modelled in different manners, which depend on the nature of the intervention. For Intervention 1, the waiting time of the elevator was changed, due to a doubling of capacity. To model this intervention the waiting time in the BIM has to be changed for the specific elevators.

Second, the nature of the typical workday, as applied to Intervention 2. Within Intervention 2, the toilet where place on each level of the building where construction work was executed. The change made to the typical workday is to change the rooms visited in the typical workday. From the room associated with the toilet on the ground level to the rooms associated with the toilets on the different level.

Third, changing the place of the elevator as applied to Intervention 3 and 4. This resulted in the change that in the BIM, the elevators where moved in another location on the construction site. The properties and rooms remained constant only the location in terms of coordinates changed due to the move.

23.2 Productivity

23.2.1 Defining productivity

To be able to provide the right input and output for this research the definition of productivity has to be defined. The following research question gives answer to this part: *Which definition and aspects of productivity to be used?*

The definition of labour productivity can be presented by Equation 10. This equation derived from previous studies that show a relationship between productive time, or value adding time, and the total time. Time is used to for measurability in this research, since the research focusses on the movements and waiting time of construction workers it is hard to express these movements and times in term of units.

Time can generally be divided into three categories: productive time (value adding activities); Muda 1 (non-value adding activities); and, Muda 2 (indirectly value adding activities). Within each of these three categories different activities of construction workers can be placed.

The categorisation of activities performed by the construction worker into three categories: walking, waiting and working. The definition of productivity is there for adjusted to these three categories to which the productive time is changed by the working time. By transforming the categories to walking, waiting and working the activities concerned with the categories change as well. With the categories having the following ratios: Productive (41.8-47.0%); Muda 1 (25.0 –

27.6%); and, Muda 2 (28.0 – 30.6%) to the three new categories change to a different ratio. Which results in the following ratio: Working (62.3 – 70.4%); Walking (12.3 - 19.7%); and, Waiting (17.4 – 17.8%).

23.2.2 Simulated change

The different simulations give different outcomes. The following research question illustrates the difference between the different simulation: *what is the simulated change in productivity?*

The simulated change in productivity can be explained by Figure 73., which shows the change in productivity per intervention in comparison with the benchmark. *Crew 1 – working (difference)* presents the simulated productivity difference. *Crew 1 – Waiting (difference)* and *Crew 1 – Walking (difference)* shows the percentile difference between the intervention and benchmark for these categories.

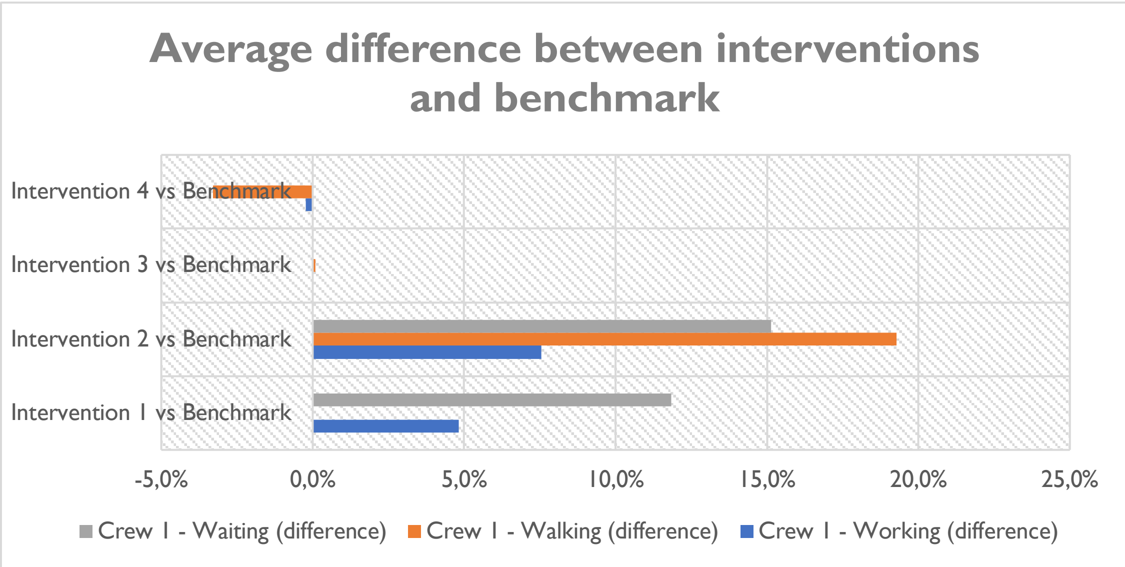

Figure 73: Difference in productivity between interventions and benchmark

The change in productivity can be explained by the implication of the interventions. Intervention 1 only influenced the waiting time of the elevators. Intervention 2 influenced the waiting time and the horizontal travel, by eliminating some vertical movements. Intervention 3 and 4 influenced the horizontal walking time, by changing the location of the elevators.

23.2.3 Realistic productivity

Whether the figures provided by the simulation provide a good representation of the reality, is answered in the following research question: *can this simulated change in productivity be proved by the physical project?*

When comparing the productivity figures of crew 1 with the productivity figures derived from previous research, as shown in Figure 74, the productivity derived from literature are higher than the simulations. Therefore, the simulated change cannot be proven by the theory. As discussed, the figures derived from literature are based on traditional logistics, as the simulations are based on smart construction logistics this can prove the difference in productivity.

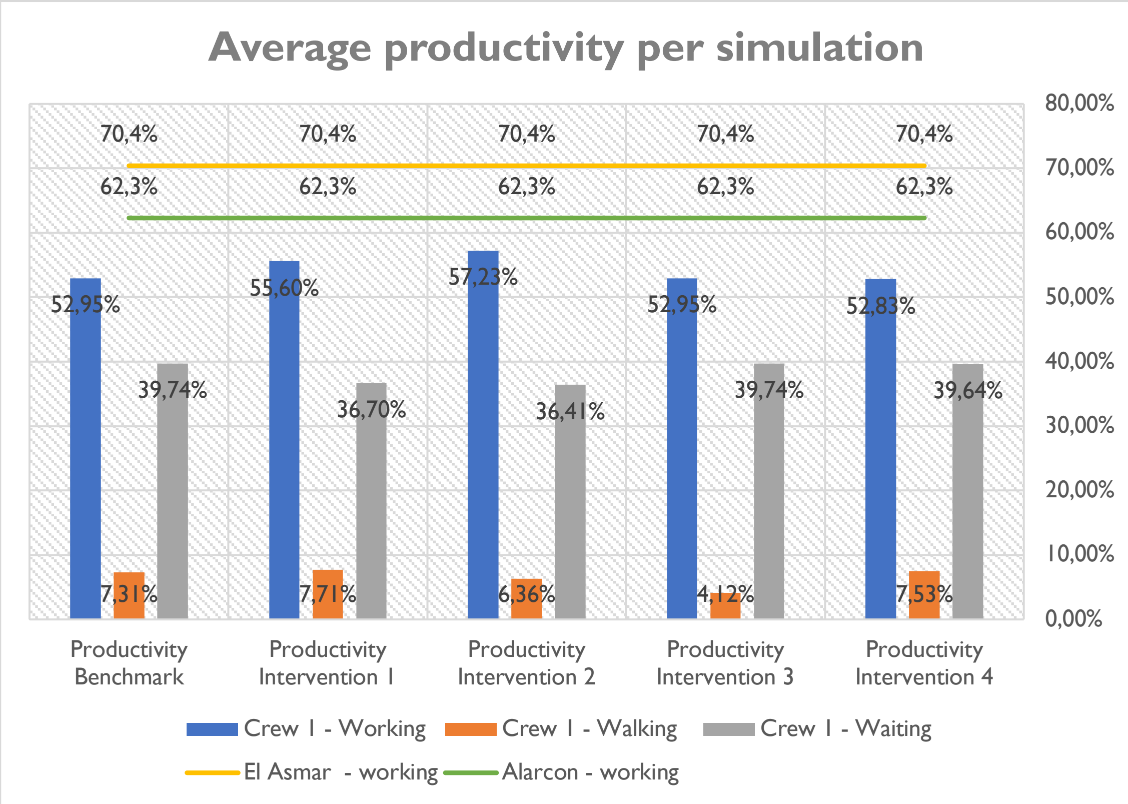

Figure 74: Productivity of simulations

23.3 Answer on main research question

The answers to the research questions discussed in the previous paragraph lead up to answering the main research question: *to what extent does the modelling of labour and movement of workforce into a 4D-BIM have the ability to give insight into and indicate potentials to increase the labour productivity on construction sites?*

In short: 4D-BIM can possibly increase labour productivity on construction sites to a big extent.. Currently, no models exist to provide insight in walking, waiting or working times of construction workers, or to visualise the movements, waiting and working times of construction workers. This model is a first step in providing this insight, as it shows how simulation can be done which generates figure on walking, waiting and working times of construction workers. Furthermore, it generates visual images that provide more insight the movements and waiting times of construction workers.

Providing insight into movements and waiting times of construction workers shows the user of 4D-BIM where non-value adding activities can be found. With this knowledge, interventions to decrease the non-value adding activities can be designed. As a consequence, labour productivity on construction sites can rise since (labour) productivity is the ratio between value adding and non-value adding activities.

24 Recommendations

24.1 Ratio working, waiting, walking

Further research is needed on the ratio between working, walking and waiting. The current categorisation gives an insight in the productivity of the three categories for conventional projects. To gain more insight in the productivity projects with smart construction logistics need to be researched. Furthermore, the definitions of working, waiting and walking need to be refined to decease the bias in categorisation of activities.

24.2 Multiple actors

In the current model, only one actor is modelled. Within this research, only the activities of the dry-wall contractor are modelled. The interdependencies between different actors are an important problem in the current construction industry, as one of the panel member indicated. By modelling multiple actors in the model, it becomes more realistic and evident where potential improvements in the construction site layout can be found. Moreover, having multiple actors can help to provide insight in the overcrowding of certain areas, since one can see in which locations activities are performed. Insight can help prevent clashes between different actors when they are working at the same location at the same time. Furthermore, a link to the construction schedule helps to define these interdependencies. Ultimately the typical workday should be defined by the construction schedule. This helps parametrise the model and to provide insight in the decisions and changes made in the schedule.

24.3 Building shape

What are the influences of the building's shape? As buildings can be different in shape it could influence walking, working, and waiting time. For example, what would be the influence of a long rectangular, square or round building be on the horizontal walking time. Expected would be that on long rectangular building the horizontal walking time would be respectively bigger, but what does the simulation show.

24.4 Order of construction

Future research should be done on the influences of construction order, since the order of activities in which actors/construction workers work may influence productivity on site. i.e. when a construction worker crosses or blocks another worker's walking path, this may induce waiting time. When it does, 4D-BIM may be used to look plan logistics of construction workers in a way that paths will not be crossed unless this is necessary or cannot be avoided and influence the project productivity.

24.5 Refinement of model

24.5.1 Visualisation of lines and waiting times

To help visualise walking lines and waiting time of the construction workers, waiting times and walking lines could be coded in a way that a gradient between two colours could indicate the amount of times a certain line is walked, or to help visualize which waiting times are high and low. The current model shows spheres at places where waiting times appears and walking lines present the walked paths, color-coding may help to assess the walking paths and waiting times.

24.5.2 Horizontal walking lines

The horizontal walking distances are currently measured by city-block distance between each room. This is a rough measure that lacks refined characteristics of rooms, like doors. By adding doors of each room to the model, the model may be more accurate in answering questions needed for construction. Future research should investigate whether refining 4D-BIM could make the model more accurate.

24.5.3 Waiting time elevator

Elevators have several peak hours during the day, usually when the day starts or ends, and during breaks. The time a construction worker waits for the elevator to arrive thus depends on when the construction worker wants to take it. To refine the model even more, it could be beneficial to gain data about the different waiting times during the day and introduce this to the model.

24.6 General construction site costs

One of the items within a construction project budget are the general construction site costs. Under these fall for example the costs for construction equipment. The current general construction site costs are based on experience and rough estimates. The added value of the model proposed here is to provide support for decision making on this item. The model allows for optimisation of the construction site and helps to establish for example the number of elevators (see Chapter 16).

Furthermore, the moment of introducing of the model in a project is important. Introducing the model in the early stages of the project, preferably during tendering, can help to introduce a better bid. This also influences the effectiveness of the model, because during the tender the costs are named and changes to the budgets can be made. After the bid is handed in, it becomes harder to make changes for example add an elevator.

25 Reflection

This reflection provides an overview of the complete graduation process: the process itself, my personal experience, the relevance for the scientific and social field, and the relation to the graduation track.

25.1 Research methodology

In this research, a distinction is made between the model and the productivity. Both aspects were relatively new to me when the graduation research started. Thus, I reviewed literature reviews, received guidance from my mentors, held meetings with experts from knowledge institutions like TNO to make myself acquainted with these aspects.

This research introduces a new way of modelling into which different existing concepts are combined to perform a new kind of simulation. This asked for a framework on how to work and what information was needed to be able to perform this kind of simulation. From this, the choice was made to perform an explorative study, in which this new kind of simulation would be explored, tested, and that would provide as in incentives for further research.

As this kind of simulation was new, it made it hard at times to obtain the right information. Information in this study was derived from literature, previous research within the graduation company, and interviews held at the graduation company. When information could not be collected, an informed assumption was made. For example, in the case of waiting times of certain rooms.

To be able to perform the simulation a parametric model was needed, which would read and write information from and to the BIM. This was mostly done by programming the model for the simulation. This model was set up step by step, guided by the overview of data derived from literature reviews done before and during the programming. This model was constantly tested to see if it worked, or that adjustments were needed.

Finally, the simulations could be performed on the hand of the model programmed. These simulations were fed with information derived in the earlier steps of this research. The results where compared with each previous research. An expert panel verified the final model and results from the simulations after a presentation about the model and results, which resulted in a discussion of the model and results.

25.2 Graduation lab

The research performed is part of the graduation lab 'Business models for robotics in construction', which is chaired by the Design and Construction Management section of the Management in the Built Environment Master Track. Students were asked to come up with a way increase the use and effects of robots and 3D-printing in building design and construction. Another part of this graduation lab was to be part of a larger research about construction logistics, where BIM and mathematical models were used to investigate if they could influence construction logistics.

At first sight, this research seems to have nothing to do with construction logistics, which is commonly seen the decrease of logistical movements to and from the construction site. But from my perspective that is not true, because it does look at construction logistics. Commonly, research on construction logistics focuses on the movement to and from the construction site, but the movement on construction sites are addressed less. Furthermore, labour productivity may be improved by decreasing the time spent on non-value adding activities of construction workers, which is important because of the high levels of waste in construction industry. Which is all supported by BIM.

25.3 Scientific relevance

The scientific relevant can be explained in threefold. First, as mentioned before by Koskela and Vrijhoef (2001); Thomas et al. (1990), labour productivity in the construction industry is relatively low. The current research contributes knowledge on increasing this productivity. Second, research is primarily focused on examining abilities of 4D-BIM in terms of site layout and construction sequencing, but not on investigating the ability of modelling labour and movements of workforce. Third, the research of the consortium on building logistics is primarily focused on the movements from to construction sites and the used of possible hubs. This research adds another aspect to this consortium, which is the logistics on the construction site itself.

25.4 Social relevance

As mentioned by Kraan et al. (2011) a majority of the construction workers is not able to work until the legal retirement age, due to the physical high demanding nature of the job. The model presented in this research provides insight and information to the contractor to make the construction site more productive. Making the construction site more productive within this research means decrease of non-value adding activities. This decrease should help to reduce the unnecessary work strain on the construction workers and make employment more sustainable.

25.5 Practical relevance

Construction site layout is primarily built on experience and gut feeling. This model helps to provide insight and indicate potential in multiple ways. It helps the contractors to crate insight in types of waste related to the construction site layout. With this insight, the contractors can make decisions construction site layout and check different scenarios. From this, a well-informed decision can be made on how to execute the construction site layout. Furthermore, 4D-BIM helps the contractor to provide insight in the simulated productivity on different project. With future research on site, the actual productivity can be monitored and checked. If necessary, adjustment can be made to the model or the site. Also, 4D-BIM helps the head-contractor to better facilitate their own employees and sub-contractors on site to execute their jobs.

25.6 Personal reflection

The learning process for me had ups and downs, and entails gaining knowledge, dealing with practice, companies and independent working. The start of the graduation process until the P2 was an educational period to me. This period went by quickly as I followed additional courses at the same time. The subject of the research evolved quickly and became quite clear to me. Since I knew I wanted to do something with BIM, the relation with the consortium of construction logistics became quite clear in conversations with the supervisors. After the P1, it felt like the elaboration of the subject can be executed. The mistake made within this part of the process was to be too reserved. Between P1 and P2 I did not appoint my supervisors as much as needed, which should have helped with the P2.

After the P2 I started to execute the graduation plan presented before. But during the first weeks I tried to execute this is found that the software chosen did not have the abilities to be able to deliver the wanted product. So, for me this was quite a setback, and made me think of alternative options. Luckily, an alternative option was found. Due to this program I had the abbility fully program the model to be able to execute the simulations. From retrospect, I quite enjoyed this. Because the chosen option did not work, I was thrown into the dark and had to find another solution. Which in the end gave me more freedom, and this let me start from scratch.

Furthermore, the internship with Dura Vermeer gave feedback and sense from practice. Which helped to defines problems and gain data needed to execute the research. From my point of view the internship had an added value to the research.

As where I enjoyed programming the model, the last part of the research was less enjoyable. This was due to the large amount of information which had to be structured I the report. During this research, I dug into the subject for one year, and for me everything was quite clear. But to be able to transfer this knowledge to other people can be quite hard. With some help of my supervisors I think a structured report is now presented.

part VII

This last part contains three elements. First, the list of references used within this research is presented. Second, the index of figures, tables and equations used within this research are presented. Third, the appendices which are complementary to this research are presented. The appendices are numbered as referred to in this research. Due to the scale of some appendices these can be requested at the author.

Addendum

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26 References

Alarcón, L. (1997). *Lean construction*: CRC Press.

Alarcon, L. F. (1997). Tools for the identification and reduction of waste in construction projects. *Lean construction, 5*, 365-377.

Autodesk. (2017, 08-02-2017). About Rooms. Retrieved at 05-12-2017

Aziz, R. F., & Hafez, S. M. (2013). Applying lean thinking in construction and performance improvement. *Alexandria Engineering Journal, 52*(4), 679-695. doi:https://doi.org/10.1016/j.aej.2013.04.008

Bohannon, R. W. (1997). Comfortable and maximum walking speed of adults aged 20—79 years: reference values and determinants. *Age and Ageing, 26*(1), 15-19. doi:10.1093/ageing/26.1.15

Brokelman, L., & Balk, W. J. (2010). *Lichte scheidingswanden en plafonds*. (Y 0090.01.01). Retrieved from on 12-05-2017 Bodegraven:

Bryde, D., Broquetas, M., & Volm, J. M. (2013). The project benefits of Building Information Modelling (BIM). *International Journal of Project Management, 31*(7), 971-980. doi:http://dx.doi.org/10.1016/j.ijproman.2012.12.001

Bryman, A. (2012). *Social research methods* (4 ed.). New York: Oxford University Press Inc.

CBS. (2016a). Arbeidsvolume naar bedrijfstak en geslacht; nationale rekeningen. Retrieved at 07-03-2017 from http://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=82579NED&D1=0&D2=0&D3=0&D4=0-1,5,39,43,55,61,65-66,81,89&D5=l&VW=T

CBS. (2016b). Bbp, productie en bestedingen; kwartalen, waarden, nationale rekeningen. Retrieved at from http://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=82601NED&D1=1&D2=0,2&D3=99&VW=T

CBS. (2016c). Bedrijfsleven; Conjunctuurbeeld per bedrijfstak, SBI 2008. Retrieved at 07-03-2017 from http://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=81838NED&D1=16&D2=0-1,7,11,17,20,24,30&D3=34,39&VW=T

CBS. (2016d). Groeirekeningen; nationale rekeningen. Retrieved at 10-4-2017 from http://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=83193ned&D1=26&D2=0&D3=0-4,18-21,25,29-31,36,41&D4=a&HDR=T,G3&STB=G1,G2&VW=T

CBS. (2016e, 8-12-2017). Werkzame beroepsbevolking; bedrijf. Retrieved at 15-12-2017 from http://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=82807NED&D1=0&D2=1-2&D3=0,7-14&D4=28&D5=l&VW=T

Doloi, H. (2013). Cost Overruns and Failure in Project Management: Understanding the Roles of Key Stakeholders in Construction Projects. *Journal of Construction Engineering and Management, 139*(3), 267-279. Retrieved from

Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2011). *BIM handbook : a guide to building information modeling for owners, managers, designers, engineers and contractors* (Second edition. ed.). Hoboken :: John Wiley & Sons.

Eaton, M. (2013). *The lean practitioner's handbook* Retrieved from 123Library http://www.123library.org/book_details/?id=98970

El Asmar, M. (2012). Modeling and Benchmarking Performance for the Integrated Project Delivery(IPD) System (Vol. 74).

Fellows, R. F., & Liu, A. M. M. (2015). *Research Methods for Construction*: Wiley.
Forbes, L. H., & Ahmed, S. M. (2011). *Modern construction : lean project delivery and integrated practices* Industrial innovation series; Industrial innovation series., Retrieved from CRCnetBASE http://www.crcnetbase.com/isbn/9781420063134
Fujiyama, T., & Tyler, N. (2004). An explicit study on walking speeds of pedestrians on stairs.
Jarkas, A. M. (2010). Critical investigation into the applicability of the learning curve theory to rebar fixing labor productivity. *Journal of Construction Engineering and Management, 136*(12), 1279-1288. doi:10.1061/(ASCE)CO.1943-7862.0000236
Klerks, S. A. W., Lucassen, I. M. P. J., Aa, S. v. d., Janssen, G. R., Merriënboer, S. A. v., Dogger, T., & Kieft, J. v. d. (2012). *Bouwlogistiek: cruciaal in efficiënt en duurzaam bouwen*. Retrieved from WorldCat.org database. Delft: TNO.
Koskela, L., Howell, G., Ballard, G., & Tommelein, I. (2002). The foundations of lean construction. *Design and construction: Building in value*, 211-226.
Koskela, L., & Vrijhoef, R. (2001). Is the current theory of construction a hindrance to innovation? *Building Research & Information, 29*(3), 197-207. doi:10.1080/09613210110039266
Koutamanis, A., van Leusen, M., & Mitossi, V. (2001). Route analysis in complex buildings *Computer aided architectural design futures 2001* (pp. 711-724): Springer.
Kraan, K., Wevers, C., Geuskens, G., & Sanders, J. (2011). *Monitor Duurzame Inzetbaarheid-Resultaten 2010 en Methodologie*: Hoofddorp: TNO.
Kumar, B. (2015). *A Practical Guide to Adopting BIM in Construction Projects*: Whittles Publishing.
Loera, I., Espinosa, G., Enríquez, C., & Rodriguez, J. (2013). Productivity in Construction and Industrial Maintenance. *Procedia Engineering, 63*, 947-955. doi:http://dx.doi.org/10.1016/j.proeng.2013.08.274
Manning, J., Kahana, M. J., & Sekuler, R. (2006). An ideal navigator model of human wayfinding: Learning one's way around a new town.
Muskens, G. H. J. (2010). *Invloed liftinzet en liftgebruik op wachttijd bouwplaatspersoneel.* (Master Afstudeerverslag), Technische Universiteit Eindhoven, Eindhoven. Retrieved from https://pure.tue.nl/ws/files/53605522/685900a.pdf
Nasirzadeh, F., & Nojedehi, P. (2013). Dynamic modeling of labor productivity in construction projects. *International Journal of Project Management, 31*(6), 903-911. doi:http://dx.doi.org/10.1016/j.ijproman.2012.11.003
O'Brien, W. (2003). 4d Cad and Dynamic Resource Planning for Subcontractors *4D CAD and Visualization in Construction*: Taylor & Francis.
Pan, B., Zhao, Y., Guo, X., Chen, X., Chen, W., & Peng, Q. (2013). Perception-motivated visualization for 3D city scenes. *The Visual Computer, 29*(4), 277-286. doi:10.1007/s00371-012-0773-1
Papadonikolaki, E., Vrijhoef, R., & Wamelink, H. (2015). Supply chain integration with BIM: a graph-based model. *Structural Survey, 33*(3), 257-277. doi:10.1108/SS-01-2015-0001
Park, H. S. H. H. S. (2005). Benchmarking of construction productivity. *Journal of Construction Engineering and Management, 131*(7), 772-778.
Platform Logistiek in de Bouw. (2014). *Factsheet Logistiek in de Bouw*. Retrieved from on 08-03-2017
Poirier, E. A., Staub-French, S., & Forgues, D. (2015). Measuring the impact of BIM on labor productivity in a small specialty contracting enterprise through action-research. *Automation in Construction, 58*, 74-84. doi:http://dx.doi.org/10.1016/j.autcon.2015.07.002
Robroek, S., Burdorf, A., Beumer, P., van der Sluis, S., & Weel, A. (2011). Dossier Duurzame Inzetbaarheid.
Sarstedt, M., & Mooi, E. (2014). A concise guide to market research. *The Process, Data, and*.
Sgambelluri, M. (2014). *Practically Dynamo: Practical Uses for Dynamo within Revit*. Retrieved from http://aucache.autodesk.com/au2014/sessionsFiles/6557/5014/handout_6557_au_2014_class_handout_AB6557_Practically_Dynamo_Marcello_Sgambelluri08.pdf on 6-11-2017

Shehata, M. E., & El-Gohary, K. M. (2011). Towards improving construction labor productivity and projects' performance. *Alexandria Engineering Journal, 50*(4), 321-330. doi:http://dx.doi.org/10.1016/j.aej.2012.02.001

Tawfik, H., & Fernando, T. (2001). *A simulation environment for construction site planning.* Paper presented at the Information Visualisation, 2001. Proceedings. Fifth International Conference on.

Thomas, H. R. (2015). Benchmarking Construction Labor Productivity. *Practice Periodical on Structural Design and Construction, 20*(4). Retrieved from

Thomas, H. R., William, F. M., Horner, R. M. W., Gary, R. S., Vir, K. H., & Steve, R. S. (1990). Modeling Construction Labor Productivity. *Journal of Construction Engineering and Management, 116*(4), 705-726. doi:10.1061/(ASCE)0733-9364(1990)116:4(705)

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

Tulke, J., & Hanff, J. (2007). *4D construction sequence planning–new process and data model.* Paper presented at the Proceedings of CIB-W78 24th International Conference on Information Technology in Construction, Maribor, Slovenia.

Vrijhoef, R. (2016). *Effects of Lean Work Organization and Industrialization on Workflow and Productive Time in Housing Renovation Projects*. Paper presented at the Proc. 24th Ann. Conf. of the Int'l. Group for Lean Construction, Boston, Ma, U.S.A.

Winch, G. (2010). *Managing construction projects : an information processing approach* Retrieved from 123Library http://www.123library.org/book_details/?id=57708

Womack, J. P., & Jones, D. T. (2003). *Lean thinking : banish waste and create wealth in your corporation* (Rev. and updated edition. ed.). New York, N.Y. :: Free Press.

Wu, C.-H., & Chen, L.-C. (2012). 3D spatial information for fire-fighting search and rescue route analysis within buildings. *Fire Safety Journal, 48*(Supplement C), 21-29. doi:https://doi.org/10.1016/j.firesaf.2011.12.006

Zhang, J. P., & Hu, Z. Z. (2011). BIM- and 4D-based integrated solution of analysis and management for conflicts and structural safety problems during construction: 1. Principles and methodologies. *Automation in Construction, 20*(2), 155-166. doi:http://dx.doi.org/10.1016/j.autcon.2010.09.013

Zhang, S., Teizer, J., Lee, J.-K., Eastman, C. M., & Venugopal, M. (2013). Building Information Modeling (BIM) and Safety: Automatic Safety Checking of Construction Models and Schedules. *Automation in Construction, 29*, 183-195. doi:http://dx.doi.org/10.1016/j.autcon.2012.05.006

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Appendix 1: Overview of available 4D BIM software

The following table presents an overview of available software packages that can be used for 4D BIM. Within the remarks column a general overview and some positive and/or negative point are named. This overview is elaborated from Eastman et al. (2011) and used to help make a choice on the software to be used within this research.

Company	Product	Remarks
Bentley	ProjectWise Navigator	ProjectWise Navigator is a stand-alone application that provides a series of services. First, it supports the importation of multiple 2D and 3D design files. Second, is allows the user to review 2D drawings and 3D models concurrently. Third, the user is able to follow the links between data files and components. Fourth, the software has the ability to review interferences, so called clashed, and to view and analyse schedule simulations.
Common Point	Project 4D ConstructSim	This software has some specialized 4D features such as conflict analyses, adding laydown objects, animation, and the ability to create 4D movies. The process of linking 4D includes automatic linking and manual drag-drop linking. Users of this software can distribute a 4D viewer to team members.
Innovaya	Visual Simulation	This software links any 3D design in DWG with either Microsoft Project or Primavera scheduling tasks and shows projects in 4D. This software is able to produce a simulation of the construction process. It is able to process changes made in either the schedule or to 3D objects. And it uses colour codes to detect potential schedule problems.
Navisworks	JetStream Timeliner	The Timeliner software includes all features of the JetStream visualisation environment and support the largest number of BIM formats and best overall visualisation capabilities. It supports automatic and manual linking of imported schedule data from various schedule applications. The software has only few custom 4D features and manual linking is not user friendly.
Synchro ltd.	Synchro 4D	Considered a powerful new tool with the most sophisticated scheduling capabilities of any of the 4D software. The tool requires knowledge of scheduling and project management to take advantage of resource and risk analysis features. The tool includes built-in tools to visualise risk, buffering, and resource utilization.
VICO Software	Virtual Construction	This software consists of 4 parts: Constructor, Estimator, Control and 5D Presenter. First, the building model is made with Constructor and objects are assigned recipes that define the tasks and resources needed to build or fabricate the. Quantities and costs are then calculated in Estimator. Next the schedule activities are defined and planned with Control and last the 4D simulation is visualised with Presenter. Instead of Control project like Microsoft Project or Primavera can be imported as well.

Table 20: Overview of 4D tools adopted from Eastman et al. (2011)

Appendix 2: Categorise typical workday

The categories of activities can be elaborated even more. The tasks described by El Asmar (2012) can be linked to the seven types of waste named by Womack and Jones (2003) : Waiting; Over production; Rejects; Motion (Excess); Processing (Over); Inventory; Transportation.

- Waiting; the unnecessary waiting time until starting a new task;
- Over production; providing too much data than needed to and the delivery of unnecessary products;
- Rejects; Defective products and repair works;
- Motion (Excess); The unnecessary movements of people or products;
- Processing (Over); To many steps for the actual product;
- Inventory; the presence of redundant stock;
- Transportation; parts and product moving unnecessary.

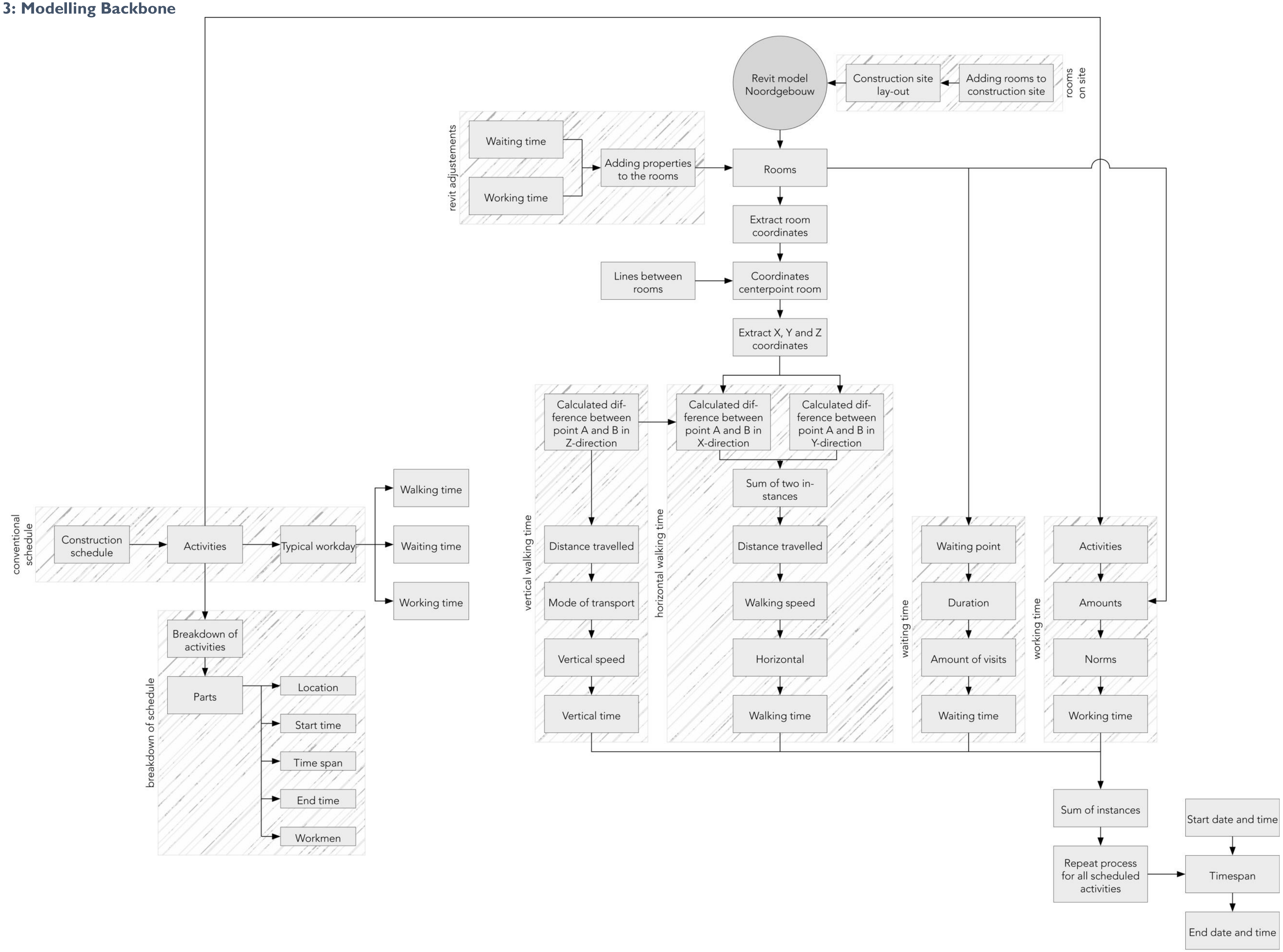
The type of waste can be compared to the typical workday break-down of El Asmar (2012) shown in Figure 4 can be translated to the seven types of waste and to the type Muda 1 and Muda 2.

Table 21: Typical workday by El Asmar (2012) divided among the three categories presented by Vrijhoef (2016)

41%	Value added	Productive	Productive
3%	Travel from and to lunch;	Motion and Transport	Muda 2
2%	Charging batteries;	Motion and Processing	Muda 2
3%	Handling / changing hand tools;	Transport, Motion and Processing	Muda 2
9%	Waiting for instructions / materials;	Waiting	Muda 2
9%	Transportation; moving equipment; walking; using vehicles;	Waiting, Transport and Motion	Muda 2
7%	Other waste; shoveling snow; removing tarps; stretching cords.	Waiting, Transport and Motion	Muda 2
9%	Change of tasks; start-up and clean-up;	Transport, Motion and Processing	Muda 2
4%	Morning coffee break;	Motion	Muda 1
3%	Locating tools / ladders;	Transport and Motion	Muda 1
4%	Locating materials	Transport and Motion	Muda 1
4%	Restroom visits;	Motion	Muda 1

Table 20 shows the classification of the typical workday presented by El Asmar (2012) broken-down into the three categories introduced by Alarcón (1997); Vrijhoef (2016) and named by the seven types of waste introduces by Womack and Jones (2003).

Appendix 3: Modelling Backbone



Appendix 4: Interview Eissink

Interviewer: Jan Tjerk Dijkstra
Geïnterviewde: Robin Workel; Projectleider; Eissink plafond- en wandsystemen
Datum: 24 November 2017 10:00
Plaats: Projectlocatie het Noordgebouw te Utrecht

[Handen worden geschut, kennis wordt gemaakt]

Interviewer: Dus dat is waar ik ben. Dan heb ik een aantal, gewoon, het zijn eigenlijk vrij simpele vragen. Over hoe de gemiddelde dag eruitziet en hoe de ploegen eruit zien. Met hoeveel mensen jullie werken in een ploeg.

Geïnterviewde: Ja.

Interviewer: Uh, ja en hoe die ploeg eruitziet? Hebben ze allemaal dezelfde functie of zijn er mensen die zeg maar het snijwerk doen en anderen die het plaatsen? Uh, ja dus de onderverdeling van de ploeg. En dan hoe jullie werkzaamheden eruitzien? Dus dan eerst blik stellen en dan de wanden dicht zetten. Nouja, hoe die volgorde eruit ziet?

Geïnterviewde: Ja.

Interviewer: En hoe jullie dagindeling eruit zit, vanaf start tot einde, met pauzes en wat daar tussenin gebeurd.

Geïnterviewde: Nouja, dat weet ik niet exact maar ......

Interviewer: Nee, maar het gaat om een globale indeling van hoe zit een gemiddelde dag eruit. Zodat ik die kan koppelen aan mijn locaties binnen de simulatie. En dan kan ik zien waar de looplijnen liggen en waar op bepaalde punten lang gewacht wordt. Bijvoorbeeld als je dan ziet dat bijvoorbeeld bij de lift lang wordt gewacht, toch nog ook al voor je eigenlijk alle materialen 's avonds aan hier. Dan kan je dus zien dat je daar bijvoorbeeld een extra lift bij had kunnen zetten. En als je dan zoveel mensen die op de bouwplaats rondlopen minderlang hoeven wachten dan zou je kosten bijvoorbeeld weer tegen elkaar weg kunnen strepen.

Geïnterviewde: Nou op dit moment is het dat niet het geval, wat die jongen doen is uh. Ze komen hier 's morgens met de trein. Ja, dat is ook ideaal. De gereedschappen liggen gewoon op de werkplek, achter slot en grendel. En ze gaan dan natuurlijk naar de werkplek toe. [Telefoon van geïnterviewde gaat af, kort gesprek volgt.]

Geïnterviewde: Maar lang verhaal kort, het eerste wat ze doen is naar de werkplek, kijken of de materialen er zijn. Al de materialen er liggen beginnen we met stelwerk van het blik, werkzaamheden.

Interviewer: Ja, ik heb hier een schema van de werkzaamheden. Ik heb vanuit vorige onderzoeken en mijn eigen kennis heb ik een lijstje gemaakt van hoe jullie werkzaamheden eruitzien. Het is wel in het Engels, hoop niet dat dat een probleem is. [Lijst cq. schema wordt aangeboden, op papier]

Geïnterviewde: Haha, ja. 'Dimensioning floor profiles', ja dat klopt, dat klopt. Maar zal ik er een krulletje bij zetten.

Interviewer: Ja, dat is goed.

Geïnterviewde: 'Placing floor and ceiling profiles' ja, uhm. Nee, het is dus eerst, ja uh. Dit is dus het algemene [Linker kolom wordt aangewezen] en dit [rechter kolom wordt aangewezen] is dus de uitleg daarvan hè.

Interviewer: Ja, klopt.

Geïnterviewde: Ja, dan uh, 'Dimensioning' is uitzetten, klopt.

Interviewer: Ja, het maatvoeren.

Geïnterviewde: 'Prepare floor profiles' klopt. 'Mount floor profiles'

Interviewer: Is het op maat maken van de profielen en daarnaa plaatsen.

Geïnterviewde: Uh. Oke, ja. Uh, ja dat klopt ook. 'Prepare ceiling', Ja. En dan 'level out ceiling profiles', Ja. Dan 'Place studs, nee. 'Place studs' wacht even. Je gaat eerst de kozijnen stellen, 'Door frames'. Dus die gaat daar naa toe en die gaat daar naartoe [aantekeningen worden gemaakt op lijst]. 'Backerboard, perpare backerboard' Nee, eerst gaat het 'gyspum, install to one side', de gaat weer daar naartoe [aantekeningen worden gemaakt in lijst]. 'Install electric and plumbing' ja dat klopt. Dat is W en E. 'Place and cut insulation' , ja als het erin zit. In heel veel wanden zit het niet. Bijna nergens. 'Install gypsum to the second side' eigenlijk moet ik daar even van zeggen. Dat er eerst getekend moet worden door de mensen dat alles erin zit. Dat is wel een heel belangrijke stap. Dus een, uh, controle ronde. [Aantekeningen worden gemaakt in lijst].

Interviewer: En wie doet dat, die controle, doet jullie voorman dat of?

Geïnterviewde: Dat doet de E de W, onze voorman en iemand van de aannemer. Dus is 'Controle of alles in de wand zit W plus E plus DV (Dura Vermeer) plus Eissink'. 'Finish walls, place cornerbeads, ja, drywall joint tape, ja,' Dat doen wij. Nog een ding vergeten wij doen de plafonds ook.

Interviewer: Ja, maar mijn onderzoek richt zich alleen op de wanden, dus in dit geval, uh.

Geïnterviewde: Ja, zo klaar. Zo ziet het er goed uit.

Interviewer: Ja er zit alleen wat volgordelijkheid in. Zitten hier ook nog volgordelijkheden in, ik heb deze volgorde van C-smart, daar hebben ze ook een keer onderzoek gedaan. Daar komt deze lijst ongeveer vandaan.

Geïnterviewde: Ja, deze, c-smart hebben wij ook gemaakt he. [Volgende lijst wordt voorgelegd, hierin kan de dagindeling worden besproken.] Zeven uur.

Interviewer: Ik weet niet hoe laat julie beginnen.

Geïnterviewde: Uh de jongens beginnne eerder al, maar dat is geen probleem. Uh, uh. Gereedschap klaar zetten, aanvang werkzaamheden [aantekeningen worden gemaakt]. Dan ga ik even de jongens bellen hoe laat ze gaan schaften. Want dat wil je graag weten.

Interviewer: Ja en hoe lang?

Geïnterviewde: Ja, dat zal een half uur zijn tussen de middag. [Voorman wordt gebeld] Hey, ik ben even van de controle afdeling. Hoe laat ben je begonnen met je werk? Ik zit in een interview dan weet je dat even, daar gaat het even om. En dan ga ik even jullie werkzaamheden helemaal omschrijven. 07.00 uur klaarzetten gereedschap, aanvang werkzaamheden, ja? 8 uur nog steeds, hoe laat ga je schaften? 09.30 schaften, een kwartier mag ik dat zeggen of is dat een half uur? 15 minuten, dat is ook goed, dat is heel goed jongen, zo mag ik het horen. 10.00 ga je door, hoe laat ben tussen de middag aan de schaft? 12.30, ja zet ik toch een half uur schaft neer, 30 minuten. En dan zit even met, hoe laat stop jij? Jij stopt om drie uur, 15.00 werkzaamheden beeindigen. Hoe laat bijgin jij hier? Kwart voor zeven, dat vermoeden had ik al, ok. Is goed jongen, dit wou ik even weten. Ik kom straks bij jou voor de rest van de zaken, en dingetjes, ja? Oke, hoi ja doei. En voor de rest doen ze werken.

Interviewer: Ja, en daar tussen in die 15 minuten, moeten ze daarin ook in heen en weer lopen of is dat puur echt de tijd dat ze hier binnen mogen zitten?

Geïnterviewde: Hun zijn echt van de half uur, ze leggen het gereedschap hierneer op dat tijdstip. Dan gaan ze naar de keet, en die jongens zijn dat half uur later ook weer aan het werk.

Interviewer: Ja.

Geïnterviewde: Nou zit daar wel heel veel verschil in hoor. Je heb de rand personen en de echt harde werkers en hier heb je een paar harde werkers lopen. De een werkt voor de baas en de ander werkt voor zichzelf. Daar zit ook veel verschil in.

Interviewer: Jullie hebben er ook een aantal zzp'er tussen lopen?

Geïnterviewde: Dit zijn zzp'ers. En volgende week komen de eigen jongens.

Interviewer: En is het een ploeg, hebben ze allemaal dezelfde functie of zitten er een paar loopjongens tussen.

Geïnterviewde: Ja ze kunnen allemaal hetzelfde. Het is het tweede ploegje dat zo komt, dat gaat de wanden sluiten en dat gaat de plafonnetjes klaar maken. Dus dat is het tweede treintje. Dus we hebben eerst een treintje voor het stellen, enkelzijdig opzetten, sparingen maken en achterhout erin. En het tweede treintje wat erachter aankomt is puur de woning klaarmaken en dan komt later een keer een smeerder.

Interviewer: Dus het tweede treintje, is de isolatie en het dichtzetten.

Geïnterviewde: Dat is niet bij ons, maar dat dicht zetten is wel bij ons. Maar de installaties dat doet de installateur.

Interviewer: En de isolatie?

Geïnterviewde: Isolatie, als het nodig is maken we die erin, maar die zit er bijna niet in. Maar dat wordt wel in het tweede treintje meegenomen.

Interviewer: En dan komt er in het derde treintje een smeerder en die smeert alles dicht.

Geïnterviewde: Ja, en dat zijn heel weinig werkzaamheden hier, want dat zijn maar een paar wandjes. Dus die gaan we ook meerder woningen tegelijk laten doen.

Interviewer: Ja want de wandjes zitten voornamelijk aan de gangen?

Geïnterviewde: Der zit uh.. heb je zon kamer? Ken je hem?

Interviewer: Ja ik ken hem, van het hotel. Je hebt de badkamer en de gangen en dat is volgens mij metal stud.

Geïnterviewde: Ja, zo simpel is het.

Interviewer: En dan heb je nog de schacht waar je moet plaatsen.

Geïnterviewde: Ja, dat is het.

Interviewer: Oké, even kijken. Het is allemaal vrij duidelijk al. En als het goed is liggen de materialen vlak bij de werkplek, dus ze hoeven niet heel vaak meer heen en weer te lopen.

Geïnterviewde: Nee, want er zijn nu nog wat aanlopers. Maar dat heeft puur met deze verdieping te maken, dat sommige werkzaamheden andersom gaan en er zijn nog wijzigingen gekomen. Dus daardoor staat nu even het treintje stil en lopen we een paar dagen vertraging op. Maar dat gaan we wel weer inhalen.

Interviewer: En dan heb ik toch het idee, want ik maak een simulatie van zo'n dag. En dan heb je in het traditionele systeem moetend dan ook nog de materialen door jullie aangeleverd, dat wordt in dit geval niet gedaan. Hoeveel zou je inschatten dat dat in jullie werktijd, dat dan ook nog zou moeten gebeuren. Want

Geïnterviewde: Dat is nog wel een beetje hoor. Ik denk dat we daar uh.. Dat je daar hier zo vier uur aan kwijt bent.

Interviewer: Per dag 1 persoon?

Geïnterviewde: Nee, twee personen, anders zou het helemaal te gek zijn. Dus twee uur per persoon per dag. Houd daar maar rekening mee. En heb je BMN al gehad.

Interviewer: Nee, ik doe niks op de HUB. Ik meer naar de bouwplaats zelf.

Geïnterviewde: Maar dat is toch ook wel belangrijk?

Interviewer: Ja, maar voor mij gaat het meer om het model erachter en de hele rekenkundige model erachter.

Geïnterviewde: Dus jij berekent ook enzo?

Interviewer: Ja, ik maak dus een simulatie in 3D die laat zien waar de looplijnen zijn op de bouwplaats. Dan moet je dus kunnen zien hoe jullie ongeveer lopen en waar de wachttijden zijn.

Geïnterviewde: Je weet hoe een verdieping loopt he? Heb je de planning gelezen?

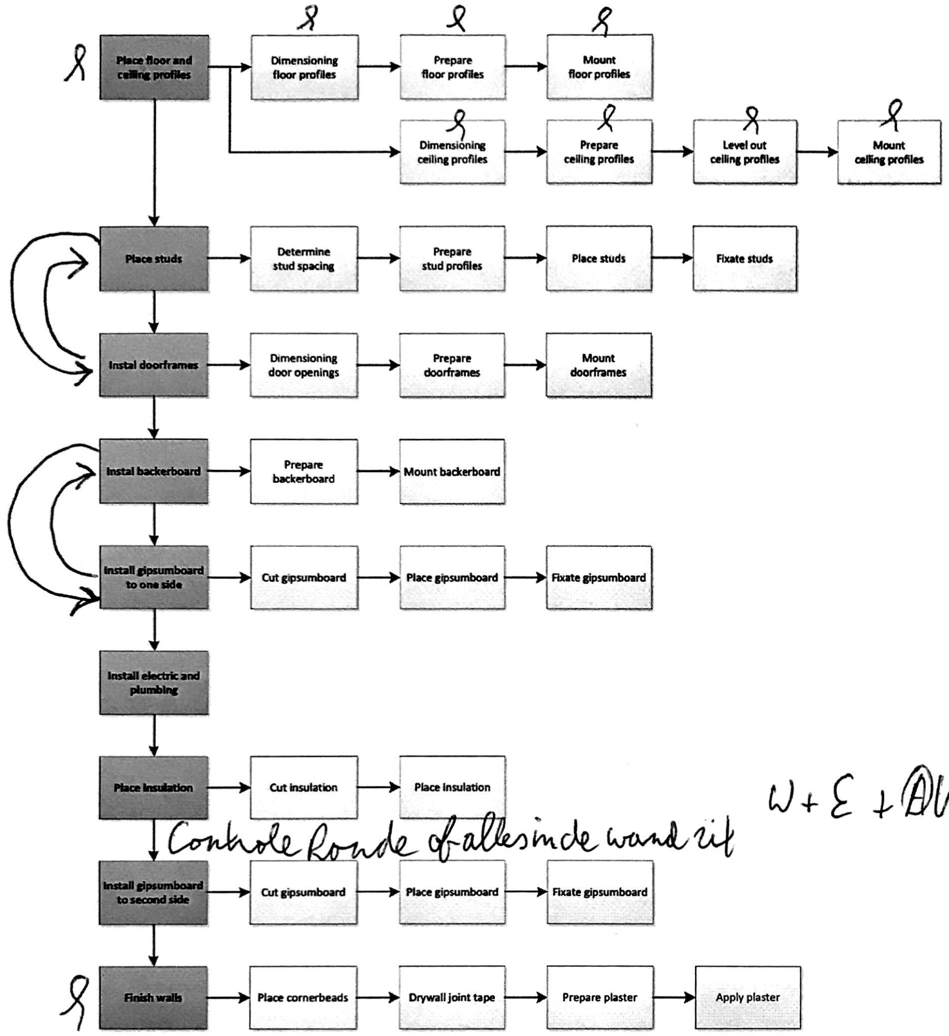
Interviewer: Ja die heb ik gezien.

Geïnterviewde: Ja want als die pakt en een plattegrond kan je het zien.

Interviewer: Ja dat heb ik begrepen, met twee woningen per dag.

Geïnterviewde: Ja en in principe zijn het twee woningen per dag. Of, ja ik noem het altijd woningen, twee kamers per dag. Dus twee kamers, zo gaan we elke keer rond. En dat geldt voor elke verdieping erboven ook. Alleen je begint op elke verdieping weer op een ander punt. Omdat dat weer met de oppersteiger te maken heeft.

Interviewer: Oké, mooi. Ja dat was het eigenlijk. Bedankt. [Afscheid wordt genomen]



W + E + AV + Einrich

6.45

07:00

Gereedschap klaarzetten

aanvang werkzaamheden

08:00

09:00

9.30 Schaft 15 min

10:00

11:00

12:00

12.30 Schaft 30 min

13:00

14:00

15:00

15 Beendigen werkzaamheden

16:00

07:00

17:00

18:00

Appendix 5: Measurements stair walking speed.

Datasheet measurements conducted on the walking speed of constructionworkers on stairs.

Participant	*Time Taken [hh:mm:ss]*	*Time taken [s]*	Start Floor	End Floor	Amount of floors	Amount of floors Absolute	Descending or Ascending	Time per floor [hh:mm:ss]	Time per floor [s]	Start height [mm]	End Height [mm]	Traveled height [mm]	Traveled height ABS [mm]	Speed [m/s]	Date
1	00:00:38	38	5	0	-5	5	-5	00:00:08	08	15870	0	15870	15870	0,42	06/12/17
2	00:01:23	83	1	9	8	8	8	00:00:10	10	3870	27870	-24000	24000	0,29	06/12/17
3	00:00:20	20	8	6	-2	2	-2	00:00:10	10	24870	18870	6000	6000	0,30	06/12/17
4	00:00:24	24	0	2	2	2	2	00:00:12	12	0	6870	-6870	6870	0,29	06/12/17
5	00:00:11	11	1	2	1	1	1	00:00:11	11	3870	6870	-3000	3000	0,27	06/12/17
6	00:01:14	74	0	5	5	5	5	00:00:15	15	0	15870	-15870	15870	0,21	06/12/17
7	00:00:29	29	1	4	3	3	3	00:00:10	10	3870	12870	-9000	9000	0,31	06/12/17
8	00:00:18	18	0	2	2	2	2	00:00:09	09	0	6870	-6870	6870	0,38	06/12/17
9	00:00:28	28	3	5	2	2	2	00:00:14	14	9870	15870	-6000	6000	0,21	06/12/17
10	00:01:04	64	6	0	-6	6	-6	00:00:11	11	18870	0	18870	18870	0,29	06/12/17
11	00:00:35	35	9	6	-3	3	-3	00:00:12	12	27870	18870	9000	9000	0,26	06/12/17
12	00:00:24	24	7	5	-2	2	-2	00:00:12	12	21870	15870	6000	6000	0,25	06/12/17
13	00:00:36	36	2	5	3	3	3	00:00:12	12	6870	15870	-9000	9000	0,25	06/12/17
14	00:00:26	26	5	2	-3	3	-3	00:00:09	09	15870	6870	9000	9000	0,35	06/12/17
15	00:00:23	23	2	0	-2	2	-2	00:00:11	12	6870	0	6870	6870	0,30	06/12/17
16	00:01:25	85	0	9	9	9	9	00:00:09	09	0	27870	-27870	27870	0,33	06/12/17
17	00:00:10	10	5	4	-1	1	-1	00:00:10	10	15870	12870	3000	3000	0,30	06/12/17
18	00:00:31	31	5	0	-5	5	-5	00:00:06	06	15870	0	15870	15870	0,51	06/12/17
19	00:00:14	14	1	2	1	1	1	00:00:14	14	3870	6870	-3000	3000	0,21	06/12/17
20	00:00:37	37	0	3	3	3	3	00:00:12	12	0	9870	-9870	9870	0,27	06/12/17
21	00:00:35	35	1	4	3	3	3	00:00:12	12	3870	12870	-9000	9000	0,26	06/12/17
22	00:00:12	12	6	5	-1	1	-1	00:00:12	12	18870	15870	3000	3000	0,25	06/12/17
23	00:00:18	18	2	0	-2	2	-2	00:00:09	09	6870	0	6870	6870	0,38	06/12/17
24	00:00:15	15	2	0	-2	2	-2	00:00:08	08	6870	0	6870	6870	0,46	06/12/17
25	00:00:26	26	3	0	-3	3	-3	00:00:09	09	9870	0	9870	9870	0,38	06/12/17
26	00:00:54	54	4	0	-4	4	-4	00:00:14	14	12870	0	12870	12870	0,24	06/12/17
27	00:01:39	99	10	0	-10	10	-10	00:00:10	10	30870	0	30870	30870	0,31	06/12/17
28	00:00:46	46	3	0	-3	3	-3	00:00:15	15	9870	0	9870	9870	0,21	07/12/17
29	00:01:38	98	8	0	-8	8	-8	00:00:12	12	24870	0	24870	24870	0,25	08/12/17
30	00:00:44	44	0	4	4	4	4	00:00:11	11	0	12870	-12870	12870	0,29	09/12/17
min	00:00:10				min	1,00	min	00:00:06					min	0,21	
max	00:01:39				max	10,00	max	00:00:15					max	0,51	
average	00:00:39				average	3,60	average	00:00:11					average	0,30	
StDev	00:00:26				StDev	2,43	StDev	00:00:02					StDev	0,07	

Appendix 6: Measurements elevator traveling speed.

Datasheet measurements conducted on the traveling speed of constructionworkers in elevatoors.

Participant	*Time Taken*	*Time taken [s]*	Start Floor	End Floor	Amount of floors	Amount of floors Absolute	Descending or Ascending	Time per floor	*Time taken [s]*	Start height	End Height	Traveled height	Traveled height ABS	Speed [m/s]	Date
1	00:00:54	54	8	0	-8	8	-8	00:00:07	07	24870	0	24870	24870	0,46	06/12/17
2	00:00:51	51	8	2	-6	6	-6	00:00:09	09	24870	6870	18000	18000	0,35	06/12/17
3	00:01:06	66	0	5	5	5	5	00:00:13	13	0	15870	-15870	15870	0,24	06/12/17
4	00:00:59	59	8	0	-8	8	-8	00:00:07	07	24870	0	24870	24870	0,42	06/12/17
5	00:01:06	66	0	8	8	8	8	00:00:08	08	0	24870	-24870	24870	0,38	06/12/17
6	00:01:11	71	0	5	5	5	5	00:00:14	14	0	15870	-15870	15870	0,22	06/12/17
7	00:01:11	71	0	8	8	8	8	00:00:09	09	0	24870	-24870	24870	0,35	06/12/17
8	00:01:16	76	0	8	8	8	8	00:00:10	10	0	24870	-24870	24870	0,33	06/12/17
9	00:01:08	68	0	5	5	5	5	00:00:14	14	0	15870	-15870	15870	0,23	06/12/17
10	00:00:49	49	0	2	2	2	2	00:00:24	25	0	6870	-6870	6870	0,14	06/12/17
11	00:00:36	36	2	5	3	3	3	00:00:12	12	6870	15870	-9000	9000	0,25	06/12/17
12	00:01:00	60	0	4	4	4	4	00:00:15	15	0	12870	-12870	12870	0,21	06/12/17
13	00:01:00	60	0	5	5	5	5	00:00:12	12	0	15870	-15870	15870	0,26	06/12/17
14	00:00:41	41	5	0	-5	5	-5	00:00:08	08	15870	0	15870	15870	0,39	06/12/17
15	00:03:06	186	0	6	6	6	6	00:00:31	31	0	18870	-18870	18870	0,10	06/12/17
16	00:01:09	69	8	0	-8	8	-8	00:00:09	09	24870	0	24870	24870	0,36	06/12/17
17	00:01:24	84	0	8	8	8	8	00:00:11	10	0	24870	-24870	24870	0,30	06/12/17
18	00:00:51	51	4	0	-4	4	-4	00:00:13	13	12870	0	12870	12870	0,25	06/12/17
19	00:00:48	48	0	2	2	2	2	00:00:24	24	0	6870	-6870	6870	0,14	06/12/17
20	00:01:21	81	0	8	8	8	8	00:00:10	10	0	24870	-24870	24870	0,31	06/12/17
21	00:00:50	50	5	0	-5	5	-5	00:00:10	10	15870	0	15870	15870	0,32	06/12/17
22	00:00:47	47	0	2	2	2	2	00:00:23	24	0	6870	-6870	6870	0,15	06/12/17
23	00:01:21	81	0	8	8	8	8	00:00:10	10	0	24870	-24870	24870	0,31	06/12/17
24	00:00:54	54	5	0	-5	5	-5	00:00:11	11	15870	0	15870	15870	0,29	06/12/17
25	00:00:48	48	8	4	-4	4	-4	00:00:12	12	24870	12870	12000	12000	0,25	06/12/17
26	00:01:46	106	0	2	2	2	2	00:00:53	53	0	6870	-6870	6870	0,06	06/12/17
27	00:01:03	63	6	0	-6	6	-6	00:00:11	11	18870	0	18870	18870	0,30	06/12/17
28	00:02:24	144	0	6	6	6	6	00:00:24	24	0	18870	-18870	18870	0,13	06/12/17
29	00:01:23	83	0	8	8	8	8	00:00:10	10	0	24870	-24870	24870	0,30	06/12/17
30	00:00:41	41	2	0	-2	2	-2	00:00:21	21	6870	0	6870	6870	0,17	06/12/17
31	00:01:15	75	0	8	8	8	8	00:00:09	09	0	24870	-24870	24870	0,33	06/12/17
32	00:00:51	51	0	1	1	1	1	00:00:51	51	0	3870	-3870	3870	0,08	06/12/17
33	00:01:21	81	0	3	3	3	3	00:00:27	27	0	9870	-9870	9870	0,12	06/12/17
34	00:01:49	109	0	2	2	2	2	00:00:54	55	0	6870	-6870	6870	0,06	06/12/17
35	00:01:16	76	2	6	4	4	4	00:00:19	19	6870	18870	-12000	12000	0,16	06/12/17
36	00:01:08	68	0	3	3	3	3	00:00:23	23	0	9870	-9870	9870	0,15	06/12/17
37	00:01:04	64	0	4	4	4	4	00:00:16	16	0	12870	-12870	12870	0,20	06/12/17
38	00:00:38	38	4	5	1	1	1	00:00:38	38	12870	15870	-3000	3000	0,08	06/12/17
39	00:00:36	36	5	6	1	1	1	00:00:36	36	15870	18870	-3000	3000	0,08	06/12/17
40	00:00:57	57	8	0	-8	8	-8	00:00:07	07	24870	0	24870	24870	0,44	06/12/17
41	00:01:16	76	0	5	5	5	5	00:00:15	15	0	15870	-15870	15870	0,21	06/12/17
42	00:00:53	53	5	8	3	3	3	00:00:18	18	15870	24870	-9000	9000	0,17	06/12/17
43	00:01:12	72	0	4	4	4	4	00:00:18	18	0	12870	-12870	12870	0,18	06/12/17
44	00:00:50	50	4	0	-4	4	-4	00:00:13	13	12870	0	12870	12870	0,26	06/12/17
45	00:02:42	162	8	2	-6	6	-6	00:00:27	27	24870	6870	18000	18000	0,11	06/12/17

46	00:01:34	94	2	0	-2	2	-2	00:00:47	47	6870	0	6870	6870	0,07	06/12/17
47	00:01:11	71	8	0	-8	8	-8	00:00:09	09	24870	0	24870	24870	0,35	06/12/17
48	00:00:56	56	0	4	4	4	4	00:00:14	14	0	12870	-12870	12870	0,23	06/12/17
49	00:00:47	47	5	8	3	3	3	00:00:16	16	15870	24870	-9000	9000	0,19	06/12/17
50	00:01:10	70	8	0	-8	8	-8	00:00:09	09	24870	0	24870	24870	0,36	06/12/17
min	00:00:36				min	1,00	min	00:00:07					min	0,06	
max	00:03:06				max	8,00	max	00:00:54					max	0,46	
average	00:01:09				average	4,92	average	00:00:18					average	0,24	
StDev	00:00:29				StDev	2,35	StDev	00:00:12					StDev	0,11	

Appendix 7: Dynamo Model Workspace

Appendix 8: Typical workday - Rooms list of all levels used in Simulation Benchmark, 1, 3 and 4

Level 2

33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324427	SK.03.01	Schaftkeet_Dagstart SK.03.01	Point(X = 25964.382, Y = -45836.911, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324342	BP.02.01	Portier BP.02.01	Point(X = 101989.965, Y = -12978.732, Z = 0.000)	00 begane grond - Peil
33324478	TQ.01.02	Tourniquet TQ.01.02	Point(X = 106241.426, Y = -10449.365, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324358	BL.01.02	Bouwlift BL.01.02	Point(X = 92158.144, Y = -3684.171, Z = 6870.000)	02 tweede verdieping hotel
255806	H.02.08	hotelkamer H.02.08	Point(X = 92503.927, Y = 20464.815, Z = 6870.000)	02 tweede verdieping hotel
33324357	TT.01.02	Trappentoren TT.01.02	Point(X = 93360.216, Y = -7303.312, Z = 6870.000)	02 tweede verdieping hotel
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324357	TT.01.02	Trappentoren TT.01.02	Point(X = 93360.216, Y = -7303.312, Z = 6870.000)	02 tweede verdieping hotel
255806	H.02.08	hotelkamer H.02.08	Point(X = 92503.927, Y = 20464.815, Z = 6870.000)	02 tweede verdieping hotel
33324357	TT.01.02	Trappentoren TT.01.02	Point(X = 93360.216, Y = -7303.312, Z = 6870.000)	02 tweede verdieping hotel
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324433	SK.03.02	Schaftkeet_Koffiepauze SK.03.02	Point(X = 25987.353, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324357	TT.01.02	Trappentoren TT.01.02	Point(X = 93360.216, Y = -7303.312, Z = 6870.000)	02 tweede verdieping hotel
223079	H.02.09	hotelkamer H.02.09	Point(X = 96696.073, Y = 20464.815, Z = 6870.000)	02 tweede verdieping hotel
33324357	TT.01.02	Trappentoren TT.01.02	Point(X = 93360.216, Y = -7303.312, Z = 6870.000)	02 tweede verdieping hotel
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324434	SK.03.03	Schaftkeet_Lunchpauze SK.03.03	Point(X = 20374.750, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324357	TT.01.02	Trappentoren TT.01.02	Point(X = 93360.216, Y = -7303.312, Z = 6870.000)	02 tweede verdieping hotel
223079	H.02.09	hotelkamer H.02.09	Point(X = 96696.073, Y = 20464.815, Z = 6870.000)	02 tweede verdieping hotel
33324357	TT.01.02	Trappentoren TT.01.02	Point(X = 93360.216, Y = -7303.312, Z = 6870.000)	02 tweede verdieping hotel
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324357	TT.01.02	Trappentoren TT.01.02	Point(X = 93360.216, Y = -7303.312, Z = 6870.000)	02 tweede verdieping hotel
223079	H.02.09	hotelkamer H.02.09	Point(X = 96696.073, Y = 20464.815, Z = 6870.000)	02 tweede verdieping hotel
33324358	BL.01.02	Bouwlift BL.01.02	Point(X = 92158.144, Y = -3684.171, Z = 6870.000)	02 tweede verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324435	SK.03.04	Schaftkeet_Dagafsluiting SK.03.04	Point(X = 20374.750, Y = -45699.081, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil

Level 3

33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324427	SK.03.01	Schaftkeet_Dagstart SK.03.01	Point(X = 25964.382, Y = -45836.911, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324342	BP.02.01	Portier BP.02.01	Point(X = 101989.965, Y = -12978.732, Z = 0.000)	00 begane grond - Peil
33324478	TQ.01.02	Tourniquet TQ.01.02	Point(X = 106241.426, Y = -10449.365, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324361	BL.01.03	Bouwlift BL.01.03	Point(X = 92112.329, Y = -3700.733, Z = 9870.000)	03 derde verdieping
1240640	H.03.13	hotelkamer H.03.13	Point(X = 92503.927, Y = 20464.815, Z = 9870.000)	03 derde verdieping
33324359	TT.01.03	Trappentoren TT.01.03	Point(X = 93371.235, Y = -7337.560, Z = 9870.000)	03 derde verdieping
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324359	TT.01.03	Trappentoren TT.01.03	Point(X = 93371.235, Y = -7337.560, Z = 9870.000)	03 derde verdieping
1240640	H.03.13	hotelkamer H.03.13	Point(X = 92503.927, Y = 20464.815, Z = 9870.000)	03 derde verdieping
33324359	TT.01.03	Trappentoren TT.01.03	Point(X = 93371.235, Y = -7337.560, Z = 9870.000)	03 derde verdieping
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324433	SK.03.02	Schaftkeet_Koffiepauze SK.03.02	Point(X = 25987.353, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324359	TT.01.03	Trappentoren TT.01.03	Point(X = 93371.235, Y = -7337.560, Z = 9870.000)	03 derde verdieping
1239881	H.03.14	hotelkamer H.03.14	Point(X = 96696.073, Y = 20464.815, Z = 9870.000)	03 derde verdieping
33324359	TT.01.03	Trappentoren TT.01.03	Point(X = 93371.235, Y = -7337.560, Z = 9870.000)	03 derde verdieping
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324434	SK.03.03	Schaftkeet_Lunchpauze SK.03.03	Point(X = 20374.750, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324359	TT.01.03	Trappentoren TT.01.03	Point(X = 93371.235, Y = -7337.560, Z = 9870.000)	03 derde verdieping
1239881	H.03.14	hotelkamer H.03.14	Point(X = 96696.073, Y = 20464.815, Z = 9870.000)	03 derde verdieping
33324359	TT.01.03	Trappentoren TT.01.03	Point(X = 93371.235, Y = -7337.560, Z = 9870.000)	03 derde verdieping
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324359	TT.01.03	Trappentoren TT.01.03	Point(X = 93371.235, Y = -7337.560, Z = 9870.000)	03 derde verdieping
1239881	H.03.14	hotelkamer H.03.14	Point(X = 96696.073, Y = 20464.815, Z = 9870.000)	03 derde verdieping
33324361	BL.01.03	Bouwlift BL.01.03	Point(X = 92112.329, Y = -3700.733, Z = 9870.000)	03 derde verdieping
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324435	SK.03.04	Schaftkeet_Dagafsluiting SK.03.04	Point(X = 20374.750, Y = -45699.081, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil

Level 4

33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324427	SK.03.01	Schaftkeet_Dagstart SK.03.01	Point(X = 25964.382, Y = -45836.911, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324342	BP.02.01	Portier BP.02.01	Point(X = 101989.965, Y = -12978.732, Z = 0.000)	00 begane grond - Peil
33324478	TQ.01.02	Tourniquet TQ.01.02	Point(X = 106241.426, Y = -10449.365, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324362	BL.01.04	Bouwlift BL.01.04	Point(X = 92037.276, Y = -3781.774, Z = 12870.000)	04 vierde verdieping hotel
11671860	H.04.14	hotelkamer H.04.14	Point(X = 92503.927, Y = 20464.815, Z = 12870.000)	04 vierde verdieping hotel
33324360	TT.01.04	Trappentoren TT.01.04	Point(X = 93395.359, Y = -7385.243, Z = 12870.000)	04 vierde verdieping hotel
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324360	TT.01.04	Trappentoren TT.01.04	Point(X = 93395.359, Y = -7385.243, Z = 12870.000)	04 vierde verdieping hotel
11671860	H.04.14	hotelkamer H.04.14	Point(X = 92503.927, Y = 20464.815, Z = 12870.000)	04 vierde verdieping hotel
33324360	TT.01.04	Trappentoren TT.01.04	Point(X = 93395.359, Y = -7385.243, Z = 12870.000)	04 vierde verdieping hotel
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324433	SK.03.02	Schaftkeet_Koffiepauze SK.03.02	Point(X = 25987.353, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324360	TT.01.04	Trappentoren TT.01.04	Point(X = 93395.359, Y = -7385.243, Z = 12870.000)	04 vierde verdieping hotel
11671841	H.04.15	hotelkamer H.04.15	Point(X = 96696.073, Y = 20464.815, Z = 12870.000)	04 vierde verdieping hotel
33324360	TT.01.04	Trappentoren TT.01.04	Point(X = 93395.359, Y = -7385.243, Z = 12870.000)	04 vierde verdieping hotel
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324434	SK.03.03	Schaftkeet_Lunchpauze SK.03.03	Point(X = 20374.750, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324360	TT.01.04	Trappentoren TT.01.04	Point(X = 93395.359, Y = -7385.243, Z = 12870.000)	04 vierde verdieping hotel
11671841	H.04.15	hotelkamer H.04.15	Point(X = 96696.073, Y = 20464.815, Z = 12870.000)	04 vierde verdieping hotel
33324360	TT.01.04	Trappentoren TT.01.04	Point(X = 93395.359, Y = -7385.243, Z = 12870.000)	04 vierde verdieping hotel
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324360	TT.01.04	Trappentoren TT.01.04	Point(X = 93395.359, Y = -7385.243, Z = 12870.000)	04 vierde verdieping hotel
11671841	H.04.15	hotelkamer H.04.15	Point(X = 96696.073, Y = 20464.815, Z = 12870.000)	04 vierde verdieping hotel
33324362	BL.01.04	Bouwlift BL.01.04	Point(X = 92037.276, Y = -3781.774, Z = 12870.000)	04 vierde verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324435	SK.03.04	Schaftkeet_Dagafsluiting SK.03.04	Point(X = 20374.750, Y = -45699.081, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil

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33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324427 SK.03.01	Schaftkeet_Dagstart SK.03.01	Point(X = 25964.382, Y = -45836.911, Z = 9870.000)	03 derde verdieping
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324342 BP.02.01	Portier BP.02.01	Point(X = 101989.965, Y = -12978.732, Z = 0.000)	00 begane grond - Peil
33324478 TQ.01.02	Tourniquet TQ.01.02	Point(X = 106241.426, Y = -10449.365, Z = 0.000)	00 begane grond - Peil
33324343 BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324353 BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324364 BL.01.05	Bouwlift BL.01.05	Point(X = 92151.908, Y = -3767.009, Z = 15870.000)	05 vijfde verdieping hotel
5788569 H.05.14	hotelkamer H.05.14	Point(X = 92503.927, Y = 20464.815, Z = 15870.000)	05 vijfde verdieping hotel
33324364 BL.01.05	Bouwlift BL.01.05	Point(X = 92151.908, Y = -3767.009, Z = 15870.000)	05 vijfde verdieping hotel
33324353 BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324503 WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324353 BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324364 BL.01.05	Bouwlift BL.01.05	Point(X = 92151.908, Y = -3767.009, Z = 15870.000)	05 vijfde verdieping hotel
5788569 H.05.14	hotelkamer H.05.14	Point(X = 92503.927, Y = 20464.815, Z = 15870.000)	05 vijfde verdieping hotel
33324364 BL.01.05	Bouwlift BL.01.05	Point(X = 92151.908, Y = -3767.009, Z = 15870.000)	05 vijfde verdieping hotel
33324353 BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324465 TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324433 SK.03.02	Schaftkeet_Koffiepauze SK.03.02	Point(X = 25987.353, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465 TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324353 BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324364 BL.01.05	Bouwlift BL.01.05	Point(X = 92151.908, Y = -3767.009, Z = 15870.000)	05 vijfde verdieping hotel
5788061 H.05.15	hotelkamer H.05.15	Point(X = 96696.073, Y = 20464.815, Z = 15870.000)	05 vijfde verdieping hotel
33324364 BL.01.05	Bouwlift BL.01.05	Point(X = 92151.908, Y = -3767.009, Z = 15870.000)	05 vijfde verdieping hotel
33324353 BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324465 TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324434 SK.03.03	Schaftkeet_Lunchpauze SK.03.03	Point(X = 20374.750, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465 TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324353 BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324364 BL.01.05	Bouwlift BL.01.05	Point(X = 92151.908, Y = -3767.009, Z = 15870.000)	05 vijfde verdieping hotel
5788061 H.05.15	hotelkamer H.05.15	Point(X = 96696.073, Y = 20464.815, Z = 15870.000)	05 vijfde verdieping hotel
33324364 BL.01.05	Bouwlift BL.01.05	Point(X = 92151.908, Y = -3767.009, Z = 15870.000)	05 vijfde verdieping hotel
33324353 BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324503 WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324353 BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324364 BL.01.05	Bouwlift BL.01.05	Point(X = 92151.908, Y = -3767.009, Z = 15870.000)	05 vijfde verdieping hotel
5788061 H.05.15	hotelkamer H.05.15	Point(X = 96696.073, Y = 20464.815, Z = 15870.000)	05 vijfde verdieping hotel
33324364 BL.01.05	Bouwlift BL.01.05	Point(X = 92151.908, Y = -3767.009, Z = 15870.000)	05 vijfde verdieping hotel
33324353 BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324343 BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324465 TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324435 SK.03.04	Schaftkeet_Dagafsluiting SK.03.04	Point(X = 20374.750, Y = -45699.081, Z = 9870.000)	03 derde verdieping
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil

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33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324427	SK.03.01	Schaftkeet_Dagstart SK.03.01	Point(X = 25964.382, Y = -45836.911, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324342	BP.02.01	Portier BP.02.01	Point(X = 101989.965, Y = -12978.732, Z = 0.000)	00 begane grond - Peil
33324478	TQ.01.02	Tourniquet TQ.01.02	Point(X = 106241.426, Y = -10449.365, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324366	BL.01.06	Bouwlift BL.01.06	Point(X = 92177.759, Y = -3728.232, Z = 18870.000)	06 zesde verdieping hotel
11426125	H.06.14	hotelkamer H.06.14	Point(X = 92503.927, Y = 20464.815, Z = 18870.000)	06 zesde verdieping hotel
33324366	BL.01.06	Bouwlift BL.01.06	Point(X = 92177.759, Y = -3728.232, Z = 18870.000)	06 zesde verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324366	BL.01.06	Bouwlift BL.01.06	Point(X = 92177.759, Y = -3728.232, Z = 18870.000)	06 zesde verdieping hotel
11426125	H.06.14	hotelkamer H.06.14	Point(X = 92503.927, Y = 20464.815, Z = 18870.000)	06 zesde verdieping hotel
33324366	BL.01.06	Bouwlift BL.01.06	Point(X = 92177.759, Y = -3728.232, Z = 18870.000)	06 zesde verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324433	SK.03.02	Schaftkeet_Koffiepauze SK.03.02	Point(X = 25987.353, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324366	BL.01.06	Bouwlift BL.01.06	Point(X = 92177.759, Y = -3728.232, Z = 18870.000)	06 zesde verdieping hotel
11426106	H.06.15	hotelkamer H.06.15	Point(X = 96696.073, Y = 20464.815, Z = 18870.000)	06 zesde verdieping hotel
33324366	BL.01.06	Bouwlift BL.01.06	Point(X = 92177.759, Y = -3728.232, Z = 18870.000)	06 zesde verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324434	SK.03.03	Schaftkeet_Lunchpauze SK.03.03	Point(X = 20374.750, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324366	BL.01.06	Bouwlift BL.01.06	Point(X = 92177.759, Y = -3728.232, Z = 18870.000)	06 zesde verdieping hotel
11426106	H.06.15	hotelkamer H.06.15	Point(X = 96696.073, Y = 20464.815, Z = 18870.000)	06 zesde verdieping hotel
33324366	BL.01.06	Bouwlift BL.01.06	Point(X = 92177.759, Y = -3728.232, Z = 18870.000)	06 zesde verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324366	BL.01.06	Bouwlift BL.01.06	Point(X = 92177.759, Y = -3728.232, Z = 18870.000)	06 zesde verdieping hotel
11426106	H.06.15	hotelkamer H.06.15	Point(X = 96696.073, Y = 20464.815, Z = 18870.000)	06 zesde verdieping hotel
33324366	BL.01.06	Bouwlift BL.01.06	Point(X = 92177.759, Y = -3728.232, Z = 18870.000)	06 zesde verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324435	SK.03.04	Schaftkeet_Dagafsluiting SK.03.04	Point(X = 20374.750, Y = -45699.081, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil

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33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324427	SK.03.01	Schaftkeet_Dagstart SK.03.01	Point(X = 25964.382, Y = -45836.911, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324342	BP.02.01	Portier BP.02.01	Point(X = 101989.965, Y = -12978.732, Z = 0.000)	00 begane grond - Peil
33324478	TQ.01.02	Tourniquet TQ.01.02	Point(X = 106241.426, Y = -10449.365, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324367	BL.01.07	Bouwlift BL.01.07	Point(X = 92074.355, Y = -3754.083, Z = 21870.000)	07 zevende verdieping hotel
11408899	H.07.14	hotelkamer H.07.14	Point(X = 92503.927, Y = 20464.815, Z = 21870.000)	07 zevende verdieping hotel
33324367	BL.01.07	Bouwlift BL.01.07	Point(X = 92074.355, Y = -3754.083, Z = 21870.000)	07 zevende verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324367	BL.01.07	Bouwlift BL.01.07	Point(X = 92074.355, Y = -3754.083, Z = 21870.000)	07 zevende verdieping hotel
11408899	H.07.14	hotelkamer H.07.14	Point(X = 92503.927, Y = 20464.815, Z = 21870.000)	07 zevende verdieping hotel
33324367	BL.01.07	Bouwlift BL.01.07	Point(X = 92074.355, Y = -3754.083, Z = 21870.000)	07 zevende verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324433	SK.03.02	Schaftkeet_Koffiepauze SK.03.02	Point(X = 25987.353, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324367	BL.01.07	Bouwlift BL.01.07	Point(X = 92074.355, Y = -3754.083, Z = 21870.000)	07 zevende verdieping hotel
11408880	H.07.15	hotelkamer H.07.15	Point(X = 96696.073, Y = 20464.815, Z = 21870.000)	07 zevende verdieping hotel
33324367	BL.01.07	Bouwlift BL.01.07	Point(X = 92074.355, Y = -3754.083, Z = 21870.000)	07 zevende verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324434	SK.03.03	Schaftkeet_Lunchpauze SK.03.03	Point(X = 20374.750, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324367	BL.01.07	Bouwlift BL.01.07	Point(X = 92074.355, Y = -3754.083, Z = 21870.000)	07 zevende verdieping hotel
11408880	H.07.15	hotelkamer H.07.15	Point(X = 96696.073, Y = 20464.815, Z = 21870.000)	07 zevende verdieping hotel
33324367	BL.01.07	Bouwlift BL.01.07	Point(X = 92074.355, Y = -3754.083, Z = 21870.000)	07 zevende verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324367	BL.01.07	Bouwlift BL.01.07	Point(X = 92074.355, Y = -3754.083, Z = 21870.000)	07 zevende verdieping hotel
11408880	H.07.15	hotelkamer H.07.15	Point(X = 96696.073, Y = 20464.815, Z = 21870.000)	07 zevende verdieping hotel
33324367	BL.01.07	Bouwlift BL.01.07	Point(X = 92074.355, Y = -3754.083, Z = 21870.000)	07 zevende verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324435	SK.03.04	Schaftkeet_Dagafsluiting SK.03.04	Point(X = 20374.750, Y = -45699.081, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil

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33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324427	SK.03.01	Schaftkeet_Dagstart SK.03.01	Point(X = 25964.382, Y = -45836.911, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324342	BP.02.01	Portier BP.02.01	Point(X = 101989.965, Y = -12978.732, Z = 0.000)	00 begane grond - Peil
33324478	TQ.01.02	Tourniquet TQ.01.02	Point(X = 106241.426, Y = -10449.365, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324369	BL.01.08	Bouwlift BL.01.08	Point(X = 92074.355, Y = -3728.232, Z = 24870.000)	08 achtste verdieping hotel
5796343	H.08.14	hotelkamer H.08.14	Point(X = 92503.927, Y = 20464.815, Z = 24870.000)	08 achtste verdieping hotel
33324369	BL.01.08	Bouwlift BL.01.08	Point(X = 92074.355, Y = -3728.232, Z = 24870.000)	08 achtste verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324369	BL.01.08	Bouwlift BL.01.08	Point(X = 92074.355, Y = -3728.232, Z = 24870.000)	08 achtste verdieping hotel
5796343	H.08.14	hotelkamer H.08.14	Point(X = 92503.927, Y = 20464.815, Z = 24870.000)	08 achtste verdieping hotel
33324369	BL.01.08	Bouwlift BL.01.08	Point(X = 92074.355, Y = -3728.232, Z = 24870.000)	08 achtste verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324433	SK.03.02	Schaftkeet_Koffiepauze SK.03.02	Point(X = 25987.353, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324369	BL.01.08	Bouwlift BL.01.08	Point(X = 92074.355, Y = -3728.232, Z = 24870.000)	08 achtste verdieping hotel
5795835	H.08.15	hotelkamer H.08.15	Point(X = 96696.073, Y = 20464.815, Z = 24870.000)	08 achtste verdieping hotel
33324369	BL.01.08	Bouwlift BL.01.08	Point(X = 92074.355, Y = -3728.232, Z = 24870.000)	08 achtste verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324434	SK.03.03	Schaftkeet_Lunchpauze SK.03.03	Point(X = 20374.750, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324369	BL.01.08	Bouwlift BL.01.08	Point(X = 92074.355, Y = -3728.232, Z = 24870.000)	08 achtste verdieping hotel
5795835	H.08.15	hotelkamer H.08.15	Point(X = 96696.073, Y = 20464.815, Z = 24870.000)	08 achtste verdieping hotel
33324369	BL.01.08	Bouwlift BL.01.08	Point(X = 92074.355, Y = -3728.232, Z = 24870.000)	08 achtste verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324369	BL.01.08	Bouwlift BL.01.08	Point(X = 92074.355, Y = -3728.232, Z = 24870.000)	08 achtste verdieping hotel
5795835	H.08.15	hotelkamer H.08.15	Point(X = 96696.073, Y = 20464.815, Z = 24870.000)	08 achtste verdieping hotel
33324369	BL.01.08	Bouwlift BL.01.08	Point(X = 92074.355, Y = -3728.232, Z = 24870.000)	08 achtste verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324435	SK.03.04	Schaftkeet_Dagafsluiting SK.03.04	Point(X = 20374.750, Y = -45699.081, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil

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33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324427	SK.03.01	Schaftkeet_Dagstart SK.03.01	Point(X = 25964.382, Y = -45836.911, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324342	BP.02.01	Portier BP.02.01	Point(X = 101989.965, Y = -12978.732, Z = 0.000)	00 begane grond - Peil
33324478	TQ.01.02	Tourniquet TQ.01.02	Point(X = 106241.426, Y = -10449.365, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324371	BL.01.09	Bouwlift BL.01.09	Point(X = 92126.057, Y = -3779.934, Z = 27870.000)	08 achtste verdieping
8943378	H.09.14	hotelkamer H.09.14	Point(X = 92754.321, Y = 20551.576, Z = 27870.000)	08 achtste verdieping
33324371	BL.01.09	Bouwlift BL.01.09	Point(X = 92126.057, Y = -3779.934, Z = 27870.000)	08 achtste verdieping
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324371	BL.01.09	Bouwlift BL.01.09	Point(X = 92126.057, Y = -3779.934, Z = 27870.000)	08 achtste verdieping
8943378	H.09.14	hotelkamer H.09.14	Point(X = 92754.321, Y = 20551.576, Z = 27870.000)	08 achtste verdieping
33324371	BL.01.09	Bouwlift BL.01.09	Point(X = 92126.057, Y = -3779.934, Z = 27870.000)	08 achtste verdieping
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324433	SK.03.02	Schaftkeet_Koffiepauze SK.03.02	Point(X = 25987.353, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324371	BL.01.09	Bouwlift BL.01.09	Point(X = 92126.057, Y = -3779.934, Z = 27870.000)	08 achtste verdieping
8943379	H.09.15	hotelkamer H.09.15	Point(X = 96495.965, Y = 20551.576, Z = 27870.000)	08 achtste verdieping
33324371	BL.01.09	Bouwlift BL.01.09	Point(X = 92126.057, Y = -3779.934, Z = 27870.000)	08 achtste verdieping
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324434	SK.03.03	Schaftkeet_Lunchpauze SK.03.03	Point(X = 20374.750, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324371	BL.01.09	Bouwlift BL.01.09	Point(X = 92126.057, Y = -3779.934, Z = 27870.000)	08 achtste verdieping
8943379	H.09.15	hotelkamer H.09.15	Point(X = 96495.965, Y = 20551.576, Z = 27870.000)	08 achtste verdieping
33324371	BL.01.09	Bouwlift BL.01.09	Point(X = 92126.057, Y = -3779.934, Z = 27870.000)	08 achtste verdieping
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324371	BL.01.09	Bouwlift BL.01.09	Point(X = 92126.057, Y = -3779.934, Z = 27870.000)	08 achtste verdieping
8943379	H.09.15	hotelkamer H.09.15	Point(X = 96495.965, Y = 20551.576, Z = 27870.000)	08 achtste verdieping
33324371	BL.01.09	Bouwlift BL.01.09	Point(X = 92126.057, Y = -3779.934, Z = 27870.000)	08 achtste verdieping
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324435	SK.03.04	Schaftkeet_Dagafsluiting SK.03.04	Point(X = 20374.750, Y = -45699.081, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil

Level 10

33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324427	SK.03.01	Schaftkeet_Dagstart SK.03.01	Point(X = 25964.382, Y = -45836.911, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324342	BP.02.01	Portier BP.02.01	Point(X = 101989.965, Y = -12978.732, Z = 0.000)	00 begane grond - Peil
33324478	TQ.01.02	Tourniquet TQ.01.02	Point(X = 106241.426, Y = -10449.365, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324373	BL.01.10	Bouwlift BL.01.10	Point(X = 92100.206, Y = -3767.009, Z = 30870.000)	10 tiende verdieping hotel
10854043	H.10.14	hotelkamer H.10.14	Point(X = 92754.321, Y = 20551.576, Z = 30870.000)	10 tiende verdieping hotel
33324373	BL.01.10	Bouwlift BL.01.10	Point(X = 92100.206, Y = -3767.009, Z = 30870.000)	10 tiende verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324373	BL.01.10	Bouwlift BL.01.10	Point(X = 92100.206, Y = -3767.009, Z = 30870.000)	10 tiende verdieping hotel
10854043	H.10.14	hotelkamer H.10.14	Point(X = 92754.321, Y = 20551.576, Z = 30870.000)	10 tiende verdieping hotel
33324373	BL.01.10	Bouwlift BL.01.10	Point(X = 92100.206, Y = -3767.009, Z = 30870.000)	10 tiende verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324433	SK.03.02	Schaftkeet_Koffiepauze SK.03.02	Point(X = 25987.353, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324373	BL.01.10	Bouwlift BL.01.10	Point(X = 92100.206, Y = -3767.009, Z = 30870.000)	10 tiende verdieping hotel
10854044	H.10.15	hotelkamer H.10.15	Point(X = 96495.965, Y = 20551.576, Z = 30870.000)	10 tiende verdieping hotel
33324373	BL.01.10	Bouwlift BL.01.10	Point(X = 92100.206, Y = -3767.009, Z = 30870.000)	10 tiende verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324434	SK.03.03	Schaftkeet_Lunchpauze SK.03.03	Point(X = 20374.750, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324373	BL.01.10	Bouwlift BL.01.10	Point(X = 92100.206, Y = -3767.009, Z = 30870.000)	10 tiende verdieping hotel
10854044	H.10.15	hotelkamer H.10.15	Point(X = 96495.965, Y = 20551.576, Z = 30870.000)	10 tiende verdieping hotel
33324373	BL.01.10	Bouwlift BL.01.10	Point(X = 92100.206, Y = -3767.009, Z = 30870.000)	10 tiende verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324373	BL.01.10	Bouwlift BL.01.10	Point(X = 92100.206, Y = -3767.009, Z = 30870.000)	10 tiende verdieping hotel
10854044	H.10.15	hotelkamer H.10.15	Point(X = 96495.965, Y = 20551.576, Z = 30870.000)	10 tiende verdieping hotel
33324373	BL.01.10	Bouwlift BL.01.10	Point(X = 92100.206, Y = -3767.009, Z = 30870.000)	10 tiende verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324435	SK.03.04	Schaftkeet_Dagafsluiting SK.03.04	Point(X = 20374.750, Y = -45699.081, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil

Appendix 9: Typical workday - Rooms list of all levels used in Simulation 2

Level 2

33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324427	SK.03.01	Schaftkeet_Dagstart SK.03.01	Point(X = 25964.382, Y = -45836.911, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324342	BP.02.01	Portier BP.02.01	Point(X = 101989.965, Y = -12978.732, Z = 0.000)	00 begane grond - Peil
33324478	TQ.01.02	Tourniquet TQ.01.02	Point(X = 106241.426, Y = -10449.365, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324358	BL.01.02	Bouwlift BL.01.02	Point(X = 92158.144, Y = -3684.171, Z = 6870.000)	02 tweede verdieping hotel
255806	H.02.08	hotelkamer H.02.08	Point(X = 92503.927, Y = 20464.815, Z = 6870.000)	02 tweede verdieping hotel
33324357	TT.01.02	Trappentoren TT.01.02	Point(X = 93360.216, Y = -7303.312, Z = 6870.000)	02 tweede verdieping hotel
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324357	TT.01.02	Trappentoren TT.01.02	Point(X = 93360.216, Y = -7303.312, Z = 6870.000)	02 tweede verdieping hotel
255806	H.02.08	hotelkamer H.02.08	Point(X = 92503.927, Y = 20464.815, Z = 6870.000)	02 tweede verdieping hotel
33324357	TT.01.02	Trappentoren TT.01.02	Point(X = 93360.216, Y = -7303.312, Z = 6870.000)	02 tweede verdieping hotel
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324433	SK.03.02	Schaftkeet_Koffiepauze SK.03.02	Point(X = 25987.353, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324357	TT.01.02	Trappentoren TT.01.02	Point(X = 93360.216, Y = -7303.312, Z = 6870.000)	02 tweede verdieping hotel
223079	H.02.09	hotelkamer H.02.09	Point(X = 96696.073, Y = 20464.815, Z = 6870.000)	02 tweede verdieping hotel
33324357	TT.01.02	Trappentoren TT.01.02	Point(X = 93360.216, Y = -7303.312, Z = 6870.000)	02 tweede verdieping hotel
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324434	SK.03.03	Schaftkeet_Lunchpauze SK.03.03	Point(X = 20374.750, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324357	TT.01.02	Trappentoren TT.01.02	Point(X = 93360.216, Y = -7303.312, Z = 6870.000)	02 tweede verdieping hotel
223079	H.02.09	hotelkamer H.02.09	Point(X = 96696.073, Y = 20464.815, Z = 6870.000)	02 tweede verdieping hotel
33324357	TT.01.02	Trappentoren TT.01.02	Point(X = 93360.216, Y = -7303.312, Z = 6870.000)	02 tweede verdieping hotel
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324352	TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324357	TT.01.02	Trappentoren TT.01.02	Point(X = 93360.216, Y = -7303.312, Z = 6870.000)	02 tweede verdieping hotel
223079	H.02.09	hotelkamer H.02.09	Point(X = 96696.073, Y = 20464.815, Z = 6870.000)	02 tweede verdieping hotel
33324358	BL.01.02	Bouwlift BL.01.02	Point(X = 92158.144, Y = -3684.171, Z = 6870.000)	02 tweede verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324435	SK.03.04	Schaftkeet_Dagafsluiting SK.03.04	Point(X = 20374.750, Y = -45699.081, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil

Level 3

33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324427 SK.03.01	Schaftkeet_Dagstart SK.03.01	Point(X = 25964.382, Y = -45836.911, Z = 9870.000)	03 derde verdieping
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324342 BP.02.01	Portier BP.02.01	Point(X = 101989.965, Y = -12978.732, Z = 0.000)	00 begane grond - Peil
33324478 TQ.01.02	Tourniquet TQ.01.02	Point(X = 106241.426, Y = -10449.365, Z = 0.000)	00 begane grond - Peil
33324343 BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324353 BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324361 BL.01.03	Bouwlift BL.01.03	Point(X = 92112.329, Y = -3700.733, Z = 9870.000)	03 derde verdieping
1240640 H.03.13	hotelkamer H.03.13	Point(X = 92503.927, Y = 20464.815, Z = 9870.000)	03 derde verdieping
33324359 TT.01.03	Trappentoren TT.01.03	Point(X = 93371.235, Y = -7337.560, Z = 9870.000)	03 derde verdieping
33324352 TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324503 WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324352 TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324359 TT.01.03	Trappentoren TT.01.03	Point(X = 93371.235, Y = -7337.560, Z = 9870.000)	03 derde verdieping
1240640 H.03.13	hotelkamer H.03.13	Point(X = 92503.927, Y = 20464.815, Z = 9870.000)	03 derde verdieping
33324359 TT.01.03	Trappentoren TT.01.03	Point(X = 93371.235, Y = -7337.560, Z = 9870.000)	03 derde verdieping
33324352 TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324465 TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324433 SK.03.02	Schaftkeet_Koffiepauze SK.03.02	Point(X = 25987.353, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465 TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324352 TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324359 TT.01.03	Trappentoren TT.01.03	Point(X = 93371.235, Y = -7337.560, Z = 9870.000)	03 derde verdieping
1239881 H.03.14	hotelkamer H.03.14	Point(X = 96696.073, Y = 20464.815, Z = 9870.000)	03 derde verdieping
33324359 TT.01.03	Trappentoren TT.01.03	Point(X = 93371.235, Y = -7337.560, Z = 9870.000)	03 derde verdieping
33324352 TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324465 TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324434 SK.03.03	Schaftkeet_Lunchpauze SK.03.03	Point(X = 20374.750, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465 TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324352 TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324359 TT.01.03	Trappentoren TT.01.03	Point(X = 93371.235, Y = -7337.560, Z = 9870.000)	03 derde verdieping
1239881 H.03.14	hotelkamer H.03.14	Point(X = 96696.073, Y = 20464.815, Z = 9870.000)	03 derde verdieping
33324359 TT.01.03	Trappentoren TT.01.03	Point(X = 93371.235, Y = -7337.560, Z = 9870.000)	03 derde verdieping
33324352 TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324503 WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324352 TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324359 TT.01.03	Trappentoren TT.01.03	Point(X = 93371.235, Y = -7337.560, Z = 9870.000)	03 derde verdieping
1239881 H.03.14	hotelkamer H.03.14	Point(X = 96696.073, Y = 20464.815, Z = 9870.000)	03 derde verdieping
33324361 BL.01.03	Bouwlift BL.01.03	Point(X = 92112.329, Y = -3700.733, Z = 9870.000)	03 derde verdieping
33324353 BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324343 BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324465 TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324435 SK.03.04	Schaftkeet_Dagafsluiting SK.03.04	Point(X = 20374.750, Y = -45699.081, Z = 9870.000)	03 derde verdieping
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil

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33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324427 SK.03.01	Schaftkeet_Dagstart SK.03.01	Point(X = 25964.382, Y = -45836.911, Z = 9870.000)	03 derde verdieping
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324342 BP.02.01	Portier BP.02.01	Point(X = 101989.965, Y = -12978.732, Z = 0.000)	00 begane grond - Peil
33324478 TQ.01.02	Tourniquet TQ.01.02	Point(X = 106241.426, Y = -10449.365, Z = 0.000)	00 begane grond - Peil
33324343 BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324353 BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324362 BL.01.04	Bouwlift BL.01.04	Point(X = 92037.276, Y = -3781.774, Z = 12870.000)	04 vierde verdieping hotel
11671860 H.04.14	hotelkamer H.04.14	Point(X = 92503.927, Y = 20464.815, Z = 12870.000)	04 vierde verdieping hotel
33324360 TT.01.04	Trappentoren TT.01.04	Point(X = 93395.359, Y = -7385.243, Z = 12870.000)	04 vierde verdieping hotel
33324352 TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324503 WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324352 TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324360 TT.01.04	Trappentoren TT.01.04	Point(X = 93395.359, Y = -7385.243, Z = 12870.000)	04 vierde verdieping hotel
11671860 H.04.14	hotelkamer H.04.14	Point(X = 92503.927, Y = 20464.815, Z = 12870.000)	04 vierde verdieping hotel
33324360 TT.01.04	Trappentoren TT.01.04	Point(X = 93395.359, Y = -7385.243, Z = 12870.000)	04 vierde verdieping hotel
33324352 TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324465 TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324433 SK.03.02	Schaftkeet_Koffiepauze SK.03.02	Point(X = 25987.353, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465 TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324352 TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324360 TT.01.04	Trappentoren TT.01.04	Point(X = 93395.359, Y = -7385.243, Z = 12870.000)	04 vierde verdieping hotel
11671841 H.04.15	hotelkamer H.04.15	Point(X = 96696.073, Y = 20464.815, Z = 12870.000)	04 vierde verdieping hotel
33324360 TT.01.04	Trappentoren TT.01.04	Point(X = 93395.359, Y = -7385.243, Z = 12870.000)	04 vierde verdieping hotel
33324352 TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324465 TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324434 SK.03.03	Schaftkeet_Lunchpauze SK.03.03	Point(X = 20374.750, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465 TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324352 TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324360 TT.01.04	Trappentoren TT.01.04	Point(X = 93395.359, Y = -7385.243, Z = 12870.000)	04 vierde verdieping hotel
11671841 H.04.15	hotelkamer H.04.15	Point(X = 96696.073, Y = 20464.815, Z = 12870.000)	04 vierde verdieping hotel
33324360 TT.01.04	Trappentoren TT.01.04	Point(X = 93395.359, Y = -7385.243, Z = 12870.000)	04 vierde verdieping hotel
33324352 TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324503 WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324352 TT.01.00	Trappentoren TT.01.00	Point(X = 93385.181, Y = -7241.567, Z = 0.000)	00 begane grond - Peil
33324360 TT.01.04	Trappentoren TT.01.04	Point(X = 93395.359, Y = -7385.243, Z = 12870.000)	04 vierde verdieping hotel
11671841 H.04.15	hotelkamer H.04.15	Point(X = 96696.073, Y = 20464.815, Z = 12870.000)	04 vierde verdieping hotel
33324362 BL.01.04	Bouwlift BL.01.04	Point(X = 92037.276, Y = -3781.774, Z = 12870.000)	04 vierde verdieping hotel
33324353 BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324343 BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324465 TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324435 SK.03.04	Schaftkeet_Dagafsluiting SK.03.04	Point(X = 20374.750, Y = -45699.081, Z = 9870.000)	03 derde verdieping
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil

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33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324427	SK.03.01	Schaftkeet_Dagstart SK.03.01	Point(X = 25964.382, Y = -45836.911, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324342	BP.02.01	Portier BP.02.01	Point(X = 101989.965, Y = -12978.732, Z = 0.000)	00 begane grond - Peil
33324478	TQ.01.02	Tourniquet TQ.01.02	Point(X = 106241.426, Y = -10449.365, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324364	BL.01.05	Bouwlift BL.01.05	Point(X = 92151.908, Y = -3767.009, Z = 15870.000)	05 vijfde verdieping hotel
5788569	H.05.14	hotelkamer H.05.14	Point(X = 92503.927, Y = 20464.815, Z = 15870.000)	05 vijfde verdieping hotel
33324364	BL.01.05	Bouwlift BL.01.05	Point(X = 92151.908, Y = -3767.009, Z = 15870.000)	05 vijfde verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324364	BL.01.05	Bouwlift BL.01.05	Point(X = 92151.908, Y = -3767.009, Z = 15870.000)	05 vijfde verdieping hotel
5788569	H.05.14	hotelkamer H.05.14	Point(X = 92503.927, Y = 20464.815, Z = 15870.000)	05 vijfde verdieping hotel
33324364	BL.01.05	Bouwlift BL.01.05	Point(X = 92151.908, Y = -3767.009, Z = 15870.000)	05 vijfde verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324433	SK.03.02	Schaftkeet_Koffiepauze SK.03.02	Point(X = 25987.353, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324364	BL.01.05	Bouwlift BL.01.05	Point(X = 92151.908, Y = -3767.009, Z = 15870.000)	05 vijfde verdieping hotel
5788061	H.05.15	hotelkamer H.05.15	Point(X = 96696.073, Y = 20464.815, Z = 15870.000)	05 vijfde verdieping hotel
33324364	BL.01.05	Bouwlift BL.01.05	Point(X = 92151.908, Y = -3767.009, Z = 15870.000)	05 vijfde verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324434	SK.03.03	Schaftkeet_Lunchpauze SK.03.03	Point(X = 20374.750, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324364	BL.01.05	Bouwlift BL.01.05	Point(X = 92151.908, Y = -3767.009, Z = 15870.000)	05 vijfde verdieping hotel
5788061	H.05.15	hotelkamer H.05.15	Point(X = 96696.073, Y = 20464.815, Z = 15870.000)	05 vijfde verdieping hotel
33324364	BL.01.05	Bouwlift BL.01.05	Point(X = 92151.908, Y = -3767.009, Z = 15870.000)	05 vijfde verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324364	BL.01.05	Bouwlift BL.01.05	Point(X = 92151.908, Y = -3767.009, Z = 15870.000)	05 vijfde verdieping hotel
5788061	H.05.15	hotelkamer H.05.15	Point(X = 96696.073, Y = 20464.815, Z = 15870.000)	05 vijfde verdieping hotel
33324364	BL.01.05	Bouwlift BL.01.05	Point(X = 92151.908, Y = -3767.009, Z = 15870.000)	05 vijfde verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324435	SK.03.04	Schaftkeet_Dagafsluiting SK.03.04	Point(X = 20374.750, Y = -45699.081, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil

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33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324427 SK.03.01	Schaftkeet_Dagstart SK.03.01	Point(X = 25964.382, Y = -45836.911, Z = 9870.000)	03 derde verdieping
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324342 BP.02.01	Portier BP.02.01	Point(X = 101989.965, Y = -12978.732, Z = 0.000)	00 begane grond - Peil
33324478 TQ.01.02	Tourniquet TQ.01.02	Point(X = 106241.426, Y = -10449.365, Z = 0.000)	00 begane grond - Peil
33324343 BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324353 BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324366 BL.01.06	Bouwlift BL.01.06	Point(X = 92177.759, Y = -3728.232, Z = 18870.000)	06 zesde verdieping hotel
11426125 H.06.14	hotelkamer H.06.14	Point(X = 92503.927, Y = 20464.815, Z = 18870.000)	06 zesde verdieping hotel
33324366 BL.01.06	Bouwlift BL.01.06	Point(X = 92177.759, Y = -3728.232, Z = 18870.000)	06 zesde verdieping hotel
33324353 BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324503 WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324353 BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324366 BL.01.06	Bouwlift BL.01.06	Point(X = 92177.759, Y = -3728.232, Z = 18870.000)	06 zesde verdieping hotel
11426125 H.06.14	hotelkamer H.06.14	Point(X = 92503.927, Y = 20464.815, Z = 18870.000)	06 zesde verdieping hotel
33324366 BL.01.06	Bouwlift BL.01.06	Point(X = 92177.759, Y = -3728.232, Z = 18870.000)	06 zesde verdieping hotel
33324353 BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324465 TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324433 SK.03.02	Schaftkeet_Koffiepauze SK.03.02	Point(X = 25987.353, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465 TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324353 BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324366 BL.01.06	Bouwlift BL.01.06	Point(X = 92177.759, Y = -3728.232, Z = 18870.000)	06 zesde verdieping hotel
11426106 H.06.15	hotelkamer H.06.15	Point(X = 96696.073, Y = 20464.815, Z = 18870.000)	06 zesde verdieping hotel
33324366 BL.01.06	Bouwlift BL.01.06	Point(X = 92177.759, Y = -3728.232, Z = 18870.000)	06 zesde verdieping hotel
33324353 BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324465 TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324434 SK.03.03	Schaftkeet_Lunchpauze SK.03.03	Point(X = 20374.750, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465 TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324353 BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324366 BL.01.06	Bouwlift BL.01.06	Point(X = 92177.759, Y = -3728.232, Z = 18870.000)	06 zesde verdieping hotel
11426106 H.06.15	hotelkamer H.06.15	Point(X = 96696.073, Y = 20464.815, Z = 18870.000)	06 zesde verdieping hotel
33324366 BL.01.06	Bouwlift BL.01.06	Point(X = 92177.759, Y = -3728.232, Z = 18870.000)	06 zesde verdieping hotel
33324353 BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324503 WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324353 BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324366 BL.01.06	Bouwlift BL.01.06	Point(X = 92177.759, Y = -3728.232, Z = 18870.000)	06 zesde verdieping hotel
11426106 H.06.15	hotelkamer H.06.15	Point(X = 96696.073, Y = 20464.815, Z = 18870.000)	06 zesde verdieping hotel
33324366 BL.01.06	Bouwlift BL.01.06	Point(X = 92177.759, Y = -3728.232, Z = 18870.000)	06 zesde verdieping hotel
33324353 BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324343 BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324465 TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324435 SK.03.04	Schaftkeet_Dagafsluiting SK.03.04	Point(X = 20374.750, Y = -45699.081, Z = 9870.000)	03 derde verdieping
33324410 PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409 PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil

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33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324427	SK.03.01	Schaftkeet_Dagstart SK.03.01	Point(X = 25964.382, Y = -45836.911, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324342	BP.02.01	Portier BP.02.01	Point(X = 101989.965, Y = -12978.732, Z = 0.000)	00 begane grond - Peil
33324478	TQ.01.02	Tourniquet TQ.01.02	Point(X = 106241.426, Y = -10449.365, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324367	BL.01.07	Bouwlift BL.01.07	Point(X = 92074.355, Y = -3754.083, Z = 21870.000)	07 zevende verdieping hotel
11408899	H.07.14	hotelkamer H.07.14	Point(X = 92503.927, Y = 20464.815, Z = 21870.000)	07 zevende verdieping hotel
33324367	BL.01.07	Bouwlift BL.01.07	Point(X = 92074.355, Y = -3754.083, Z = 21870.000)	07 zevende verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324367	BL.01.07	Bouwlift BL.01.07	Point(X = 92074.355, Y = -3754.083, Z = 21870.000)	07 zevende verdieping hotel
11408899	H.07.14	hotelkamer H.07.14	Point(X = 92503.927, Y = 20464.815, Z = 21870.000)	07 zevende verdieping hotel
33324367	BL.01.07	Bouwlift BL.01.07	Point(X = 92074.355, Y = -3754.083, Z = 21870.000)	07 zevende verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324433	SK.03.02	Schaftkeet_Koffiepauze SK.03.02	Point(X = 25987.353, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324367	BL.01.07	Bouwlift BL.01.07	Point(X = 92074.355, Y = -3754.083, Z = 21870.000)	07 zevende verdieping hotel
11408880	H.07.15	hotelkamer H.07.15	Point(X = 96696.073, Y = 20464.815, Z = 21870.000)	07 zevende verdieping hotel
33324367	BL.01.07	Bouwlift BL.01.07	Point(X = 92074.355, Y = -3754.083, Z = 21870.000)	07 zevende verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324434	SK.03.03	Schaftkeet_Lunchpauze SK.03.03	Point(X = 20374.750, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324367	BL.01.07	Bouwlift BL.01.07	Point(X = 92074.355, Y = -3754.083, Z = 21870.000)	07 zevende verdieping hotel
11408880	H.07.15	hotelkamer H.07.15	Point(X = 96696.073, Y = 20464.815, Z = 21870.000)	07 zevende verdieping hotel
33324367	BL.01.07	Bouwlift BL.01.07	Point(X = 92074.355, Y = -3754.083, Z = 21870.000)	07 zevende verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324367	BL.01.07	Bouwlift BL.01.07	Point(X = 92074.355, Y = -3754.083, Z = 21870.000)	07 zevende verdieping hotel
11408880	H.07.15	hotelkamer H.07.15	Point(X = 96696.073, Y = 20464.815, Z = 21870.000)	07 zevende verdieping hotel
33324367	BL.01.07	Bouwlift BL.01.07	Point(X = 92074.355, Y = -3754.083, Z = 21870.000)	07 zevende verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324435	SK.03.04	Schaftkeet_Dagafsluiting SK.03.04	Point(X = 20374.750, Y = -45699.081, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil

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33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324427	SK.03.01	Schaftkeet_Dagstart SK.03.01	Point(X = 25964.382, Y = -45836.911, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324342	BP.02.01	Portier BP.02.01	Point(X = 101989.965, Y = -12978.732, Z = 0.000)	00 begane grond - Peil
33324478	TQ.01.02	Tourniquet TQ.01.02	Point(X = 106241.426, Y = -10449.365, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324369	BL.01.08	Bouwlift BL.01.08	Point(X = 92074.355, Y = -3728.232, Z = 24870.000)	08 achtste verdieping hotel
5796343	H.08.14	hotelkamer H.08.14	Point(X = 92503.927, Y = 20464.815, Z = 24870.000)	08 achtste verdieping hotel
33324369	BL.01.08	Bouwlift BL.01.08	Point(X = 92074.355, Y = -3728.232, Z = 24870.000)	08 achtste verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324369	BL.01.08	Bouwlift BL.01.08	Point(X = 92074.355, Y = -3728.232, Z = 24870.000)	08 achtste verdieping hotel
5796343	H.08.14	hotelkamer H.08.14	Point(X = 92503.927, Y = 20464.815, Z = 24870.000)	08 achtste verdieping hotel
33324369	BL.01.08	Bouwlift BL.01.08	Point(X = 92074.355, Y = -3728.232, Z = 24870.000)	08 achtste verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324433	SK.03.02	Schaftkeet_Koffiepauze SK.03.02	Point(X = 25987.353, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324369	BL.01.08	Bouwlift BL.01.08	Point(X = 92074.355, Y = -3728.232, Z = 24870.000)	08 achtste verdieping hotel
5795835	H.08.15	hotelkamer H.08.15	Point(X = 96696.073, Y = 20464.815, Z = 24870.000)	08 achtste verdieping hotel
33324369	BL.01.08	Bouwlift BL.01.08	Point(X = 92074.355, Y = -3728.232, Z = 24870.000)	08 achtste verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324434	SK.03.03	Schaftkeet_Lunchpauze SK.03.03	Point(X = 20374.750, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324369	BL.01.08	Bouwlift BL.01.08	Point(X = 92074.355, Y = -3728.232, Z = 24870.000)	08 achtste verdieping hotel
5795835	H.08.15	hotelkamer H.08.15	Point(X = 96696.073, Y = 20464.815, Z = 24870.000)	08 achtste verdieping hotel
33324369	BL.01.08	Bouwlift BL.01.08	Point(X = 92074.355, Y = -3728.232, Z = 24870.000)	08 achtste verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324369	BL.01.08	Bouwlift BL.01.08	Point(X = 92074.355, Y = -3728.232, Z = 24870.000)	08 achtste verdieping hotel
5795835	H.08.15	hotelkamer H.08.15	Point(X = 96696.073, Y = 20464.815, Z = 24870.000)	08 achtste verdieping hotel
33324369	BL.01.08	Bouwlift BL.01.08	Point(X = 92074.355, Y = -3728.232, Z = 24870.000)	08 achtste verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324435	SK.03.04	Schaftkeet_Dagafsluiting SK.03.04	Point(X = 20374.750, Y = -45699.081, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil

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33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324427	SK.03.01	Schaftkeet_Dagstart SK.03.01	Point(X = 25964.382, Y = -45836.911, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324342	BP.02.01	Portier BP.02.01	Point(X = 101989.965, Y = -12978.732, Z = 0.000)	00 begane grond - Peil
33324478	TQ.01.02	Tourniquet TQ.01.02	Point(X = 106241.426, Y = -10449.365, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324371	BL.01.09	Bouwlift BL.01.09	Point(X = 92126.057, Y = -3779.934, Z = 27870.000)	08 achtste verdieping
8943378	H.09.14	hotelkamer H.09.14	Point(X = 92754.321, Y = 20551.576, Z = 27870.000)	08 achtste verdieping
33324371	BL.01.09	Bouwlift BL.01.09	Point(X = 92126.057, Y = -3779.934, Z = 27870.000)	08 achtste verdieping
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324371	BL.01.09	Bouwlift BL.01.09	Point(X = 92126.057, Y = -3779.934, Z = 27870.000)	08 achtste verdieping
8943378	H.09.14	hotelkamer H.09.14	Point(X = 92754.321, Y = 20551.576, Z = 27870.000)	08 achtste verdieping
33324371	BL.01.09	Bouwlift BL.01.09	Point(X = 92126.057, Y = -3779.934, Z = 27870.000)	08 achtste verdieping
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324433	SK.03.02	Schaftkeet_Koffiepauze SK.03.02	Point(X = 25987.353, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324371	BL.01.09	Bouwlift BL.01.09	Point(X = 92126.057, Y = -3779.934, Z = 27870.000)	08 achtste verdieping
8943379	H.09.15	hotelkamer H.09.15	Point(X = 96495.965, Y = 20551.576, Z = 27870.000)	08 achtste verdieping
33324371	BL.01.09	Bouwlift BL.01.09	Point(X = 92126.057, Y = -3779.934, Z = 27870.000)	08 achtste verdieping
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324434	SK.03.03	Schaftkeet_Lunchpauze SK.03.03	Point(X = 20374.750, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324371	BL.01.09	Bouwlift BL.01.09	Point(X = 92126.057, Y = -3779.934, Z = 27870.000)	08 achtste verdieping
8943379	H.09.15	hotelkamer H.09.15	Point(X = 96495.965, Y = 20551.576, Z = 27870.000)	08 achtste verdieping
33324371	BL.01.09	Bouwlift BL.01.09	Point(X = 92126.057, Y = -3779.934, Z = 27870.000)	08 achtste verdieping
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324371	BL.01.09	Bouwlift BL.01.09	Point(X = 92126.057, Y = -3779.934, Z = 27870.000)	08 achtste verdieping
8943379	H.09.15	hotelkamer H.09.15	Point(X = 96495.965, Y = 20551.576, Z = 27870.000)	08 achtste verdieping
33324371	BL.01.09	Bouwlift BL.01.09	Point(X = 92126.057, Y = -3779.934, Z = 27870.000)	08 achtste verdieping
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324435	SK.03.04	Schaftkeet_Dagafsluiting SK.03.04	Point(X = 20374.750, Y = -45699.081, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil

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33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324427	SK.03.01	Schaftkeet_Dagstart SK.03.01	Point(X = 25964.382, Y = -45836.911, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324342	BP.02.01	Portier BP.02.01	Point(X = 101989.965, Y = -12978.732, Z = 0.000)	00 begane grond - Peil
33324478	TQ.01.02	Tourniquet TQ.01.02	Point(X = 106241.426, Y = -10449.365, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324373	BL.01.10	Bouwlift BL.01.10	Point(X = 92100.206, Y = -3767.009, Z = 30870.000)	10 tiende verdieping hotel
10854043	H.10.14	hotelkamer H.10.14	Point(X = 92754.321, Y = 20551.576, Z = 30870.000)	10 tiende verdieping hotel
33324373	BL.01.10	Bouwlift BL.01.10	Point(X = 92100.206, Y = -3767.009, Z = 30870.000)	10 tiende verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324373	BL.01.10	Bouwlift BL.01.10	Point(X = 92100.206, Y = -3767.009, Z = 30870.000)	10 tiende verdieping hotel
10854043	H.10.14	hotelkamer H.10.14	Point(X = 92754.321, Y = 20551.576, Z = 30870.000)	10 tiende verdieping hotel
33324373	BL.01.10	Bouwlift BL.01.10	Point(X = 92100.206, Y = -3767.009, Z = 30870.000)	10 tiende verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324433	SK.03.02	Schaftkeet_Koffiepauze SK.03.02	Point(X = 25987.353, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324373	BL.01.10	Bouwlift BL.01.10	Point(X = 92100.206, Y = -3767.009, Z = 30870.000)	10 tiende verdieping hotel
10854044	H.10.15	hotelkamer H.10.15	Point(X = 96495.965, Y = 20551.576, Z = 30870.000)	10 tiende verdieping hotel
33324373	BL.01.10	Bouwlift BL.01.10	Point(X = 92100.206, Y = -3767.009, Z = 30870.000)	10 tiende verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324434	SK.03.03	Schaftkeet_Lunchpauze SK.03.03	Point(X = 20374.750, Y = -43187.444, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324373	BL.01.10	Bouwlift BL.01.10	Point(X = 92100.206, Y = -3767.009, Z = 30870.000)	10 tiende verdieping hotel
10854044	H.10.15	hotelkamer H.10.15	Point(X = 96495.965, Y = 20551.576, Z = 30870.000)	10 tiende verdieping hotel
33324373	BL.01.10	Bouwlift BL.01.10	Point(X = 92100.206, Y = -3767.009, Z = 30870.000)	10 tiende verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324503	WC.00.01	Dixie 1 WC.00.01	Point(X = 65704.135, Y = -8327.430, Z = 0.000)	00 begane grond - Peil
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324373	BL.01.10	Bouwlift BL.01.10	Point(X = 92100.206, Y = -3767.009, Z = 30870.000)	10 tiende verdieping hotel
10854044	H.10.15	hotelkamer H.10.15	Point(X = 96495.965, Y = 20551.576, Z = 30870.000)	10 tiende verdieping hotel
33324373	BL.01.10	Bouwlift BL.01.10	Point(X = 92100.206, Y = -3767.009, Z = 30870.000)	10 tiende verdieping hotel
33324353	BL.01.00	Bouwlift BL.01.00	Point(X = 92108.450, Y = -3682.727, Z = 0.000)	00 begane grond - Peil
33324343	BP.01.02	Opslag Bouwplaats BP.01.02	Point(X = 68592.920, Y = -20654.721, Z = 0.000)	00 begane grond - Peil
33324465	TQ.01.01	Tourniquet TQ.01.01	Point(X = 45326.555, Y = -19466.734, Z = 0.000)	00 begane grond - Peil
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324435	SK.03.04	Schaftkeet_Dagafsluiting SK.03.04	Point(X = 20374.750, Y = -45699.081, Z = 9870.000)	03 derde verdieping
33324410	PL.03.01	Bouwlift PL.03.01	Point(X = 35257.023, Y = -46117.399, Z = 9870.000)	03 derde verdieping
33324409	PL.00.01	Bouwlift PL.00.01	Point(X = 35321.702, Y = -46070.289, Z = 0.000)	00 begane grond - Peil

Appendix 10: Calculations of working time in hotel room type I

Walltypes	amount of sheeted sides	single or double sheetes	total amount of sheets	Sheet width	c.t.c distance studs	Insulation
W111 75/100	2 sided	single sheet	2 sheets	1200	400	No
W112 100/150	2 sided	double sheet	4 sheets	1200	400	Yes
W625 50/63 H2	1 sided	single sheet	1 sheet	1200	400	No
W629 75/105 DF/DB	1 sided	double sheet	2 sheets	1200	400	No

Kamer type I

Walls Measurements					Core activties										
	Length [mm]	Length [m]	Area [m2]	Remarks	Norm Studs	Time Studs	Insulation [yes=1; no=0]	Norm insulation	Time Insulation	Norm Sheeting	Number of sides	Time Sheeting	Norm Finishing [Finishingclass-B)	Number of sides	Time Finishing
W112 100/150	3700,0	3,7000	7,8450		0,0494	0,3875	1	0,0260	0,2040	0,0508	2	0,7971	0,0500	1	0,3923
	110,0	0,1100	0,2730	*head end of wall	0,0917	0,0250	1	0,0260	0,0071	0,0584	2	0,0319	0,0500	1	0,0137
	100,0	0,1000	0,2820	*head end of wall	0,0917	0,0259	1	0,0260	0,0073	0,0584	2	0,0329	0,0500	1	0,0141
W111 75/100	2687,5	2,6875	5,0340		0,0623	0,3136	0	0,0260	0,0000	0,0366	2	0,3685	0,0500	1	0,2517
	1853,7	1,8537	5,2270		0,0623	0,3256	0	0,0260	0,0000	0,0366	2	0,3826	0,0500	1	0,2614
W625 50/63 H2	1500,0	1,5000	1,7810	*height 1187,5; kneewall for toilet and vanity	0,0917	0,1633	0	0,0260	0,0000	0,0366	1	0,0652	0,0500	0	0,0000
W629 75/105 DF/DB	947,5	0,9475	2,8200		0,0917	0,2586	0	0,0260	0,0000	0,0584	1	0,1647	0,0500	0	0,0000
	447,5	0,4475	1,1140		0,9170	1,0215	0	0,0260	0,0000	0,0584	1	0,0651	0,0500	0	0,0000
						2,5211			0,2184			1,9079			0,9331

Additional factors					Additional factors			
	total	single sheet	double sheet		Norm single sheet	Norm double sheet	Time single sheet	Time double sheet
Doorframes	2 pieces	1	1		0,0520	0,1030	0,0520	0,1030
Recepticals	10 pieces	9	1		0,0300	0,0600	0,2700	0,0600
Holes	15 pieces	11	4		0,0200	0,0400	0,2200	0,1600
Backerboard	6 pieces	4	2		0,0350	0,0350	0,1400	0,0700
							0,6820	0,3930

Total	6,6555

Appendix 11: Floorplans of *het Noordgebouw* hotel-section

The floorplans can be requested at the author if necessary.

Appendix 12: Floorplans with metal-stud walls demarcation of *het Noordgebouw* hotel-section.

The floorplans can be requested at the author if necessary.

Appendix 13: Python codes used in the Dynamo model

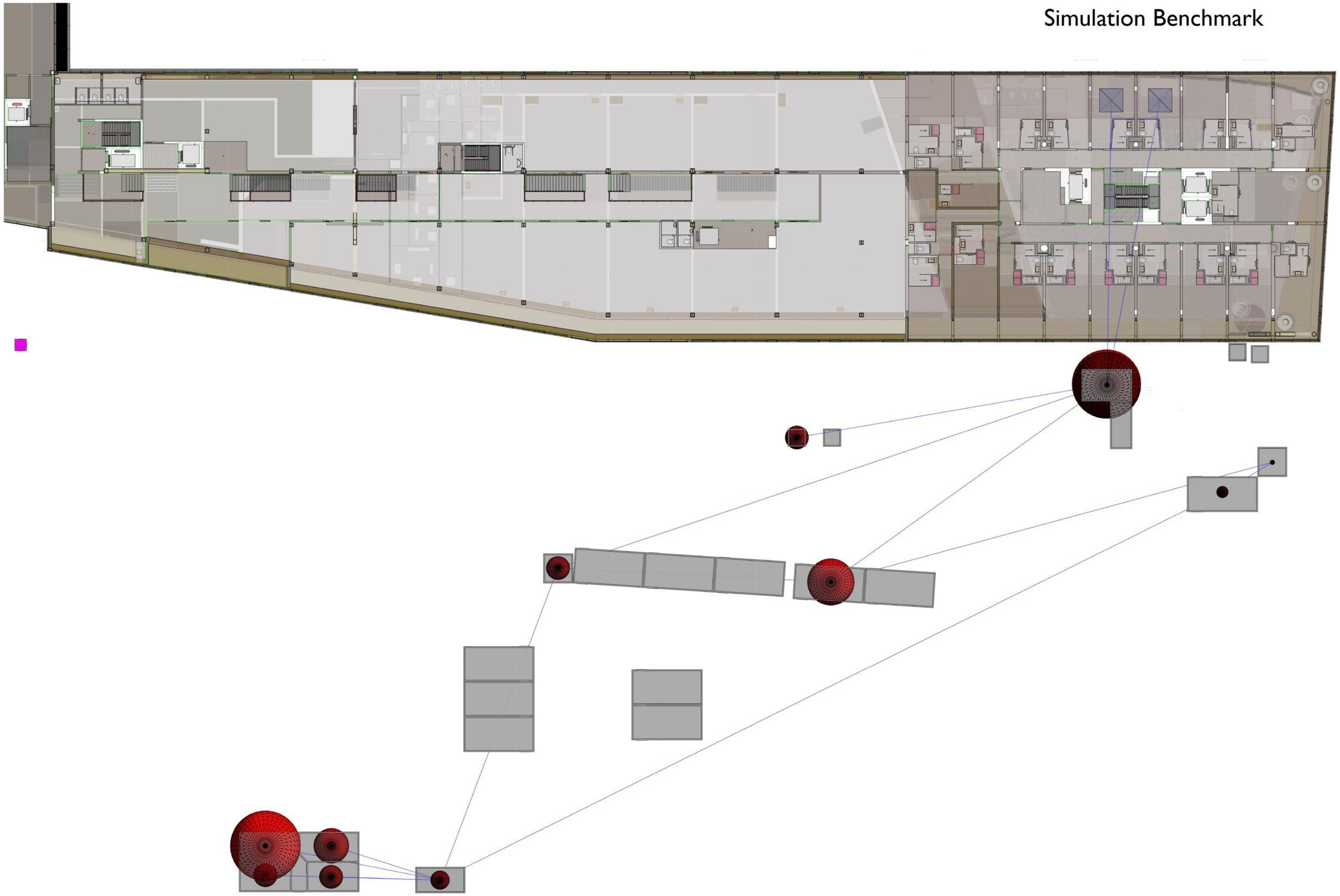
Generate Keys To Find Order List

```
import clr
clr.AddReference('ProtoGeometry')
from Autodesk.DesignScript.Geometry import *
#The inputs to this node will be stored as a list in the IN varia-
bles.
dataEnteringNode = IN
OUT = []

list_excel = map(lambda x: str(x), IN[0])
list_revit = IN[1]

for index in xrange(0, len(list_revit)):

	item = list_revit[index]
	item_str = str(item)
	return_index = list_excel.index(item_str)

	OUT.Add(return_index)
```

Two Lists Find Equals As True

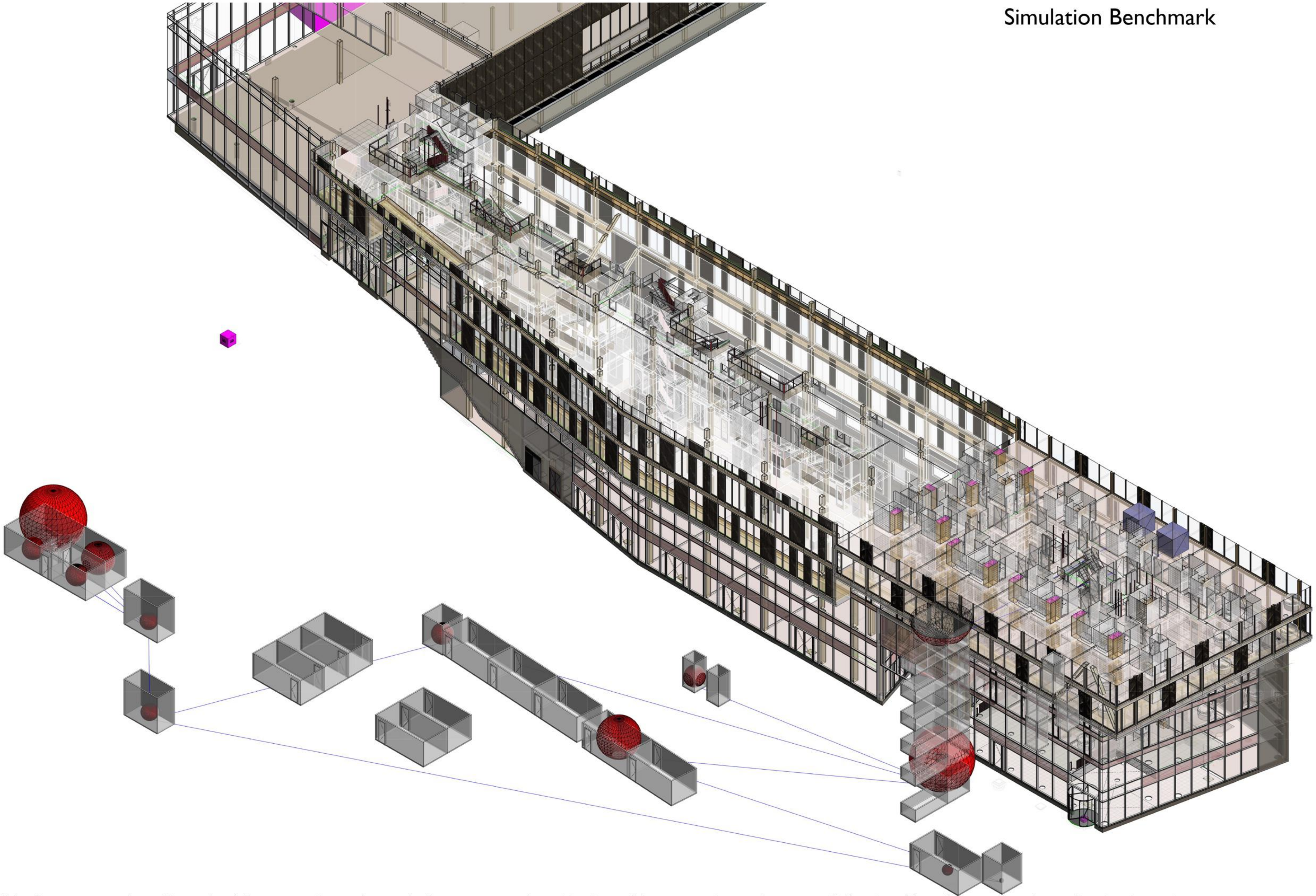
```
import clr
clr.AddReference('ProtoGeometry')
from Autodesk.DesignScript.Geometry import *
#The inputs to this node will be stored as a list in the IN varia-
bles.
list_revit=IN[0]
list_excel=IN[1]

OUT=[]

for index_revit in xrange(0,len(list_revit)):

	value_revit = list_revit[index_revit]
	return_value = False

	for index_excel in xrange(0,len(list_excel)):

		if str(value_revit) == str(list_excel[index_excel]):
			return_value = True

	OUT.Add(return_value)
```

Appendix 14: Visualisation of Benchmark simulation



*blue lines represent the walking paths of the construction workers; red spheres represent the waiting times of the construction workers at specific locations; blue cubes represent the working time in certain areas.

Simulation Benchmark

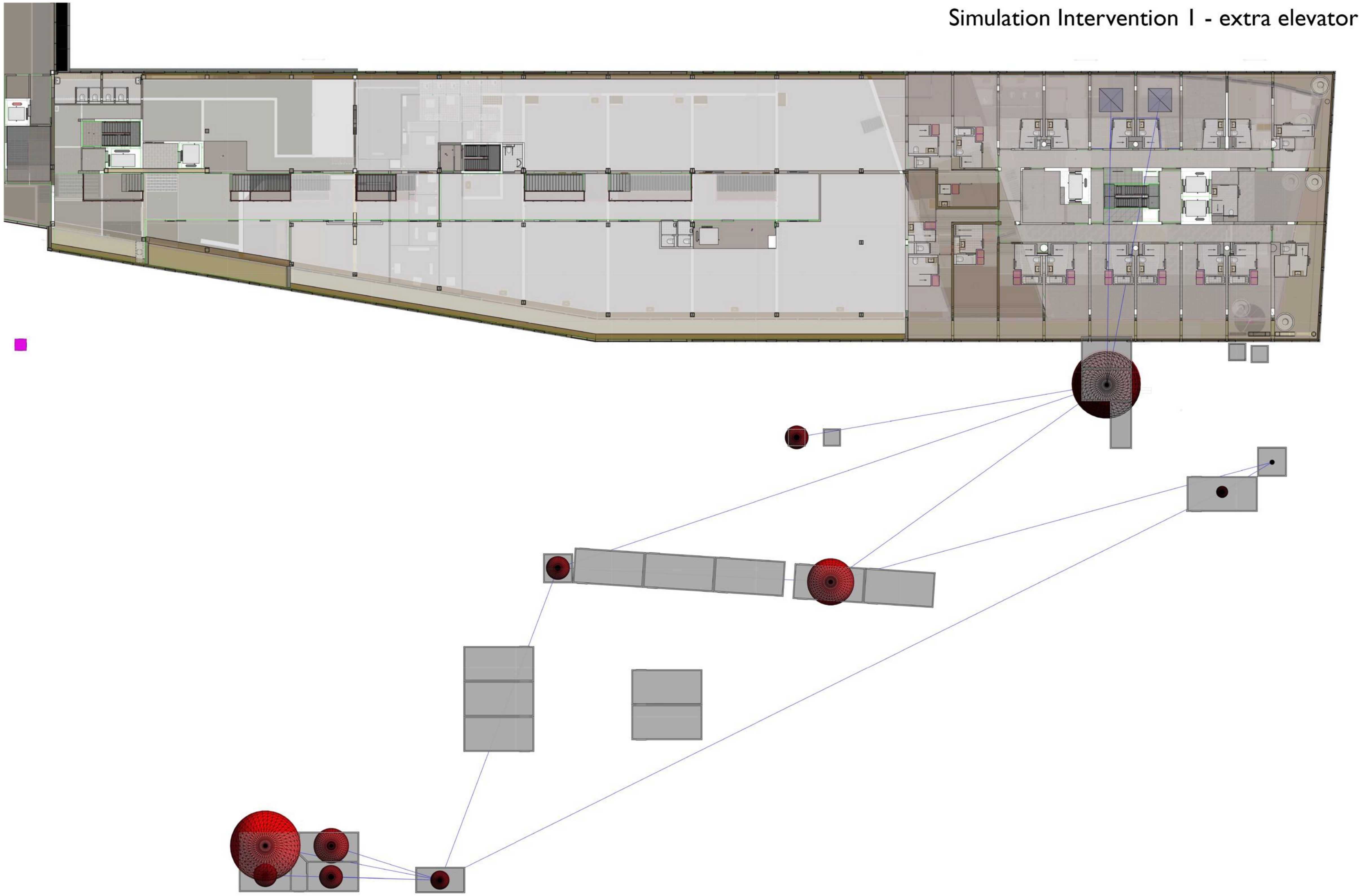


*blue lines represent the walking paths of the construction workers; red spheres represent the waiting times of the construction workers at specific locations; blue cubes represent the working time in certain areas.

Simulation Benchmark

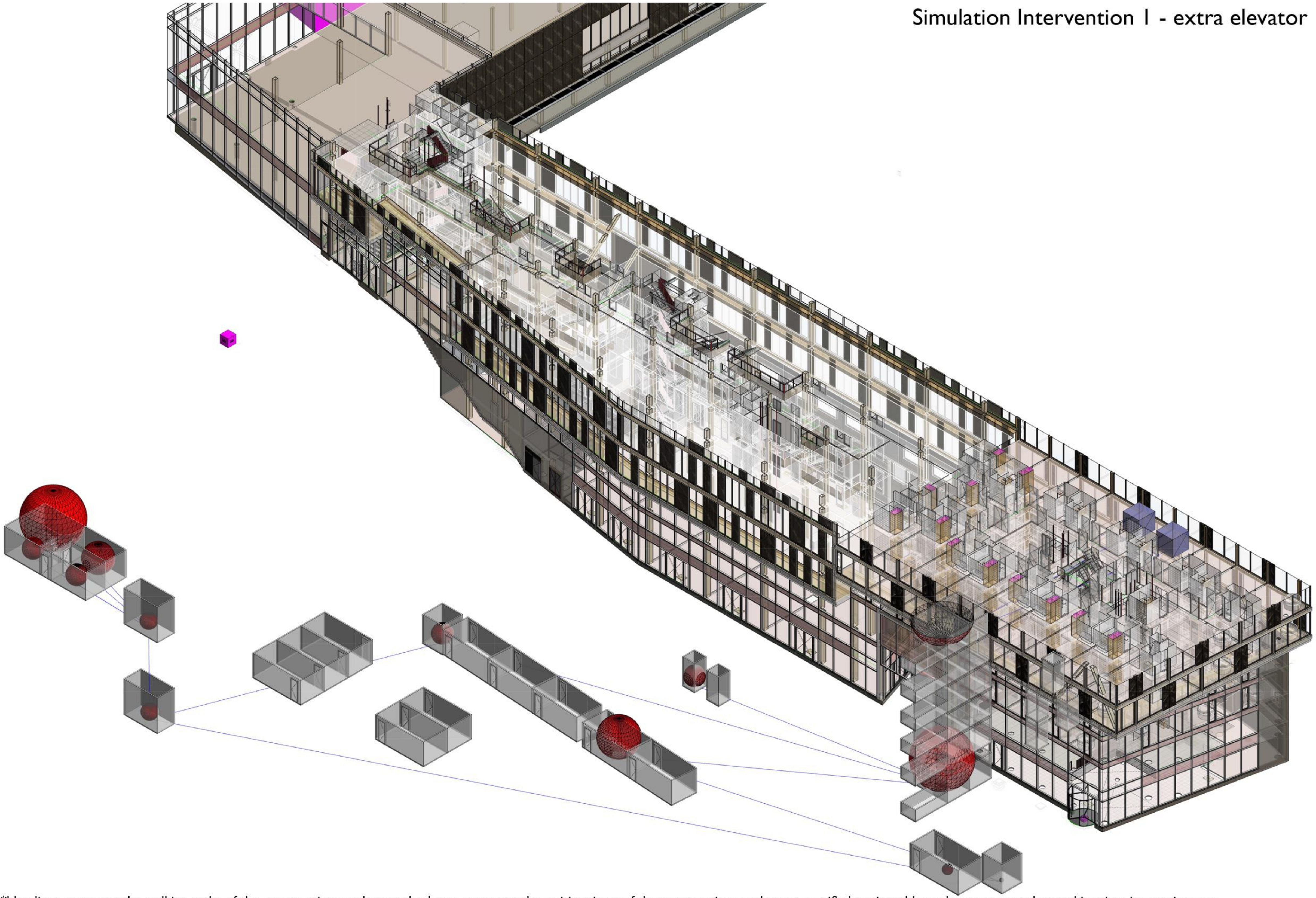
*blue lines represent the walking paths of the construction workers; red spheres represent the waiting times of the construction workers at specific locations; blue cubes represent the working time in certain areas.

Appendix 15: Visualisation of Intervention 1 simulation



*blue lines represent the walking paths of the construction workers; red spheres represent the waiting times of the construction workers at specific locations; blue cubes represent the working time in certain areas.

Simulation Intervention 1 - extra elevator

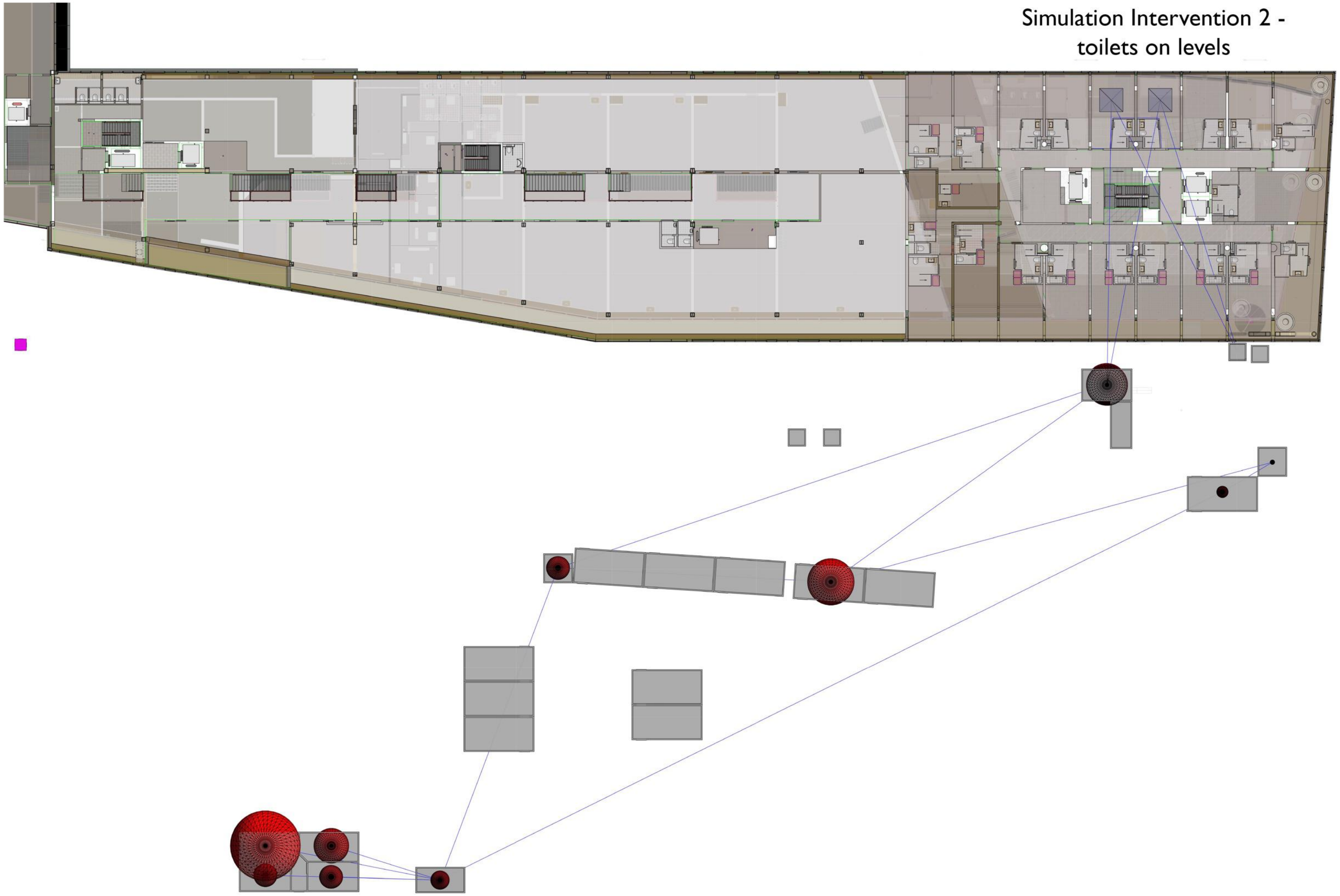


*blue lines represent the walking paths of the construction workers; red spheres represent the waiting times of the construction workers at specific locations; blue cubes represent the working time in certain areas.

Simulation Intervention 1 - extra elevator

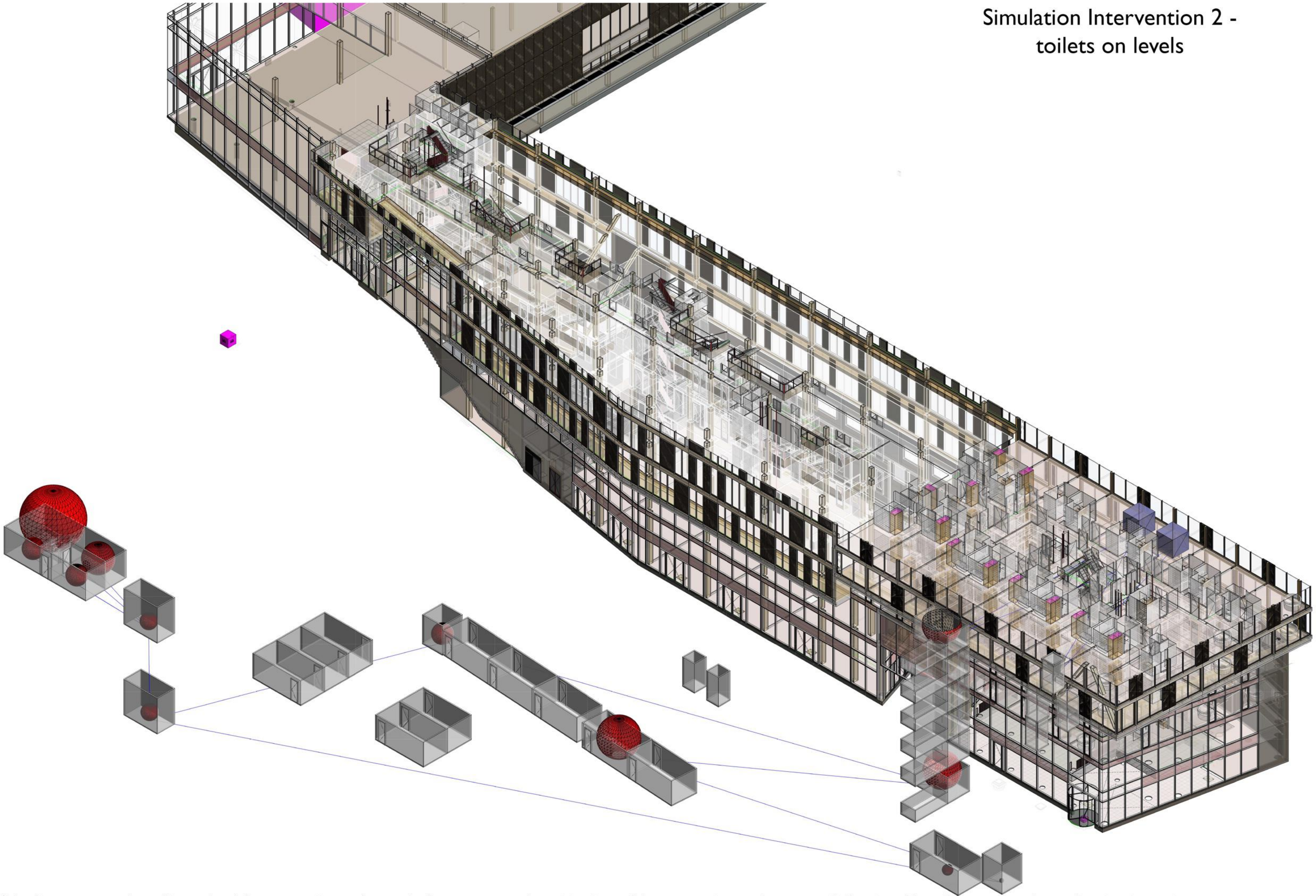
*blue lines represent the walking paths of the construction workers; red spheres represent the waiting times of the construction workers at specific locations; blue cubes represent the working time in certain areas.

Appendix 16: Visualisation of Intervention 2 simulation



*blue lines represent the walking paths of the construction workers; red spheres represent the waiting times of the construction workers at specific locations; blue cubes represent the working time in certain areas.

Simulation Intervention 2 - toilets on levels

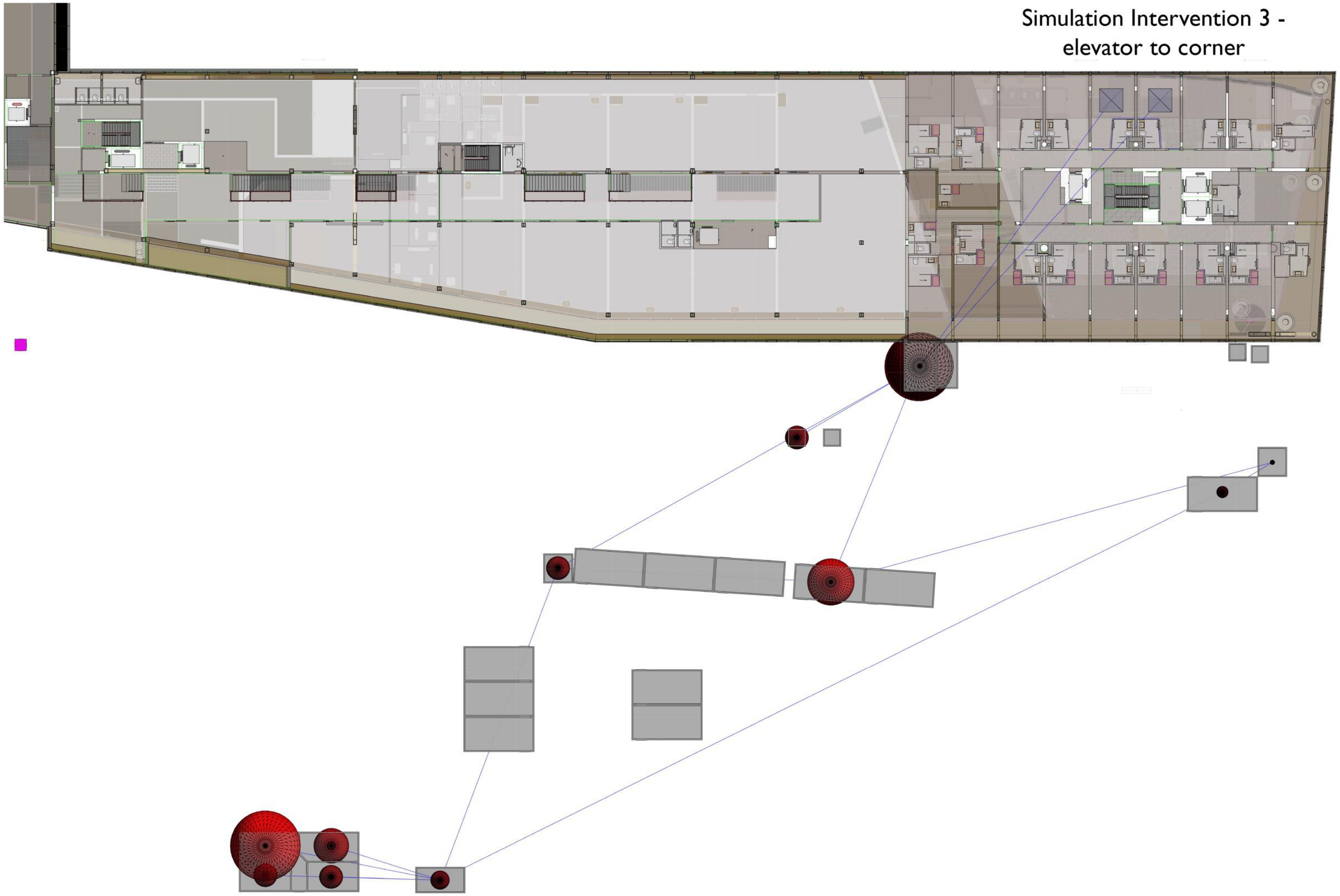


*blue lines represent the walking paths of the construction workers; red spheres represent the waiting times of the construction workers at specific locations; blue cubes represent the working time in certain areas.

Simulation Intervention 2 - toilets on levels

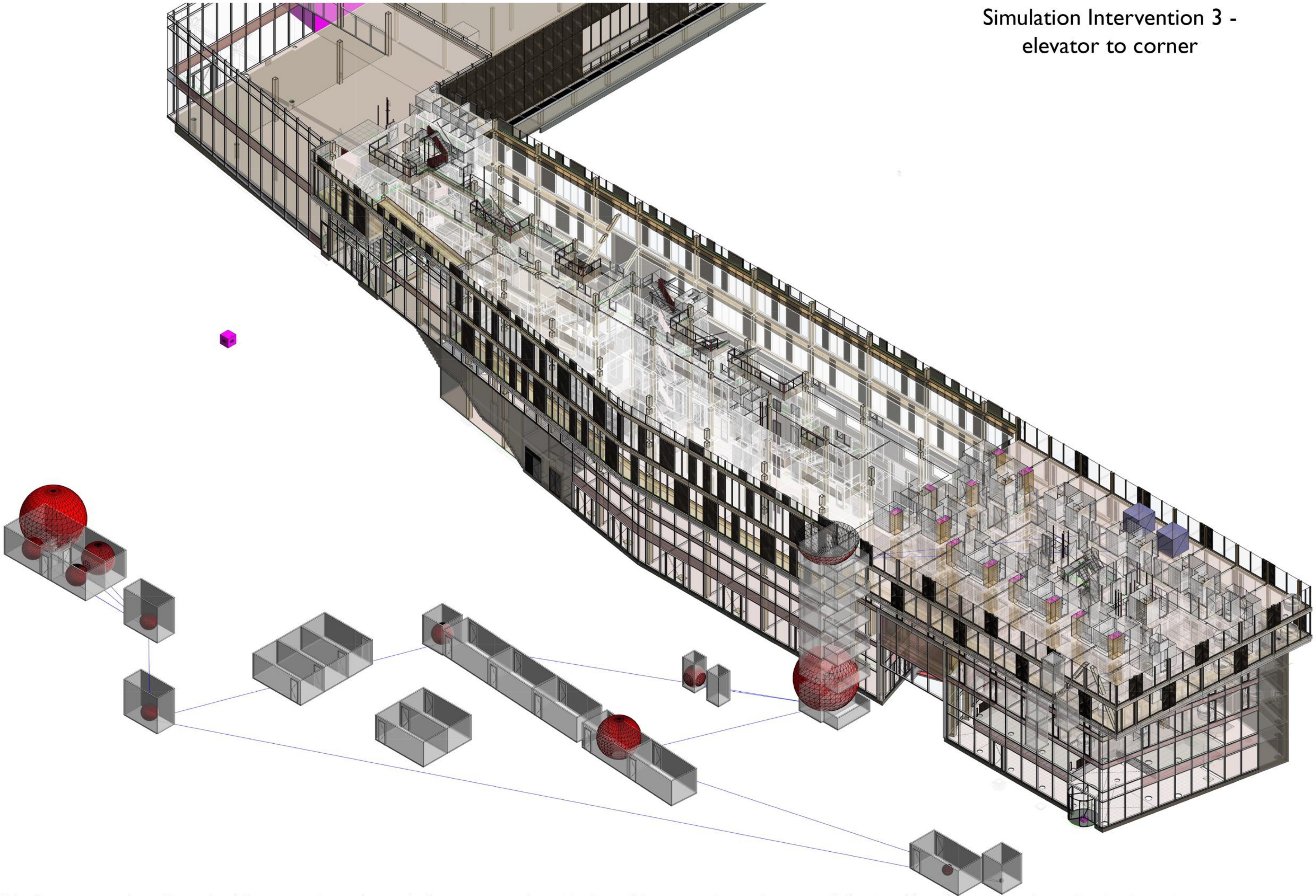
*blue lines represent the walking paths of the construction workers; red spheres represent the waiting times of the construction workers at specific locations; blue cubes represent the working time in certain areas.

Appendix 17: Visualisation of Intervention 3 simulation



*blue lines represent the walking paths of the construction workers; red spheres represent the waiting times of the construction workers at specific locations; blue cubes represent the working time in certain areas.

Simulation Intervention 3 - elevator to corner

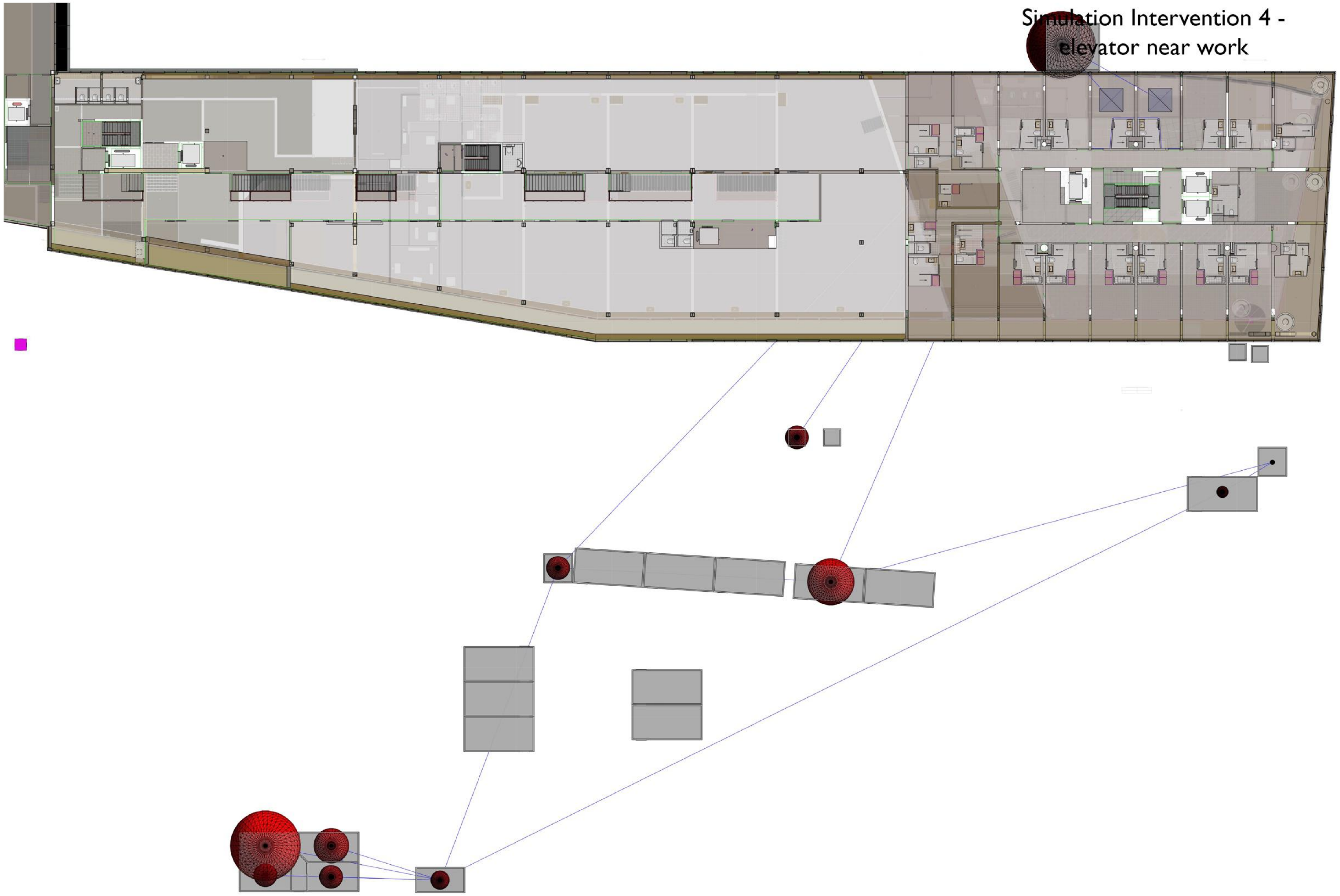


*blue lines represent the walking paths of the construction workers; red spheres represent the waiting times of the construction workers at specific locations; blue cubes represent the working time in certain areas.

Simulation Intervention 3 - elevator to corner

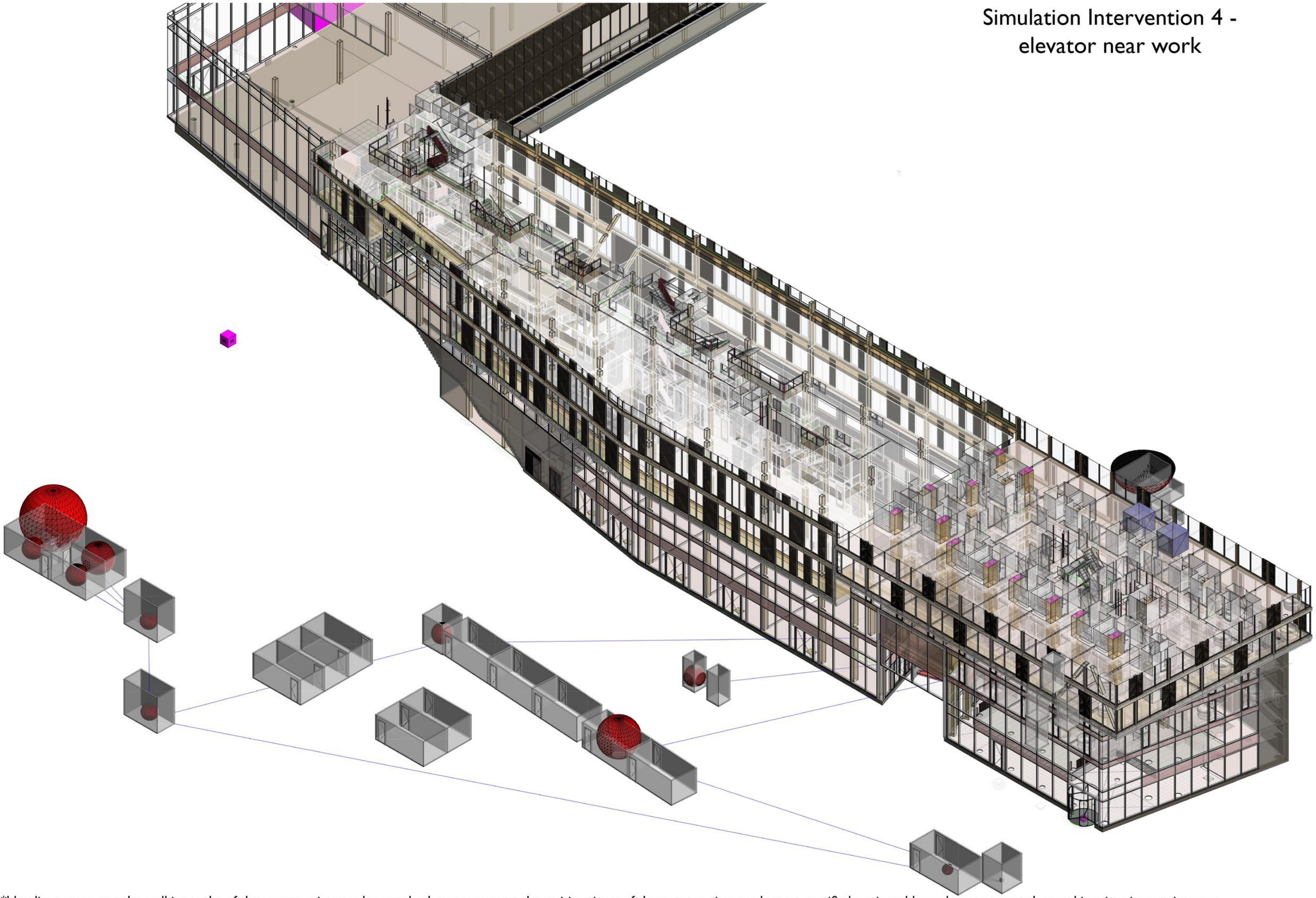
*blue lines represent the walking paths of the construction workers; red spheres represent the waiting times of the construction workers at specific locations; blue cubes represent the working time in certain areas.

Appendix 18: Visualisation of Intervention 4 simulation



*blue lines represent the walking paths of the construction workers; red spheres represent the waiting times of the construction workers at specific locations; blue cubes represent the working time in certain areas.

Simulation Intervention 4 - elevator near work



*blue lines represent the walking paths of the construction workers; red spheres represent the waiting times of the construction workers at specific locations; blue cubes represent the working time in certain areas.

Simulation Simulation Intervention 4 - elevator near work

*blue lines represent the walking paths of the construction workers; red spheres represent the waiting times of the construction workers at specific locations; blue cubes represent the working time in certain areas.