5D-based estimation of indirect construction costs

Development of an adaptive automation tool for improved efficiency of the ABK estimation process

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Development of an adaptive automation tool for improved efficiency of the ABK estimation process

Master of Science Thesis

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PREFACE

This graduation thesis fulfils the last phase for obtaining the master's degree for the Master of Science in Construction Management and Engineering at the faculty of Civil Engineering and Geosciences of the Delft University of Technology. Delft University of Technology and Heijmans N.V. collaborated on this research. I am thankful for the opportunity I have been given at this company to carry out the graduation project and for the support I received. In addition to the formal conversations, the interviewees were always willing to answer questions and share their knowledge and expertise. This project has been experienced as an interesting opportunity to expand the theoretical basis gained during the master's programme with insights from practice.

I would like to thank all members of the graduation committee, Hans Bakker, Sander van Nederveen, Peter de Jong and Willem van Dijk for their helpfulness, guidance, critical views and constructive feedback, which have helped me a lot during the graduation process. Furthermore, I am grateful for the support my family and friends gave me and for the push in the right direction when needed.

Hugo Smienk
Rotterdam, December 2022

EXECUTIVE SUMMARY

One of the fundamental goals for the success of a construction project is found to be completion within the budget. To reach this goal, cost estimation is a key process. The main items in a cost estimate can be divided into direct and indirect costs. Unlike direct costs, indirect costs are not directly connected with the performance of any particular element of a project which makes proper allocation of these costs a challenging issue. Previous studies have shown that indirect costs can be seen as a factor of the construction company's competitiveness, and therefore should be managed adequately in order for the company to remain eligible to participate in tenders with acceptable prices.

Although the classification in the ABK model (2018) provides clarity regarding the content of the indirect cost items, estimation of these costs (ABK) and especially the task of quantity extraction was identified as time-consuming and lacking standardised guidelines and procedures.

Building Information Models (BIM), which are increasingly used, offer an effective platform for linking data regarding construction costs. The fifth dimension of BIM in particular adds cost information to the 3D construction model. Full interoperability between the various information models is still a goal that has not been reached yet within the construction sector. Recent studies have examined inefficiencies caused by inadequate interoperability, like manual re-entry of data and duplication of tasks. This research aims to positively contribute to the efficiency of the indirect cost estimation process by developing a 5D computer-based tool. To fulfil this development objective, a main research question was formulated:

"How can indirect construction costs be managed in a more efficient way on the basis of adaptive computer-based tooling?"

In order to answer the main research question, this research is related to a development cycle which was subdivided into four phases: theory, knowledge, development and outcome. The theory phase consists of a literature review where a theoretical basis is developed, explaining the concepts and methods regarding the indirect cost estimation process. The knowledge phase consists of semi-structured interviews with advisors in planning and logistics from the construction company Heijmans N.V to gain practical insights into the ABK estimation process and determine the needs for development. The development phase translates the development needs into technical requirements which were used as starting points for the development and eventually for the verification of the estimation tool. The outcome phase starts with the validation process where it was aimed, by making use of a reference project, to evaluate the added value of

the tool regarding the efficiency of the ABK estimation process. Finally, a conclusion was drawn, the results were reflected and future recommendations for practical implementation of the tool and for future research were formulated.

The process analysis resulting from the theory and knowledge phase, shows that the process steps for ABK estimation within Heijmans N.V. could be clustered into five main sub-processes: project analyses, scheduling, drafting construction site layout, drawing up ABK estimation and technical completion. Within these last two sub-processes, problems related to obtaining cost item data were identified: the absence of automated links between the BIM software and the outcome of the ABK estimation means that consequences of variations in planning and changes in design cannot easily and quickly be made visible. Moreover, the lack of guidelines and the manual characteristics of quantity take-offs (QTO) diminishes the audit trail of the estimate and leads to additional, time-consuming tasks for the advisors. Therefore, improvements in consistency, interoperability and adaptability were determined as needs for development.

BIM is used for allocating and linking the required quantity-related data for cost estimates. By making use of the benefits of BIM, the tool was able to replace several manual tasks within the last two sub-processes of the ABK estimation. Based on a coding structure, the estimation tool semi-automatically extracted and processed cost item data from the information models. By amalgamating this data, an outcome of the estimate was generated.

Improving the interoperability between BIM software by the tool has resulted in a reduction in total process duration of 12,96%. From practice, this achieved reduction in task time was confirmed as a satisfactory result. Compared to current practice, new and adapted cost items could be assimilated in a shorter period of time. Main benefits of the tool were hereby the structured guidelines for quantity take-offs, a reduction in time for QTO tasks and implementation of project changes within the outcome of the ABK estimate. It was assumed that by providing structured guidelines for the extraction of indirect cost data, greater uniformity can be achieved among the indirect cost estimates.

Eventually, this research did fulfil its main objective to develop a 5D computer-based tool to improve the efficiency of the indirect cost estimation process. Features of BIM applications were used and linked to the outcome of the indirect cost estimate. The tool was able to reduce manual interventions and reduce task durations, which resulted in a positive contribution to the efficiency of the indirect cost estimation process which allows the advisors to use their time to focus on other important factors for the development of high-quality estimates. Following this transition to a semi-automated 5D estimate, further development can focus on the general applicability of the tool on a wider range of software and in other sub-sectors of the construction industry.

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GLOSSARY

Term/Abbreviation	Definition
ABK	Algemene Bouwplaatskosten (English: Site overhead costs). Costs that are directly related to the construction project, but are not directly related with the components of the building object and which do not remain behind in the project. A subset of the indirect construction costs.
ABK model	Brochure published by the NVBK and Bouwend Nederland to provide clarity and unambiguity about the classification of indirect construction costs.
AEC	Architectural Engineering and Construction. The sector of the construction industry that provides the services on the architectural design, engineering design and construction services.
ANN	Artificial Neural Networks. Refer to mathematical structures and their software-or hardware-based models which compute or process signals. The structure of the network and its mode of action is based on the brain and learning phenomena.
BIM	Building Information Modelling. The process for creating and managing information on a construction project throughout its whole life cycle.
DBK	Directe Bouwkosten (English: Direct construction costs). See: Direct construction costs
Direct construction costs	Costs that can directly be linked to the components of the construction object.
Fte	Full time equivalent. A unit to measure employed persons or students in a way that makes them comparable although they may work or study a different number of hours per week. One fte corresponds to the full working week of one employee.
IBIS-TRAD	A calculation program/software with which most contractors in the construction sector in the Netherlands submit their tender budgets for building and civil engineering projects.
Indirect construction costs	Costs which are incurred while completing a construction project, but are not directly related to the components of the building object.
Information model	A digital model of a construction, made up of objects to which information is linked. In addition to the geometry and position of these objects, a model can also contain information such as building material, duration of deployment or costs.
ISO	International Organisation for Standardisation. An independent, non-governmental international organisation, which brings together experts to share knowledge and develop voluntary, consensus-based, market relevant International Standards that support innovation and provide solutions to global challenges.
KLIC	Kabels en Leidingen Informatie Centrum (English: Information centre for cables and pipes). A service of the Land Registry that registers where cables and pipelines are located in the Netherlands. This is to prevent excavation damage and to promote the safety of the digger and the immediate environment.
NEN	Nederlandse Norm (English: Dutch Standard). The name of the partnership of the Royal Netherlands Standardisation Institute and the Royal Netherlands Electrotechnical Committee Foundation (NEC). NEN guides and stimulates the development of standards.
NVBK	Nederlandse Vereniging van Bouwkostendeskundigen (English: Dutch Association of Construction Cost Experts). Professional organisation of cost experts in construction, civil engineering, installations and housing.
UTA	Uitvoerend Technisch Administratief (English: Executive, Technical and Administrative). This broad group of employees includes functions as project managers, planners and calculators.
QTO	Quantity Take-Off. A detailed measurement of materials and labour needed to complete a construction project.

THEORY

1 | RESEARCH INTRODUCTION

1.1 CONTEXT

To determine the success of a construction project, three fundamental goals must be obtained: completion within planned time, achieving the expected quality of construction works and completion within the budget. To reach the goal of completion within the budget, cost estimation is a key process (Juszczyk & Leśniak, 2019). Cost estimation is the process of forecasting the costs associated with accomplishing a project. Both overestimating and underestimating a project's costs can be catastrophic, possibly affecting multiple parties involved in the development of the project (Nicholas & Steyn, 2020).

The main items in a cost estimate can be divided into direct and indirect costs. Together they form the contractor's project construction cost representing all expenditures internal to a project and essential for completion in accordance with its requirements (Chao, 2008). The amount of direct costs is dependent on the scope of works, unit prices of materials, wage tariffs and costs of machinery usage. This type of costs can directly be linked to objects of the building project, and can therefore be determined in a detailed way. Construction project indirect costs, also called overhead costs, refer to the cost of providing site-based services and facilities by the contractors such as construction site management, security and transport. Unlike direct costs, indirect costs are not directly linked with the performance of any specific element of a construction project, but are essential for running the project as a whole. Therefore, a proper allocation of these costs is a challenging issue (Plebankiewicz & Leśniak, 2013). Besides, the lack of a specific set of rules on how contractors must classify them, in practice leads to regular discussion about the content of the indirect costs items. To guide clear delineation and classification of indirect construction costs, the Dutch Association of Construction Cost Experts (Dutch: NVBK) and Bouwend Nederland have published a model in 2018, called the ABK model (Dutch: model Algemene Bouwplaatskosten). The ABK model, which can be used for the determination of the indirect construction costs, distinguishes these indirect costs according to project characteristics, nature of the facilities and cost characteristics (NVBK & Bouwend Nederland, 2018).

Previous research showed that project indirect costs represent a range of 8-15 percent of the total project costs (Enshassi & Aziz, 2008). Taking into consideration that indirect costs can be seen as a factor of the construction company's competitiveness, it is clear that indirect costs must be managed adequately in order for the construction company to be able to participate in tenders with acceptable rates (Hermanová & Hanák, 2017).

El-Sawalhi and El-Riyati (2015) mentioned that the estimation of project indirect cost is a time-consuming and inexact task, and therefore often a percentage of direct costs as an estimate of indirect cost is applied by contractors. This method of applying a fixed percentage to the overall value for project indirect costs is particular used in case of small-scaled, repetitive works. Due to the fact that many preliminary cost items have no direct relation to the value of works, this could lead to an underestimation. Academics suggested that efforts should be made at improving the process of indirect cost estimation in order to increase the accuracy of tender pricing (Chan & Pasquire, 2002). Besides indirect cost estimates are expected to be accurate, there is an increasing need to reduce the time required to deliver these estimates (Juszczyk & Leśniak, 2019).

An ongoing development within the construction industry that has an important effect on the process of cost estimation in general is Building Information Modelling (BIM). BIM represents the process of development and use of computer-generated information models to simulate the planning, design, construction and execution of a construction project (Azhar, 2011). The increasing application of 3D models has facilitated their use in processes known as 4D planning and 5D cost estimating. New and potential improvements regarding efficiency, quality and precision throughout the process of cost management have been fostered by developments in the fifth dimension of BIM (Vigneault, Boton, Chong & Cooper-Cooke, 2020). With the ability to make quick and adjustable cost estimates, BIM can support the cost estimation of construction projects, but its estimation modules are mainly focused on direct costs which leaves room for development of indirect cost estimation processes (Sepasgozar et al., 2022).

1.2 PROBLEM DEFINITION

Although the content of the indirect cost items has been made clear by the classification in the ABK model, estimation of these costs has been identified as inaccurate, subjective on estimator's own knowledge and lacking standardised guidelines and procedures (Ossa Mesa, 2021). Resulting higher variability among the estimates of indirect costs means a greater non-uniformity among the competing bidders, which implies a larger inaccuracy (Chan, 2012). Besides, estimating indirect costs is a time-consuming procedure. The task of extracting quantities of indirect cost items in this process in particular takes a lot of time (Schram, 2015).

Traditionally, to obtain an estimate of the indirect costs, the formal practice is to determine cost items and calculate how much is needed for each item, based on a plan that meets the project conditions and requirements (Chao, 2008). This used approach for the completion of the indirect cost estimation needs manual intervention for extracting quantity take-off-related data. In practice, cost data is reused by manually taking over every cost item, which is found time-consuming, prone to human errors and affects the overall consistency and reliability of the bid (Chan, 2012). In addition, construction works are subject to change during the design process. As a result, indirect cost estimates may need to be revised. The absence of dynamic links between building information models means that variations and change orders cannot be calculated reliably, easily and quickly every time a change occurs (Mitchell, 2013). The manual drafting and implementation of changes in indirect cost estimates is therefore found inefficient (Schram, 2015).

At the same time, information technology can provide an efficient platform for estimators to obtain quotations for their bid estimates (Chan, 2012). The increasing use of BIM can immediately save time for allocating the required quantities and for linking construction cost data (Schram, 2015). However, Monteiro and Poças Martins (2013) have found that certain quantities, including those of indirect cost items, can not be extracted directly from the information models, due to the current tool's capabilities, the information structure in the model, or simply because some elements are not modelled. Therefore, expertise and knowledge of advisors will still be needed to derive quantities from the model's available data or even augment the models by modelling missing information (Vigneault et al., 2020).

1.3 DEVELOPMENT OBJECTIVE

In this research, it is aimed to improve the efficiency of the indirect cost estimation process. The main objective is to develop a 5D computer-based tool to semi-automatically extract quantity take-off-related data from building information models and process this data in order to estimate the indirect cost items of the ABK model. The tool will be able to eliminate the manual tasks of quantity take-offs within this process. Consequences of occurring changes within the construction project will therefore be directly visible in the outcome of the indirect cost estimate. In addition, the target is to enable advisors to use their time more efficiently to focus on other project specific elements such as factoring risks and identifying alternative construction methods that are crucial for high-quality cost estimates. This more consistent approach to the determination of indirect construction costs will have to ensure greater uniformity among the estimates of the advisors.

1.4 RESEARCH QUESTIONS

To be able to fulfil the development objective stated above, a main research question is formulated:

"How can indirect construction costs be managed in a more efficient way on the basis of adaptive computer-based tooling?"

To provide a systematic approach for this research, the main research question is broken down into three sub-questions:

1. How is the current process of indirect cost estimation set up?
2. How can BIM be used to estimate the indirect cost items of the ABK model?
3. How can efficiency be improved in the indirect cost estimation process?

1.5 METHODOLOGY AND THESIS OUTLINE

Qualitative research is used to develop a theoretical basis, explore how the current indirect cost estimation process is set up and describe the nature of professionals' experience in the field of cost estimation. Insights are formulated which reflect the needs of the potential end-users of the tool. These needs form the basis for the requirements and development of the tool. Quantitative cost data needs to be extracted from building information models during the process of development. After the tool is developed to its desired state, a reference project is used to address questions about the magnitude of effect the implementation of the tool will have on the current process of indirect cost estimation. The research can be subdivided in various phases which are related to a development cycle (figure 1).

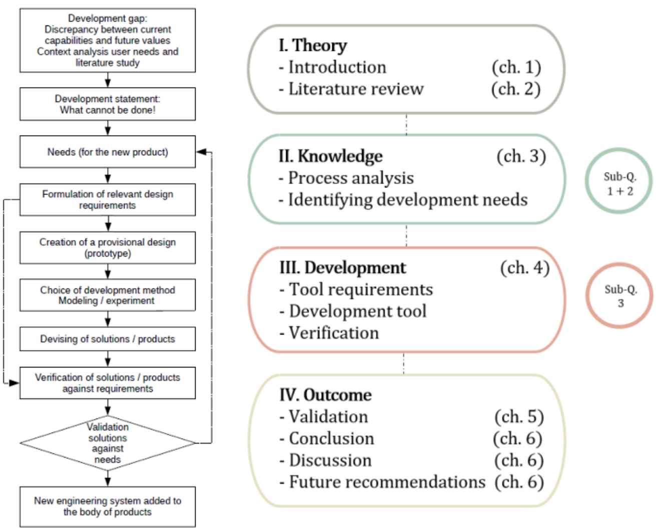


Figure 1: *Development cycle and thesis outline (Delft University of Technology, 2021)*

1.5.1 THEORY

This cycle will start with the establishment of a theoretical basis, which arises from a literature review. The literature review will provide a description of the concept of indirect construction costs and corresponding methods for the estimation of these costs. The application of the ABK model (2018) will be discussed, as well as the definition of efficiency. It is aimed to gain general understanding of the relevant concepts and describe the gap between the current capabilities and the future demands within the field of indirect cost estimation. The literature review will be used to substantiate the introduction of this research and will provide the basis for the analysis of the indirect cost estimation process.

1.5.2 KNOWLEDGE

The process analysis will consist of collecting qualitative data to gain insight in the process of drawing up the ABK estimation. To complement the theoretical basis with industry-specific knowledge, semi-structured interviews will be performed with three advisors in planning and logistics at the construction company Heijmans N.V. By performing a thematic analysis on the interview results, the various sub-processes of indirect cost estimation will be identified. Here, it is important to determine which information models are used and what kind of data is generated and exchanged between these models. By making use of a flow-chart diagram it is aimed to present the practical implementation of the indirect cost estimation process in a structured way. The process will be reflected against the theoretical findings. Hereafter, answers can be provided to the first and second sub-question of this research. Besides mapping out the practical implementation of the process, the theoretical basis and the results of the interviews will be used to determine the needs for development which will initiate the development phase.

1.5.3 DEVELOPMENT

The purpose of the third phase is to determine a suitable solution for the problem statement. The development needs will be translated into technical requirements for the tool. It is aimed to create adaptive links between various BIM applications to semi-automatically estimate the cost items of the ABK model. Functions of Microsoft Excel will be used to serve as an intermediate step between the information models and the estimation of the indirect cost items of the ABK model. Microsoft Excel is a frequently used integration technique to develop an optimisation tool, as this software provides possibilities to extract data from different information models (Dasović, Galić & Klanšek, 2020). During development, the tool will be verified against its requirements, which will ensure that all elements of the tool are accurately developed and are free of errors. In the development phase, the answer to the third sub-question of this research will be provided.

1.5.4 OUTCOME

The solution which the tool provides will be validated against the earlier defined development needs. The validation aims to evaluate the added value of the estimation tool regarding the efficiency of the indirect cost estimation process. The validation is performed by the implementation of the tool within a reference project. This phase will also indicate whether the tool can be recommended for use in the estimation process and where further development or improvement is desired. Finally, the research results will be discussed, and a final conclusion and recommendations for future research will be made.

1.6 SCOPE OF DEVELOPMENT

The scope of this research will start wide, to gain general understanding of the indirect construction costs, its estimation process and BIM applications. Based on insights gained from this wider perspective, the scope will be narrowed down, to gain understanding of the specific tasks of quantity take-offs in the indirect cost estimation process. The development of the tool is based on the specific knowledge gained within this narrow scope.

This research will concentrate on the estimation of the indirect cost items drawn up in the ABK model (2018). This model takes into account common practice and a classification of cost items has been made which can be used for most Dutch construction projects. Consequently, the outcome of the research will mainly be focused on the Dutch construction industry. The construction industry can be divided into two main sectors: residential and non-residential, which has three subsectors (heavy industrial, institutional and commercial, infrastructure). The conversations and interviews that take place within the company will be held with advisors working within the institutional and commercial subsector. Institutional and commercial construction refers to the building of structures such as high-rise condos and office towers, schools, and malls. Accordingly, the developed tool can therefore only be applied in this subsector. The results of this research focus on the estimation process of the specific element cluster of general construction site costs or ABK within the ABK model (element cluster B5B). Therefore from now on, indirect costs will also be referred to as “ABK”. The estimation tool will be established for the planners and advisors in the ABK estimation process to extract quantities of cost data to generate ABK estimates in a more efficient way. The goal of this research is to develop a proof-of-concept tool and not a fully developed tool. The steps taken into account serve as examples of the possibilities to be achieved by this tool.

2 | LITERATURE REVIEW

In the previous chapter, the context of this research has been established. The subsequent paragraphs focus on the theoretical perspective concerning the estimation of indirect construction costs. The chapter starts with a general explanation of indirect construction costs and the classification of these costs in the ABK model (2.1). In paragraph 2.2 the process of estimating indirect costs will be covered based on used processes described in literature. Hereafter, the use of building information modelling and its opportunities to support the process of indirect cost estimation will be described in paragraph 2.3. Several BIM applications that will be used for the development of the final solution of this research are elaborated upon. As the goal of this research is to improve the efficiency of a specific process, paragraph 2.4 will formulate the definition of efficiency and describe how to measure its increase within a process. The objective of this chapter is to create a theoretical basis in order to understand the concepts used in this research and gain insight in the relationship between project data in information models and the estimation of indirect costs.[1]

2.1 PROJECT INDIRECT COSTS – THE ABK MODEL

Construction costs are all costs resulting from obligations entered into for the physical realisation of the construction project. These construction costs can be divided into direct and indirect costs. The indirect costs of a project are seen as one of the most difficult costs to control, because contrary to direct costs, there is often no clear relationship between this type of expenditure. Indirect costs are naturally spread over multiple cost items and it is difficult to predict exactly in advance when they will occur (Leśniak & Juszczyk, 2018).

The indirect costs of a construction project can be defined as costs that cannot be identified with or charged to a construction project or to a unit of construction production. However, these costs are necessary to realise the project. For the project indirect costs there are several other definitions used in existing literature. Filicetti (2016) defined indirect costs as costs which are imposed during business but are not directly attributed to a specific product. AACE International Recommended Practice (2022) defined the indirect costs as costs that are not explicitly related to the execution of activity; however, they are distributed over all project activities.

[1] Gray areas at the beginning or end of a chapter respectively indicate the introduction and the conclusion of that chapter.

In the Netherlands, the classification of construction costs is drawn up by the Royal Netherlands Standardisation Institute (Nederlands Normalisatie Instituut, 2017) and is represented in section B of the NEN 2699 standard. This classification is shown in table 1.

Table 1: *Classification of construction costs in accordance with NEN 2699 (Nederlands Normalisatie Instituut, 2017)*

NEN 2699	Cost type	Explanation
B1	Architectural works	The costs for the structural work and its finishing.
B2	Installations	Costs to provide the structure with water, heating, cooling, ventilation and electricity.
B3	Permanent establishments and facilities	The costs of furnishing the construction. For example, sanitary and kitchen amenities.
B4	Terrain	The costs of furnishing the terrain. For example, planting and fence.
B5	General execution costs/miscellaneous	Costs of equipment and/or labour required for the execution of a construction project, insofar as these costs are not related to resources, such as materials, that remain on the construction site upon completion.

The scope of the budget for indirect construction costs is often subject of discussion in practice. Therefore, the Dutch Association of Building Cost Experts (Dutch: NVBK) and the Dutch association of construction and infrastructure companies (Bouwend Nederland) have released a publication known as the ABK model to precisely define and categorise the indirect construction expenses. In order to arrive at a widely supported model in the construction sector, the ABK model has been linked to the classification of NEN 2699. Because the entire cluster B5 of the NEN 2699 not only includes execution costs, but all costs that cannot be directly allocated to a building component or element, NEN has been requested to change the title to 'Indirect costs'. In addition, in consultation with NEN it is established to reclassify the underlying level of element cluster B5B in accordance with the overview below (figure 2). This separates the costs of management and equipment and the classification has been adapted to the one of the ABK model (NVBK & Bouwend Nederland, 2018).

B			Construction costs
5			Indirect construction costs
	A		To be detailed
		99	To be detailed (not further specified in provisional plans)
	B		Algemene bouwplaatskosten (ABK)
		01	Managerial and support staff
		02	Facilities for construction site personnel
		03	Layout and management of the construction site
		04	Transport and logistics
		05	Temporary connections
		06	Use of small equipment
		07	Special ABK (specials)
	C		Coordination costs
		01	Coordination costs
	D		General operating expenses (AK)
		01	General operating expenses surcharge
	E		Profit and Risk
		01	CAR/DIC
		02	Profit and risk surcharge
		03	Surcharge for the risk of price increases

Figure 2: *Positioning of the ABK within element cluster B5B of the NEN 2699 (NVBK & Bouwend Nederland, 2018)*

This research will focus on the estimation of elements within the specific element cluster B5B. Therefore, the definition of ABK formulated by the NVBK and Bouwend Nederland (2018) will be used and is stated as follows:

"ABK are costs that are directly related to the construction project, but are not directly related with the components of the building object. ABK are costs of facilities, means of production and associated labour used in the project, which cannot directly be allocated to parts of the construction object and which do not remain behind in the project."

The items in the ABK model consist of both one-off (fixed) costs and time-related costs. One-off costs are costs for, for example, placing and the removal and disposal of equipment. Time-related costs are, for example, the rental of cranes and construction sheds, the costs for managerial and support staff and electricity costs. These costs depend on the amount of days, weeks or months the cost item is deployed. In the ABK model, the cost items are subdivided in 7 sections. Section 1 consists only of time-related costs regarding managerial and support staff. Sections 2 to 7 consist of costs for equipment and facilities that are non-recurring and of costs associated with the duration of the use of services. Each section can be subdivided in clusters followed by division in item clusters (see Appendix A).

2.2 INDIRECT COST ESTIMATION

In general, cost estimation can be seen as the task determining the amount of work that needs to be done, along with the rate of production and cost of the resources needed to perform that work (Al-Mashta, 2010). The estimating process of indirect costs consists of five main elements: the building information and scope of the current project, cost data of historical projects, current unit costs and rates, the estimation methodology and the user who employs all elements in making an estimate. The determination of the estimation methodology relies on the purpose of the estimate, characteristics of the data that is available, the level of detail and the preferences of the estimator. Eventually it is the estimator who applies the methodology and the available information (Kim, Seo & Hyun, 2012).

In the past Chao (2008) and Assaf (2001) have performed studies on indirect cost estimation practices by conducting surveys and interviews. These studies revealed that most contractors estimated indirect costs as a percentage of the direct cost. This method totals all indirect costs for a given accounting period and scales them against the total direct costs for the same period, resulting in a percentage of indirect costs that can be applied to future projects. This ratio is compared with those for past similar projects to determine if the resulting indirect cost level is normal (Chao 2008). This method is easily applicable to almost all types of construction projects and therefore widely used. However, a quick method as applying a percentage may not be sufficiently accurate for most estimates. In deciding the final amount of indirect costs that has to be added to project direct costs, contractors may not exactly use computations resulting from the calculation. Instead they use other elements including the competition level, the complexity of the project and the payment schedule (Assaf, 2001). Furthermore, estimates of indirect costs vary and contractors can therefore not depend on a fixed percentage for every project. Indirect cost estimation should accordingly take into account the project specific factors and be calculated for each individual project (Saini, Khursheed, Paul & Kumar, 2021).

Activity Based Costing (ABC) is another approach for estimating indirect costs. In this process-based costing method it is assumed that resources are assigned to activities. These activities are allocated to parts of the construction project. The cost driver is defined as an allocation base of costs to activities and is fundamental to ABC. Instead of traditional resource-based costing where resources are directly assigned to segments of projects, ABC uses multiple cost drivers to assign activity costs to services or products. The objective of ABC is not only preventing a misrepresentation of indirect costs but also outlining a process view, thereby helping to eliminate non-value added activities (Kim & Ballard 2001). Nonetheless, it is impossible to allocate all indirect costs to specific activities and the implementation process of ABC is complex. The high level of detail and specificity of information needed to perform ABC contributes to this complexity which makes the decision making process last longer (Mahal & Hossain, 2015).

Most of the recently proposed estimation techniques tried to meet the expectation by generating models to be applied at the tendering level to help the process of decision-making (Tayefeh Hashemi, Ebadati & Kaur, 2020). Some authors have proposed artificial neural networks (Leśniak & Plebankiewicz, 2018), cluster centre and linear regression (Chao, 2008) as being effective tools for the estimation of indirect cost ratios based on past bid data.
A more reliable estimate may however be obtained by using a model that is based on real cost data and relates the indirect cost estimate to project characteristics and quantities of indirect cost elements instead of using historical data (Saini, et al., 2021). A detailed estimate of indirect costs can be made by setting up line items and subsequently multiplying these items by their current unit cost. Quantification of the line items is an important step of this method which demands a lot of time, is exposed to human errors due to the large volume of manual calculations and therefore not favoured by many contractors (Fazeli, Dashti, Jalaei, & Khanzadi, 2020).

2.3 BUILDING INFORMATION MODELLING (BIM)

As stated in the definition, ABK are not directly related to the components of the building object, which increases the difficulty to establish an accurate estimate. Setting up line items can however contribute to a detailed indirect cost estimation process. This method starts with quantification (Sabol 2008). The quantities for this determination are subsequently multiplied by their unit cost to estimate the indirect cost items of the project.

Quantity take-off (QTO) is an area which can benefit from BIM. BIM is the process of creating and managing information for a built asset. Based on an intelligent model, BIM integrates structured, multi-disciplinary data to produce a digital representation of an asset across its lifecycle, from planning and design to construction and operation. During the preconstruction phase, BIM can be used to estimate costs and quantities, as well as to integrate and coordinate building components and their scheduling data. The advances BIM provides, may be used to visualise construction projects from the design phase and integrate them with project cost estimation and control. Drawings can be replaced by a building information model, which allows generating quantity take-offs, counts and measurements from the underlying model. As a result, the information is consistent with the design. When changes are made to the design, the related construction documents and schedules, as well as the quantity take-offs, counts and measurements that the estimator uses, may be affected automatically (Elbeltagi, Hosny, Dawood & Elhakeem, 2014).

Developments within the field of BIM mainly concern direct cost estimation and its estimation modules often do not include the estimation of indirect construction costs. However, a description of the use and capabilities of BIM is required to gain insight into the possibilities information models can provide in the ABK estimation process.

A data enriched 3D model of the construction site in BIM can prevent unforeseen problems and delays. Sudden changes in the logistics can be easily and quickly adjusted in the model. Besides, data from 3D objects can be reused in subsequent construction projects, which saves a lot of time. Addition of specific parameters to this modelling are known as BIM dimensions (figure 3).

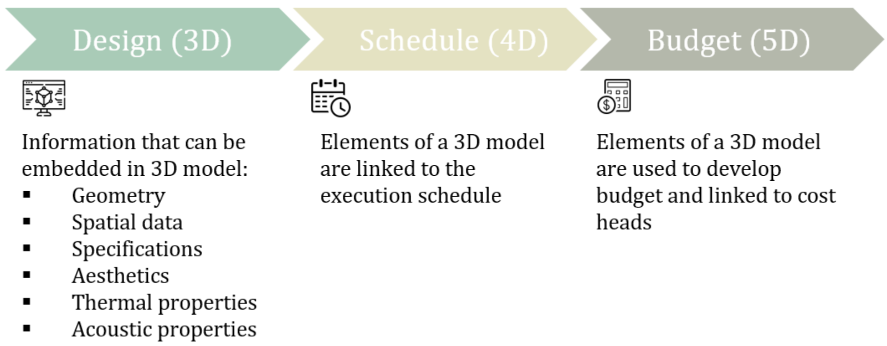


Figure 3: *Dimensions of BIM up to 5D*

Adding the fourth dimension (4D) of BIM includes the scheduling information which allows better visualisation of the development of the project during its construction. The addition of scheduling information enables to identify clashes and resolve problems beforehand. For example, positions of temporary support structures such as shoring posts or scaffoldings can possibly collide in BIM with other construction elements.
5D BIM adds to the fourth dimension with the ability to link costing information to the digital model and the project's schedule to allow better cost management (Vigneault, et al., 2020). The cost estimating capabilities of most 5D BIM tools enable generating cost estimates that reflect the actual costs of a project with more precision. These tools typically have functions that let estimators assign costs to quantities or link them to external databases. There are a variety of ways of getting quantities and equipment definitions out of a building information model into a cost estimating system. Not every BIM model however contains all the required information to generate a complete quantity take-off at the click of a button (Vigneault et al., 2020).

Asta Powerproject and Autodesk Revit are BIM applications commonly used in the construction industry for indirect cost estimation (Carvalho, Braganca, & Mateus, 2021). Asta Powerproject has been the project scheduling standard for UK and European firms for the last 25 years. In general, the wide use of Powerproject is related to the ease of use, a short learning curve and low cost of ownership (Bien, 2017). The software of Powerproject is able to set up schedules for personnel and equipment needed in the project, which are in accordance with the indirect cost items of the ABK model.

Several studies have stated Revit as one of the most popular BIM software (Carvalho et al., 2021). Revit can be used to visualise the construction site by modelling physical ABK elements, such as cranes, construction sheds and building fences. When changes are made to the building model it can be set up to automatically update project quantities, which are needed to estimate the indirect construction costs.

As Powerproject and Revit are able to support the QTO feature, these BIM software programs can help to develop a detailed indirect cost estimation of the construction project and are therefore described in more detail in the next paragraphs.

2.3.1 ASTA POWERPROJECT

Asta Powerproject is a project management software tool that is specifically designed to plan and deliver projects on time and within budget (Bien, 2017). For the purpose of time planning Powerproject provides comprehensive features such as the planning of tasks in units from hours, days, weeks, months to years. It can use detailed calendaring to schedule tasks and resources, link categories, task splitting and positioning to finely tune a project schedule.

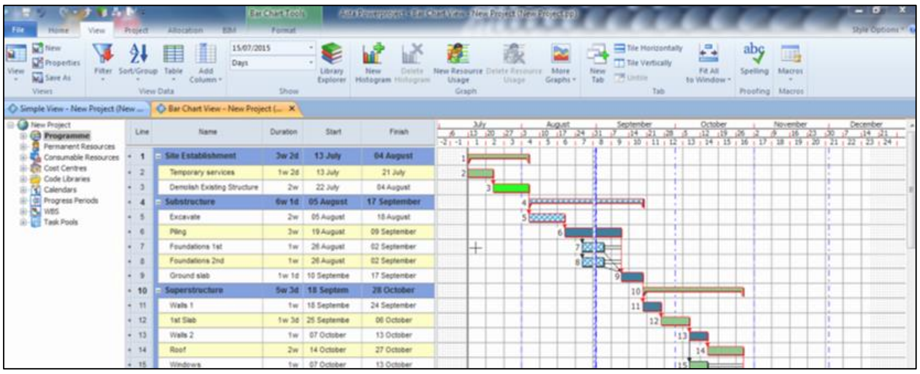


Figure 4: *Asta Powerproject software layout (Elecosoft, 2007)*

The table in figure 4 shows information about tasks and allocations. A typical table could show the name, start, duration and end of a construction activity. The program allows displaying multiple graphs and histograms of personnel requirements, equipment or finances. Edits can be made to the plan which can be immediately seen as the impact on resources levels. Powerproject comes preloaded with templates and common layouts and has taken on a BIM integration as it allows presenting and progress monitoring in 3D (Elecosoft, 2017). The construction of the 4D models enables the various participants (designers, supplier, consultant, contractors, and clients) of a construction project, to visualise the entire duration of a series of events and display the progress of construction activities through the lifetime of the project. The range of data included in the program can read and enable data exchange with different project planning systems (Turbit, 2012). Employing Powerproject, the line items of the ABK can be identified. Subsequently, their corresponding costs still need to be determined.

2.3.2 AUTODESK REVIT

The BIM solution Revit is a design and documentation platform with which detailed model-based 3D designs can be made. The 3D model can be provided with data and product properties, which can form the source for construction drawings, quantity schedules and overviews. Indirect cost estimating is an element within the construction process that can benefit from computable building information (Autodesk, 2007). Revit can contribute to the ABK estimation process by automatically extracting quantities and cost data of modelled physical construction site elements (figure 5). Measurement parameters can be defined to measure selected elements within the model. Revit allows selection of all the object types in the model database, thus making it possible to extract quantities related to all types of elements. Revit can export schedules in TXT format containing quantity and cost data of the modelled construction site elements. These schedules often require further processing in order to handle the data in subsequent phases of the indirect cost estimation process (Shick Alshabab, Vysotskiy & Petrichenko, 2019).

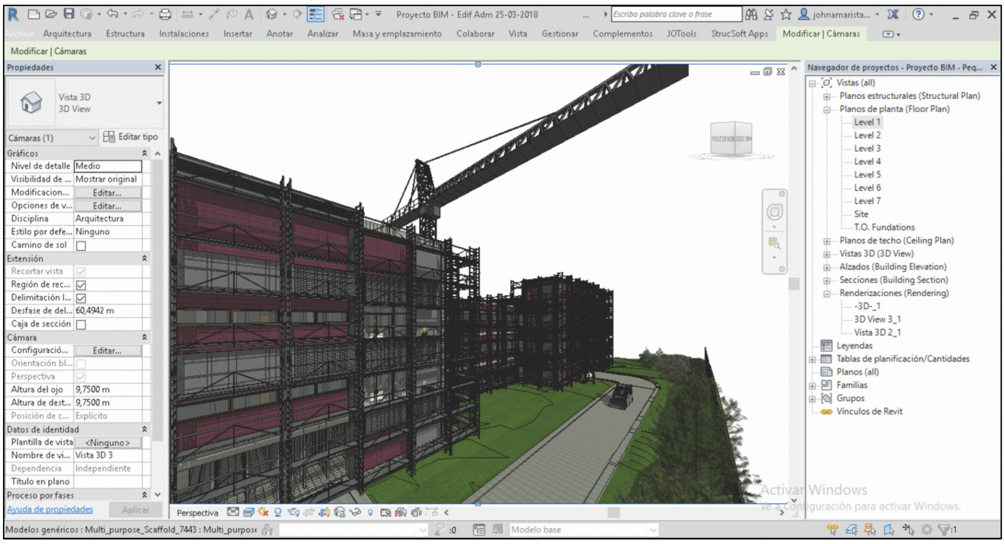


Figure 5: *Construction site elements modelled in Revit Autodesk, (Amarista, 2018)*

With the advancement of building modelling technologies, like Powerproject and Revit, links between digital project data can be created in real-time that are consistent, saving time and money while improving project productivity (Bhagat & Agrawal, 2015). Interoperability is a basic requirement to allow this interdisciplinary work in the construction industry. In BIM context, a supportive way of interoperability is machine readable information facilitating communication and collaboration. The goal of full interoperability between the different information models in the AEC sector has however not been reached yet. Recent studies considered inefficiencies brought by inadequate interoperability such as manual re-entry of data and duplication of tasks (Grilo & Jardim-Goncalves, 2010).

2.4 EFFICIENCY

The utilisation of the BIM models has the potential to increase the efficiency of cost estimation processes (Doumbouya, Gao, Guan, 2016). As opposed to traditional methods, all of the cost estimation data can be exchanged through software with the help of collaborative platforms and open data exchanges standard for BIM. This information exchange can significantly reduce the amount of workload and human-oriented errors (Banihashemi, Khalili, Sheikhkhoshkar & Fazeli, 2022).

The aim of this research is to use the mentioned potential of BIM to increase the efficiency of the ABK estimation process. The International Organization for Standardization (ISO) has published standards for determining and measuring efficiency of a system development (Bevan, Carter, Earthy, Geis & Harker, 2016). ISO is an international standard development organisation composed of representatives from the national standards organisations of member countries. ISO standards are internationally agreed by experts and represent a consensus on the current state-of-the art, concerning product development. ISO defines efficiency as the resources expended in relation to the accuracy and completeness with which users achieve goals. Relevant resources can here include time to complete the task, materials or the financial cost of usage (ISO, 2016). Within ISO 25022, standards for quality in use include for example task time, productive time ratio, cost-effectiveness and unnecessary actions. In this research, the implementation of the tool will mainly focus on the reduction of task time in the ABK estimation process. Following ISO standards, with the same or even higher accuracy and completeness of tasks, a reduction in task time will contribute positively to the efficiency of a process. Value changes in task time after implementation of the proposed development will determine the impact the tool will have on the efficiency of the ABK estimation process.

The literature review provided the definition of indirect construction costs and the classification of this type of expenditure within NEN 2699 and the ABK model. To develop a theoretical basis for the process analysis, methods for indirect cost estimation were described. The determination of line item quantities was found to be an important step within this process. The use and capabilities of BIM were presented to gain insight into the possibilities BIM might provide in the ABK estimation process. Based on literature, BIM solutions do not automatically generate indirect cost estimates by any means, but they can offer advantages over traditional based systems by minimising manual quantity take-offs. This research will focus on the determination of the ABK by making use of the mentioned BIM applications Powerproject and Revit. The presented ISO standards will be used later on in this research to assess the influence of the proposed development on the efficiency of the ABK estimation process. Now that theoretical insights have been obtained, the next chapter will elaborate upon the practical implementation of the ABK estimation process.

II
KNOWLEDGE

3 | **PROCESS ANALYSIS**

In chapter 2, a theoretical perspective concerning indirect cost estimation was described. In this chapter, the practical functioning of the currently used ABK estimation process is elaborated upon. Redesign of this process calls for a more systematic description to understand the weaknesses of present procedures and to identify new processes.

Semi-structured interviews with three advisors (i.e. senior advisors planning and logistics) within Heijmans N.V. were conducted to expand the theoretical knowledge with practical experience. From these interviews, three main topics concerning the ABK estimation process could be distinguished: process steps, required data and adaptability (see table 2). These topics form the basis for the process description which is worked out in the form of a flow-chart diagram in paragraph 3.1. Identified problems in each of the topics have been further elaborated upon in paragraph 3.2. Following these problems, the needs for development within the ABK estimation process are formulated in paragraph 3.3. Full interview transcripts and results of the corresponding thematic analysis are included in Appendix B.

Table 2: *Topic-based results interviews ABK estimation process*

Topic	**Description**
Process steps	▪ Analyses of project data and construction site environment. ▪ Set up of execution schedule for UTA, equipment and crane planning. ▪ Drafting construction site layout. ▪ Amalgamation obtained project documents; extraction of required quantities. ▪ Technical completion.
Required data	▪ Data contained by project documents developed during the ABK estimation process: - Powerproject: duration of deployment, fte. - Revit: quantities and costs of physical construction site elements. - External database Excel: hourly rates of managerial and support staff.
Adaptability	▪ Manually adjusting and re-entering data due to changes in project design or planning.

3.1 PROCESS DESCRIPTION

As indicated by advisor 1, the process of ABK estimation concerns the estimate of the type of cost which can be related to “how something should be built”. The main goal of the process is to determine the optimal implementation with regard to integrated planning, system choices, deployment of personnel and equipment, and corresponding costs. From the interviews, the five main elements of the estimation process: building information, historical and current cost data, method of cost estimation and advisor (Al Mashta, 2010) were recognized. As indicated by all three advisors, for the estimation methodology, a number of sub-processes can be identified: project data analyses, scheduling, determining construction site layout and drawing up and technical completion of the ABK estimation (figure 6).

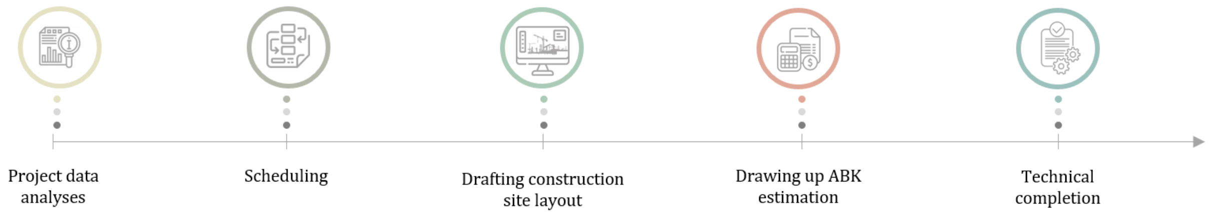


Figure 6: Sub-processes ABK estimation process

Each of the sub-processes as described by the interviewees will be further explained in the next paragraphs. For the purpose of clarity, the process steps are mapped out in a chronological order, however, in practice the process contains rather iterative characteristics.

3.1.1 PROJECT DATA ANALYSES

At the start of the ABK estimation process, substantive knowledge about the project is obtained from various project documents. The advisors analyse architectural and constructive drawings to make an inventorisation of the project data. An analysis is made of the construction site as well, in order to identify risks and opportunities in terms of planning and logistics (figure 7, step 1). Subsequently, the inventorised project data are used together with demarcation agreements to determine the main features of the construction method and logistics to be used. These agreements concerning the ABK and direct construction costs (in Dutch: DBK) are worked out at project-specific level. In addition, the outlines of construction methods for various scenarios are set up (figure 7, step 2). From the interviews it emerged that the advisors differ in the order in which they perform these first steps of the process.

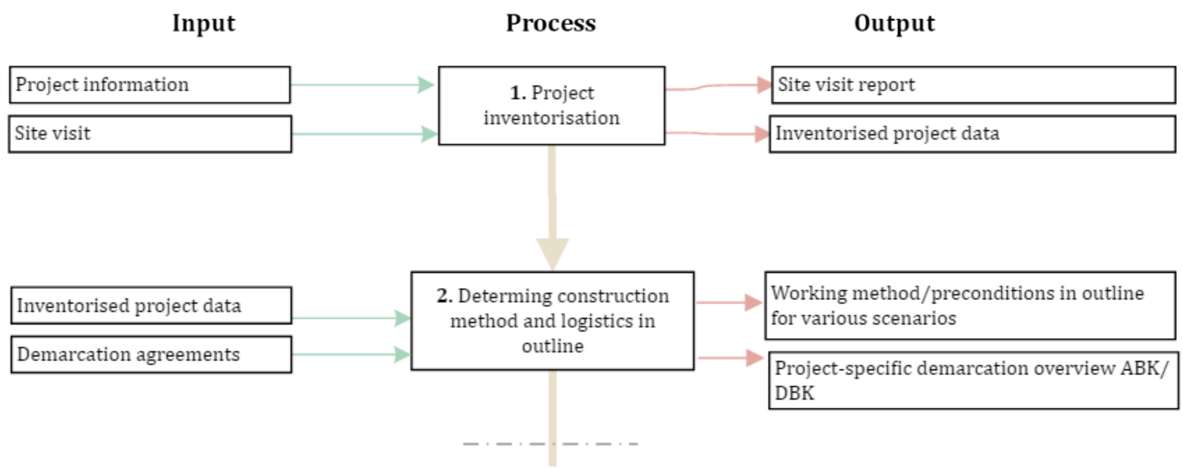


Figure 7: Flow-chart diagram representing steps 1 and 2 of the ABK estimation process

3.1.2 SCHEDULING

Based on the first analyses, all advisors are able to establish a first global estimate of the quantities concerning the personnel and equipment to be deployed. Quantity statements within this global estimate are mainly based on the advisors experience and expertise. "Only a limited number of personnel possess the specific knowledge to derive the execution schedule, personnel planning and the construction layout from project data" (advisor 2). An execution schedule of all construction activities is drawn up in Powerproject on the basis of the first global estimate (figure 8, step 3).

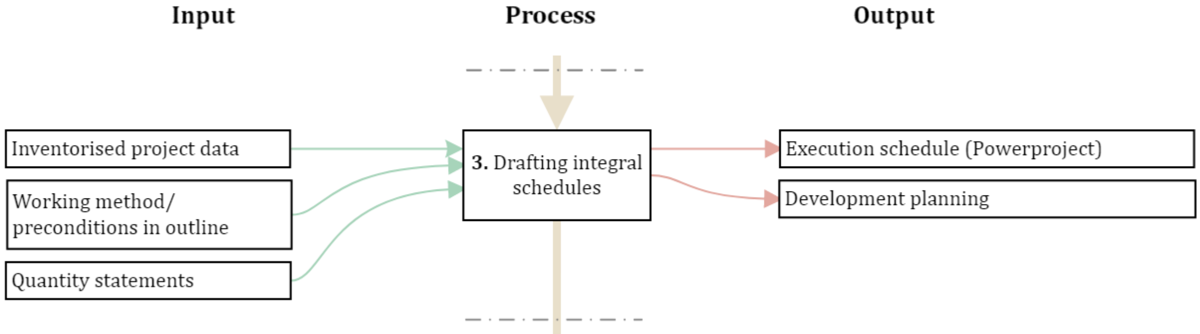


Figure 8: Flow-chart diagram representing step 3 of the ABK estimation process

Hereafter, a crane planning is set up concerning the use and positioning of cranes (figure 9, step 4). Situation drawings, floor plans and cross-sections of the project are decisive in the design of the crane planning. Using the data of the execution schedule and with the layout of the construction site in mind, the advisors are able to determine which type of cranes will be put into use and at which location on the construction site they will operate.

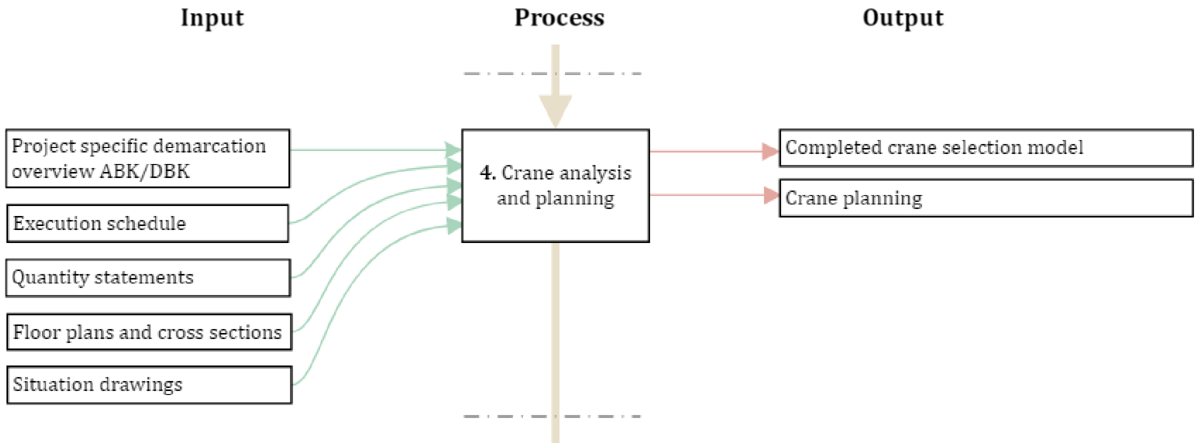


Figure 9: Flow-chart diagram representing step 4 of the ABK estimation process

Once the execution schedule and crane planning have been established, the optimal deployment of staff and equipment will be determined by making use of Powerproject (figure 10, step 5). Linked to the execution schedule, a planning is drawn up for the executive, technical and administrative personnel, called the UTA planning (Dutch: Uitvoerend, Technisch en Administratief). This planning represents the level of personnel required during the execution of the project. A full-time equivalent (fte) is allocated to each cost item within the UTA planning to indicate its workload. These scheduling steps are processed in the same way by all advisors.

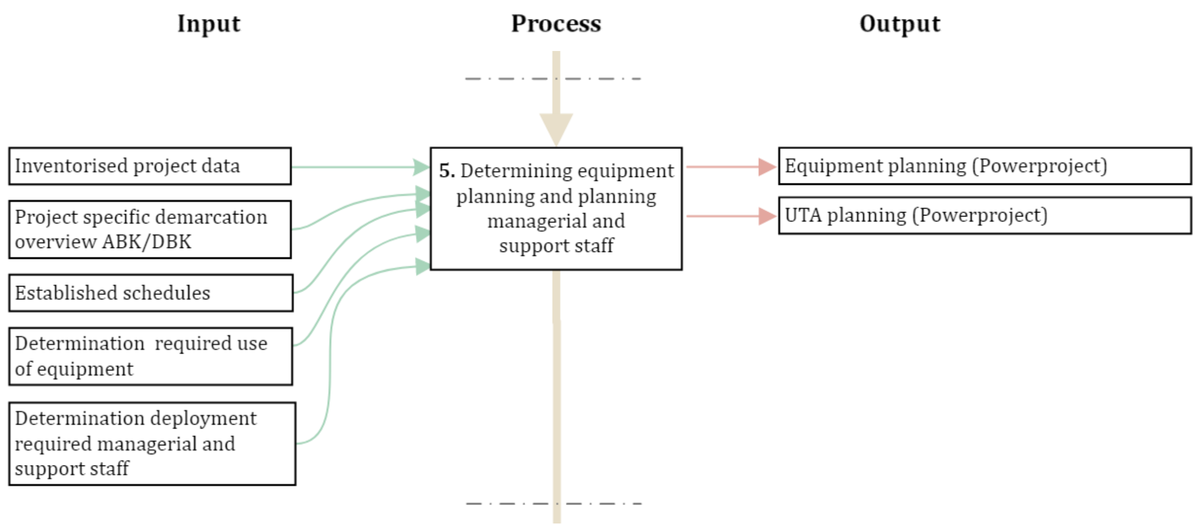


Figure 10: Flow-chart diagram representing step 5 of the ABK estimation process

3.1.3 DRAFTING CONSTRUCTION SITE LAYOUT

Situation, architectural and installation drawings serve as input for the development of the construction site layout plan. The optimal use of this layout is determined and shown in a 2D construction site layout drawing, as are the logistical principles (figure 11, step 6). In case a 3D model of the building is provided, the construction site layout can as well be modelled in 3D and added to the existing model of the building in Revit. Advisor 3 stated that 3D models of the construction site layout are increasingly used.

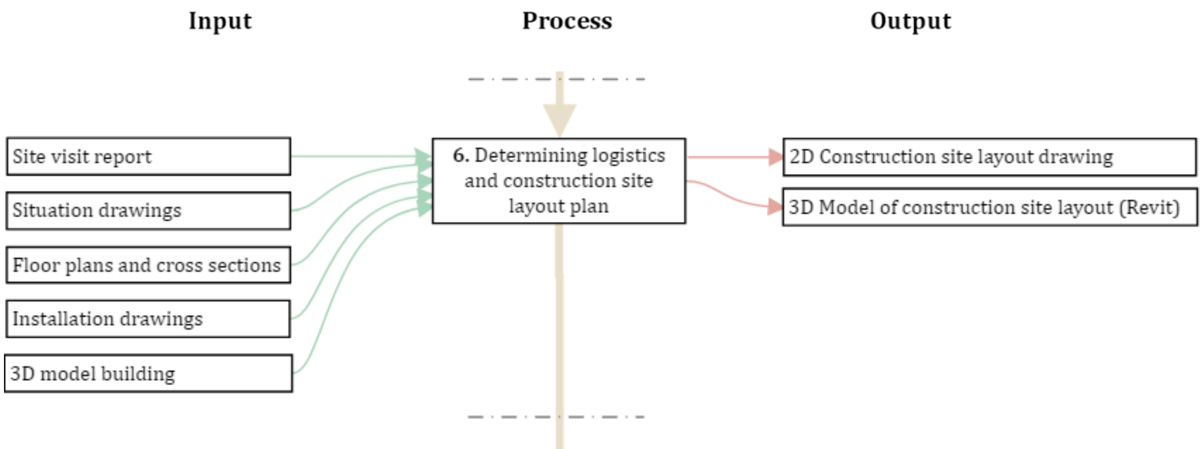


Figure 11: Flow-chart diagram representing step 6 of the ABK estimation process

3.1.4 DRAWING UP ABK ESTIMATION

The final ABK estimation is an amalgamation of input from the developed schedules and construction site documents. Once the UTA planning, equipment planning and the construction site layout are drawn up, the cost of their containing line items will be determined.

The pricing of staff costs is done by means of predetermined hourly rates. The hourly rates are fixed per function and are re-established every year and adjusted if necessary in an external worksheet in Excel.
In order to price the equipment and facilities, it may be needed to request quotations for certain construction site parts or cranes. The market-based prices for equipment or facilities will then be acquired by the equipment department (figure 12, step 7). The equipment department will verify the choices made for the use of equipment and facilities and will request the corresponding prices from the suppliers. For some equipment or facilities, there are costs for additional services. For example, when using a crane, the costs for the crane operator, the lifting supervisor and the traffic controller will also be included. Rates of standard cost items determined in advance can be entered in the ABK estimate in one go and are not requested from the equipment department for each individual project.

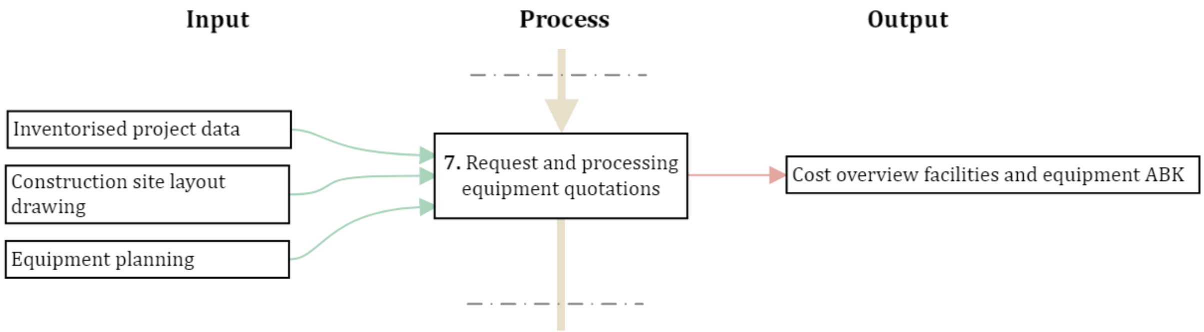


Figure 12: Flow-chart diagram representing step 7 of the ABK estimation process.

3.1.5 TECHNICAL COMPLETION

In accordance with the classification of the ABK model (2018), the cost items of the final ABK estimation are drawn up in a calculation program, called IBIS-TRAD. Quantity-related data to estimate each cost item are manually extracted from the information models in Powerproject and construction site layout drawings. The UTA planning provides quantities of personnel, their corresponding duration of deployment and fte. Quantities of facilities and equipment and corresponding duration of deployment are also manually extracted from the equipment planning in Powerproject and from the construction site layout drawings. After drawing up all line items of the ABK, a technical completion takes place (figure 13, step 8). None of the advisors mentioned digital tools to support these tasks.

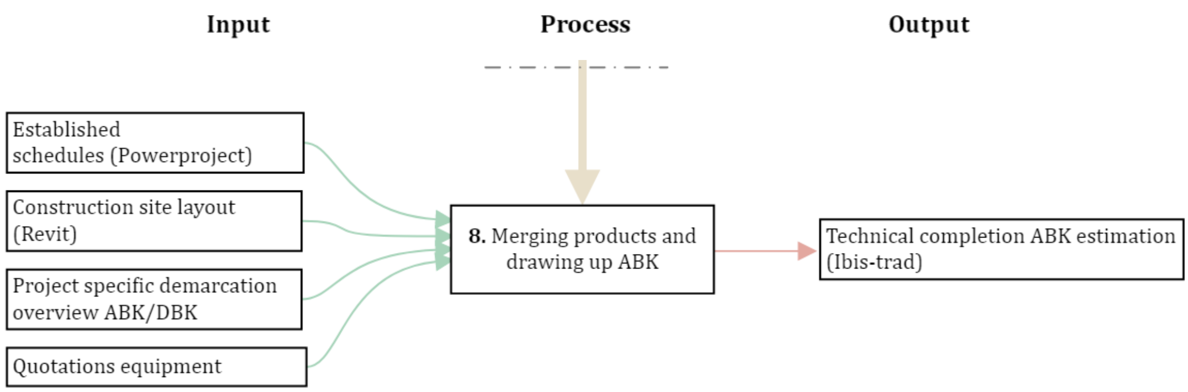


Figure 13: *Flow-chart diagram representing step 8 of the ABK estimation process*

Within a project, design or planning adjustments can take place. All advisors mention that as a result of these adjustments, changes can occur within the information models. Consequently, data needs to be manually extracted and re-entered in the ABK estimation after the technical completion. Advisor 2 confirms that "In some cases, the UTA planning is adjusted, which leads to the manual implementation of that change in the ABK estimation".

All interviewed advisors go through the same process steps as presented in the flow-chart diagrams and mention the same products and data required to prepare the ABK estimate. Although the process steps were clearly defined, implementation of these steps is mainly based on the expertise of the advisors. This is particularly applicable to the translation of project data into the integral planning and schedules. Differences can be pointed out in the preparation of the construction site layout. Depending on the availability of a 3D model of the building, the construction site layout is modelled in 3D or is worked out in 2D drawings. During technical completion of the ABK estimation, quantity-related data extraction is dependent on manual tasks. Described elements in the process which provide opportunities for improvement are included in the problem identification.

3.2 PROBLEM IDENTIFICATION

Related to the three main topics from the interviews, problems within the ABK estimation process were identified. These problems are substantiated by findings from the literature review.

3.2.1 PROCESS STEPS

Several elements within the elaboration of the ABK estimation were described as non-efficient by the advisors. In particular step 8, "merging products and drawing up ABK", is seen as a step that can be set up in a more efficient and consistent way. There is currently no singular checklist referenced to build up the contents of the estimate. Instead, the advisors have to manage various sources of information and amalgamate them into the ABK estimate. As stated by Clark and

Alzraiee (2019), the amalgamation diminishes the audit trail of the estimate. Furthermore, the implementation of the process steps is dependent on the experience of the advisors, resulting in different methods of estimation. This lack of consistency is in accordance with findings in previously conducted research (Ossa Mesa, 2021).

Corresponding with the methods described in literature, line items are set up to perform a detailed estimate of the indirect construction costs (Chao & Kuo, 2016). Based on project data, a translation into execution and personnel schedule is required. Expertise related to drawing up these schedules and deriving a construction site layout is decisive in making choices within the estimation process. It emerges from the interviews that currently only a small number of advisors possess this specific knowledge. In line with Banihashemi et al. (2022) advisor 2 mentioned that if simple manual tasks could be removed, there would be more space and time left to focus on other project-specific elements that are crucial for high-quality estimates, such as the identification of alternative building techniques, developing pricing and accounting for risks.

3.2.2 REQUIRED DATA

One of the problems defined by all interviewees is the lack of data interoperability among the information models used in the ABK estimation process. BIM applications Powerproject and Revit are used in the estimation process as they can provide various types of schedules and 3D visualisations of the construction site. However, the method used to extract cost item data from the building information models relies on human intervention. To complete the ABK estimation, once entered cost item data in Powerproject and Revit had to be manually taken over and entered into the calculation program IBIS-TRAD. The missing link between the BIM software and the calculation program leads to additional actions. Each line item needed to be manually added in the ABK estimation by referencing the drawings, specifications, and recalling specific knowledge. This manual re-entry of existing data and duplication of tasks is time-consuming and considered as inefficient (Grilo & Jardim-Goncalves, 2010).

3.2.3 ADAPTABILITY

Within a project, minor or major adjustments can take place, which can take quite some time to keep up with (Elbeltagi et al., 2014). The currently applied approach for ABK estimation decreases the extent to which direct insight into consequences of change can be obtained. Current practice does not effectively manage the dynamic change of the project once the estimate is finalised and construction is underway. Project changes will first have to be implemented in the information models and then manually re-entered into the calculation program. In accordance with Elbetagi et al. (2014), advisor 1 indicates that the required manual adjustments after change in duration or costs in line items is found time-consuming and thereby prone to errors.

3.3 NEEDS FOR DEVELOPMENT

From both theoretical and practical findings, a number of problems within the ABK estimation process have been identified. The missing links between the BIM applications, the reusability of project data and the invisibility in consequences of project changes are described as inefficient and inconsistent. Based on these problems, needs for development within this process are formulated in table 3.

Table 3: *Identification of development needs for the ABK estimation process*

Topic	Problems	Development needs
Process steps	There is no singular checklist referenced to build out the contents of the estimate, which leads to inconsistent estimation outcomes. The amalgamation of various information sources diminishes the audit trail of the final ABK estimate.	**Consistency** Guidelines to obtain quantities from various project documents in order to improve the consistency and audit trail of the process.
Required data	There is a lack of interoperability between the various used BIM software programs. The missing link between these programs leads to time-consuming tasks. The quantity take-off of cost item data is seen as a step that can be set up in a faster and more consistent way.	**Interoperability** Improvement of interoperability between BIM software in order to reuse project data and eliminate time-consuming tasks.
Adaptability	Current practice does not effectively manage the dynamic change in an ABK estimate once the estimate is finalised and construction is underway. The task of manually taking over project changes is time-consuming and prone to errors.	**Adaptability** Direct visibility in consequences of project changes without full dependence on manual intervention.

The needs for development mainly focus on the final steps in the ABK estimation process (figure 14). These steps involve the time-consuming task of manually extracting quantities from the used information models. By automating this task, substance can be given to the needs for improvement in consistency, interoperability and adaptability.

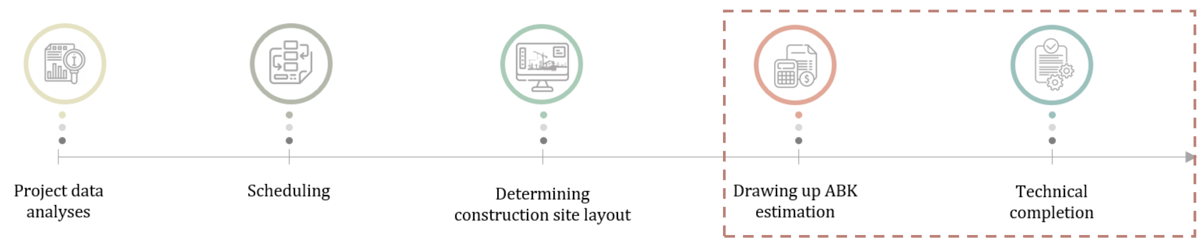
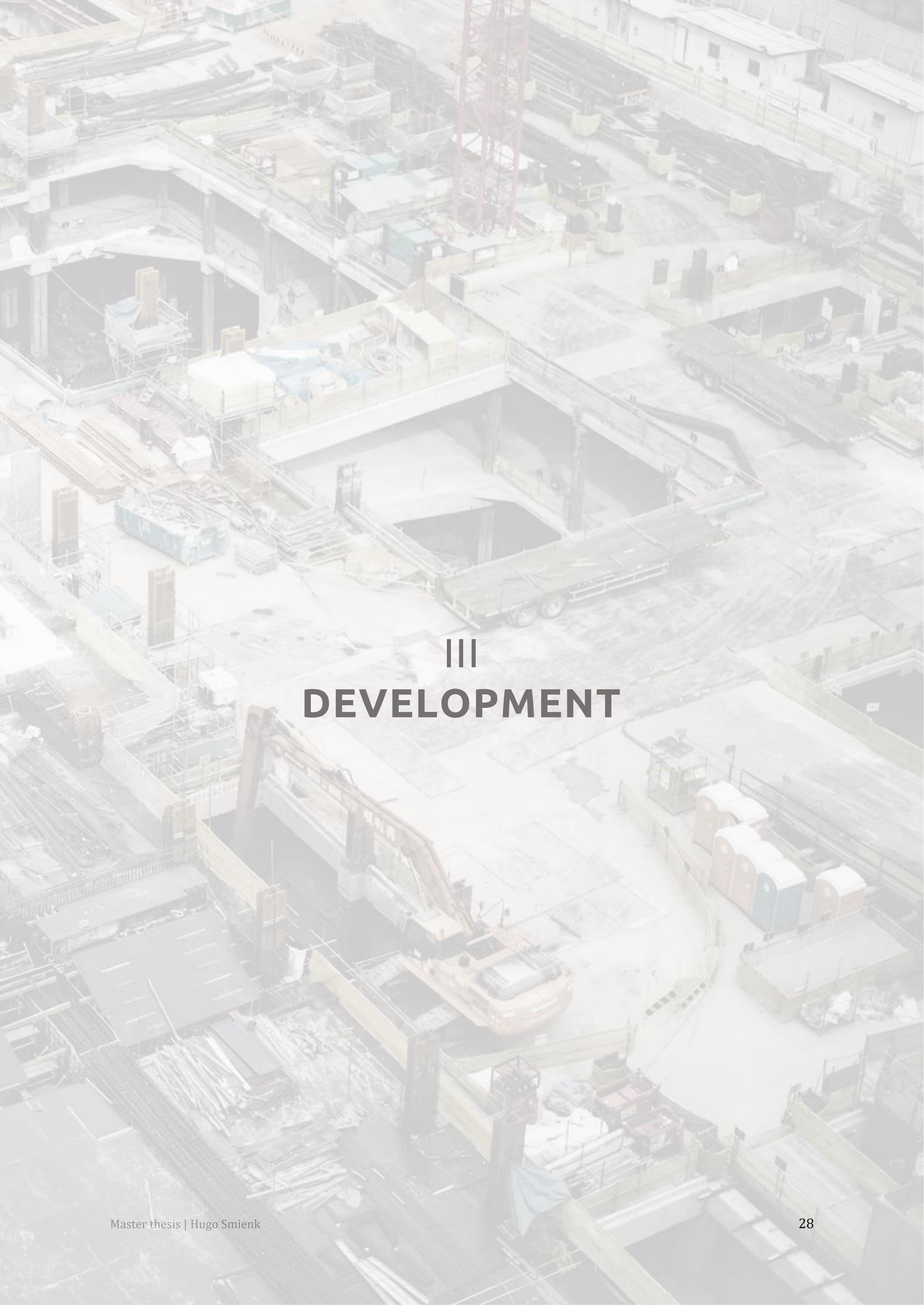


Figure 14: *Focus of development*

In conclusion, literature review and the practical functioning of the used ABK estimation process have contributed to answering the first research sub-question concerning how the current process of indirect cost estimation is set up. From the semi-structured interviews with three advisors in planning and logistics it was possible to identify the different steps taken within the process of the ABK estimation within Heijmans N.V. These steps can be clustered into five main subprocesses: project data analyses, scheduling, drafting construction site layout, drawing up ABK estimation and technical completion.

Regarding the second research sub-question, two information models to estimate the indirect cost items of the ABK model are used. BIM applications Powerproject and Revit provide various types of schedules and 3D visualisations. The software of Powerproject is used to draw up the execution schedule, UTA planning and equipment planning. A 3D model of the construction site layout is developed in Revit. However, the possibilities Revit can provide to automatically extract quantities from the 3D model for ABK estimation are not used in practice.

Within the last two sub-processes, the absence of automated links between the BIM software and the outcome of the ABK estimation means that consequences of variations in planning and changes in design cannot easily and quickly be made visible. Moreover, manual quantity take-offs lead to additional, time-consuming tasks for the advisors. Based on these problems, needs for improvement in consistency, interoperability and adaptability are formulated. A solution to the identified needs for development will be addressed in the next chapter.



III
DEVELOPMENT

4 | TOOL DEVELOPMENT

The process analysis contributed to the determination of the development needs in the ABK estimation process. In this chapter, these needs from the construction industry will be used to initiate the development of the ABK estimation tool. The tool aims at semi-automating extracting cost item data from the used information models in the ABK estimation process.
In paragraph 4.1, the development needs will be translated into tool requirements which determine the features and behaviour of the tool. The development process will be described step by step in paragraph 4.2. The last paragraph in this chapter (4.3) includes the process of verification, which will determine if the tool meets the technical requirement specifications and works as intended.

4.1 TOOL REQUIREMENTS

The identification of development needs in the process analysis was an important step for determining the features and functions of the ABK estimation tool. Table 4 presents a list of general requirements based on the defined development needs. They specify the overall intended functioning of the tool, required to provide solutions to the development needs. An overview of the translation from the identified problems into the tool requirements is included in appendix C.

Table 4: *General requirements according to the identified needs for development in the process analysis*

Development needs		General requirements
Consistency Guidelines to obtain quantities from various project documents in order to improve the consistency and audit trail of the process.	1.1	The tool provides insight into the steps that should be taken to obtain cost item data for the ABK estimation.
	1.2	The tool substantiates choices in use of cost item data.
Interoperability Improvement of interoperability between BIM software in order to reuse project data and eliminate time-consuming tasks.	2.1	The tool links BIM software to the outcome of the ABK estimation.
	2.2	The tool reuses once entered project data for the estimation of the ABK.
	2.3	The tool reduces the task time of extracting cost item data from BIM software.
Adaptability Direct visibility in consequences of project changes without full dependence on manual intervention.	3.1	The tool shows changes within the project in terms of consequences for the final ABK estimate.
	3.2	The tool is able to reduce manual tasks for obtaining cost item data for the ABK estimation.

It is aimed to meet the general requirements by semi-automating the task of extracting cost item data from the information models and thereby to improve the consistency, interoperability and adaptability of the process. The improvement in consistency will be supported by drawing up guidelines for data extraction and by the implementation of a coding system. The improvement in interoperability and adaptability will be mainly driven by the reduction in task time for generating the final ABK estimation outcome.

To show in a more tangible way how the tool will fulfil its general requirements, more detailed technical requirements are set up (table 5). They can be described as the factors required to deliver the desired functioning and behaviour from the tool. The technical requirements are formulated as objective measures and will be used for the verification of the tool later in the development process.

Table 5: *Technical requirements for the design of the tool*

Development needs		Technical requirements
Consistency	1.	The tool facilitates a structured description for obtaining cost item data from the information models.
	2.	Cost items in the information models Powerproject, Revit and Excel are provided with an ABK code in accordance with the classification of the ABK model 2018.
Interoperability	3.	The tool exchanges data from Powerproject to the estimation tool in Excel. The amount of information received by the tool is in accordance with the amount of information required.
	4.	The tool exchanges data from Revit to the estimation tool in Excel. The amount of information received by the tool is in accordance with the amount of information required.
	5.	The tool generates an outcome of the ABK estimation based on the extracted data from Powerproject, Revit and Excel.
Adaptability	6.	In every phase of the construction process, cost data can be extracted from the information models and imported in the estimation tool.
	7.	Any new or adapted cost items, obtained by changes in the information models, such as schedule changes or changes in the construction site layout, are directly visible in the ABK estimation outcome.
	8.	Change in the final ABK estimation outcome is directly noticed after adjustments are made in the linked information models.

4.2 DEVELOPMENT STEPS

The technical requirements are used as a starting point for the development of the ABK estimation tool. The tool consists of an Excel document, which is used to accumulate and process data from information models in order to generate an outcome of the ABK estimation. The development process can be divided into five steps. This paragraph will describe each of the steps in a chronological order. In practice, however, the development of the tool was an iterative process where development steps were not performed sequentially.

4.2.1 IDENTIFYING COST ITEM PARAMETERS

The cost of each item in the ABK estimation is related to a number of parameters. First the parameters required for estimation of each of the cost items are identified. A distinction can be made between the parameters needed for cost items in section 1 and cost items in sections 2 till 7 of the ABK model. The first section of the ABK model (see figure 2, B5B01) contains information about the managerial and supporting staff. Sections 2 till 7 contain information about equipment and facility costs (see figure 2, B5B02-07). Therefore, the quantity (fte), labour and hourly rate parameters are not applicable here. Table 6 shows an overview and description of the required parameters for cost items in each section of the ABK model.

Table 6: *Overview of required cost item parameters*

ABK section	Cost item parameter	Units	Description
1	ABK code	-	Coding of cost item based on classification ABK model 2018
	Item description	-	Description of cost item
	Duration	Weeks	Deployment duration of cost item
	Quantity	fte	Full time equivalent
	Labour	Hours per week	Number of working hours per week
	Hourly rate	Cost per hour in €	Hourly rate of cost item
2-7	ABK code	-	Coding of cost item based on classification ABK model 2018
	Item description	-	Description of cost item
	Duration	Weeks	Deployment duration of cost item
	Quantity	-, m1, m2, m3, etc.	Amount of equipment deployment
	Cost	Costs per week in €	Equipment cost per week of deployment
	Sub contractor	Costs per week in €	Sub contractor cost per week of deployment

4.2.2 LOCATING DATA

After identifying the cost item parameters, the second step in the development process is to determine the location of the data that serves as input for these parameters. The location of this data could be determined from the process description in paragraph 3.1. Here, it was found that the construction site model, UTA and equipment planning and the hourly rates table contain the required input data for the parameters of the cost items. These products are contained by the information models in Powerproject and Revit and in Excel. Figure 15 represents the location of input data for the cost item parameters.

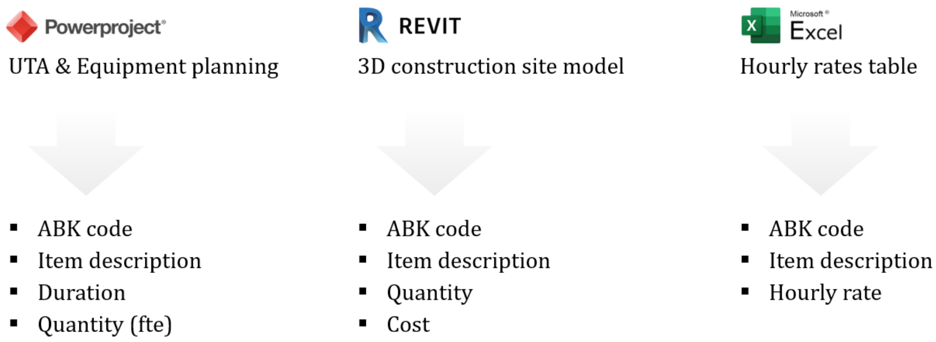


Figure 15: *Location input data*

4.2.3 COST ITEM CLASSIFICATION

A specific code is assigned to all cost items in the information models, which is based on the classification of the ABK model 2018 (see figure 2). The coding enables recognition and processing of each individual cost item once they are imported in Excel. The basis of the coding structure consists of a fold-out table. This table can be folded-out both horizontally and vertically and works from global to detailed (figure 16).

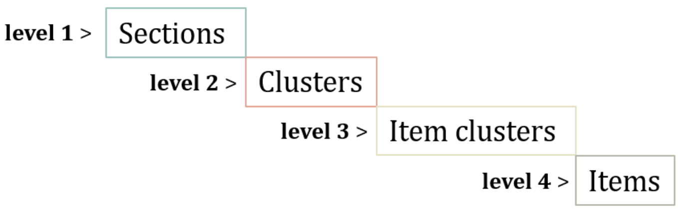


Figure 16: *Schematic representation of the structure of the fold-out table*

The first level represents the sections of the ABK model. Each section is subdivided into multiple clusters. The clusters correspond to the subheadings of each section. Sets of similar items within a cluster are combined into item clusters. Level 4 represents each individual cost item within the item cluster (see Appendix A). The code of a cost item according to this classification structure can, for example, be set up as follows: “3.8.2.1 Access control system”. This item is part of the layout and management of the construction site which is included in section 3 of the ABK model. Within this section, the item is subject to cluster 8: monitoring construction site and accommodations. The item is assigned to item cluster 2, which includes items for access control and security. Because this item is the first one that is assigned in its item cluster, the code ends with 1.

To apply this coding structure, a new parameter is set up in the information models, named ‘ABK code’. An item specific ‘ABK code’ has been assigned to each of the cost items in the UTA planning, equipment planning, construction site model and hourly rates table.

4.2.4 DATA EXTRACTION

Once the coding of the cost items has been completed, the input data can be extracted from the information models. Before extracting data from Revit, a quantity take-off (QTO) schedule needs to be set up first. This schedule will show an overview of the quantities of all cost items present in the construction site model. In Revit, a QTO schedule can be set up by selecting the "Schedule/Quantity" window (figure 17).

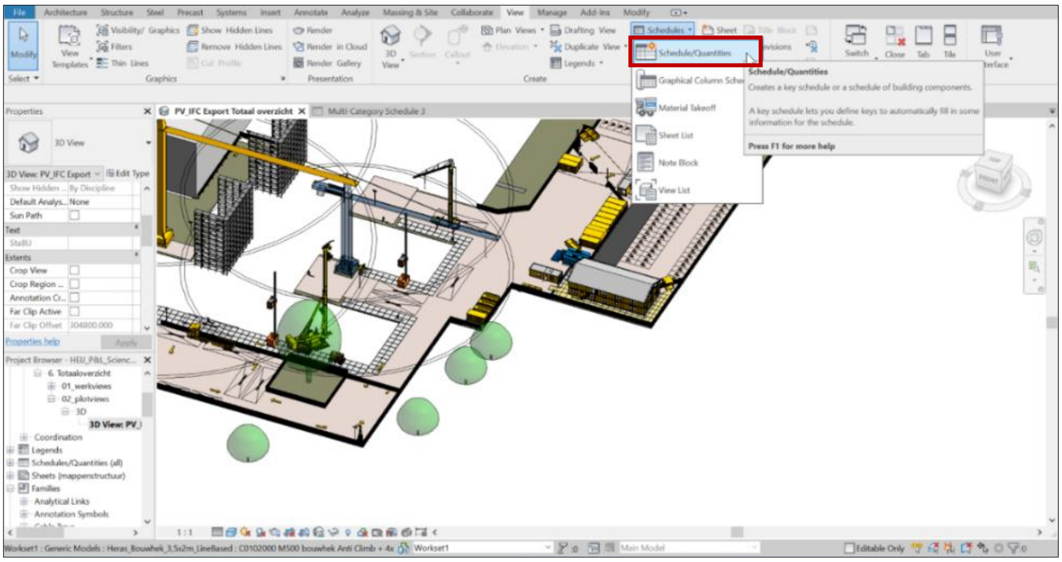


Figure 17: First step of creating a QTO schedule in Revit

After selecting the required parameters for data extraction, an overview of quantities of cost items present in the 3D model will be shown (figure 18). A complete description of all steps for setting up a QTO schedule in Revit is included in appendix C.

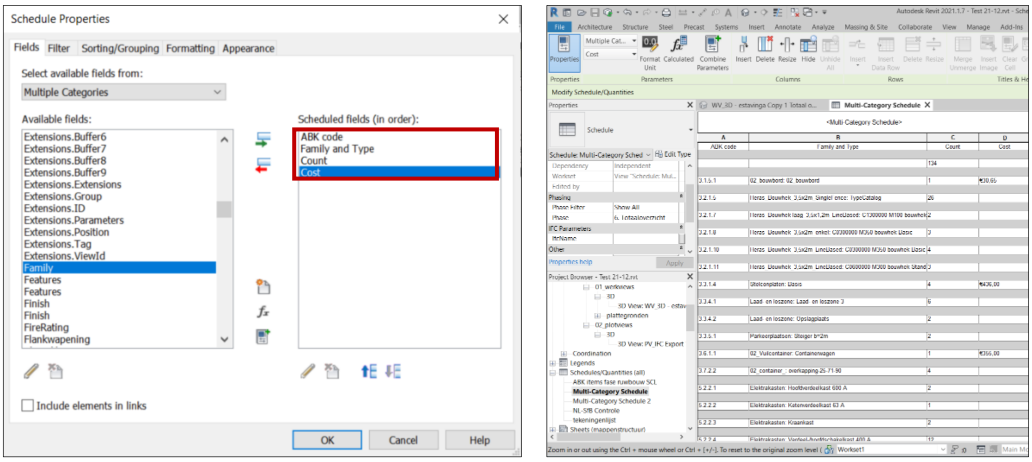


Figure 18: Second step of selecting cost item parameters and overview of a QTO schedule in Revit

Once the QTO schedule in Revit is completed, the data is ready to be extracted. It is required that data in the information models is translatable into the Excel file format of the ABK estimation tool, so that all data can be transferred correctly. This can be achieved by exporting the data to a CSV (Comma-separated values) file. The data in Powerproject does not require any additional steps in order to be exported to a CSV file. The CSV files can be imported in Excel in the designated “import sheets” of the tool. The last sheet of the estimation tool (“Guidelines data extraction”) includes a structured description of the required steps for the task of data extraction from Revit and Powerproject. By following these steps, the current practice of manually re-entering each cost item from the information models into the ABK estimate is converted into a semi-automated task.

4.2.5 PROCESSING DATA

After extracting and importing, the final step is to translate the data into an outcome of the ABK estimation. The tool merges data from the various information models using the corresponding ‘ABK code’. Figure 19 shows an example of how the tool uses the ‘ABK codes’ to read out the data from the import sheets in order to generate an overview of the cost items. Parameter values of each item will be multiplied in order to establish its costs. The final output will contain an overview of the classified cost items and their corresponding costs.

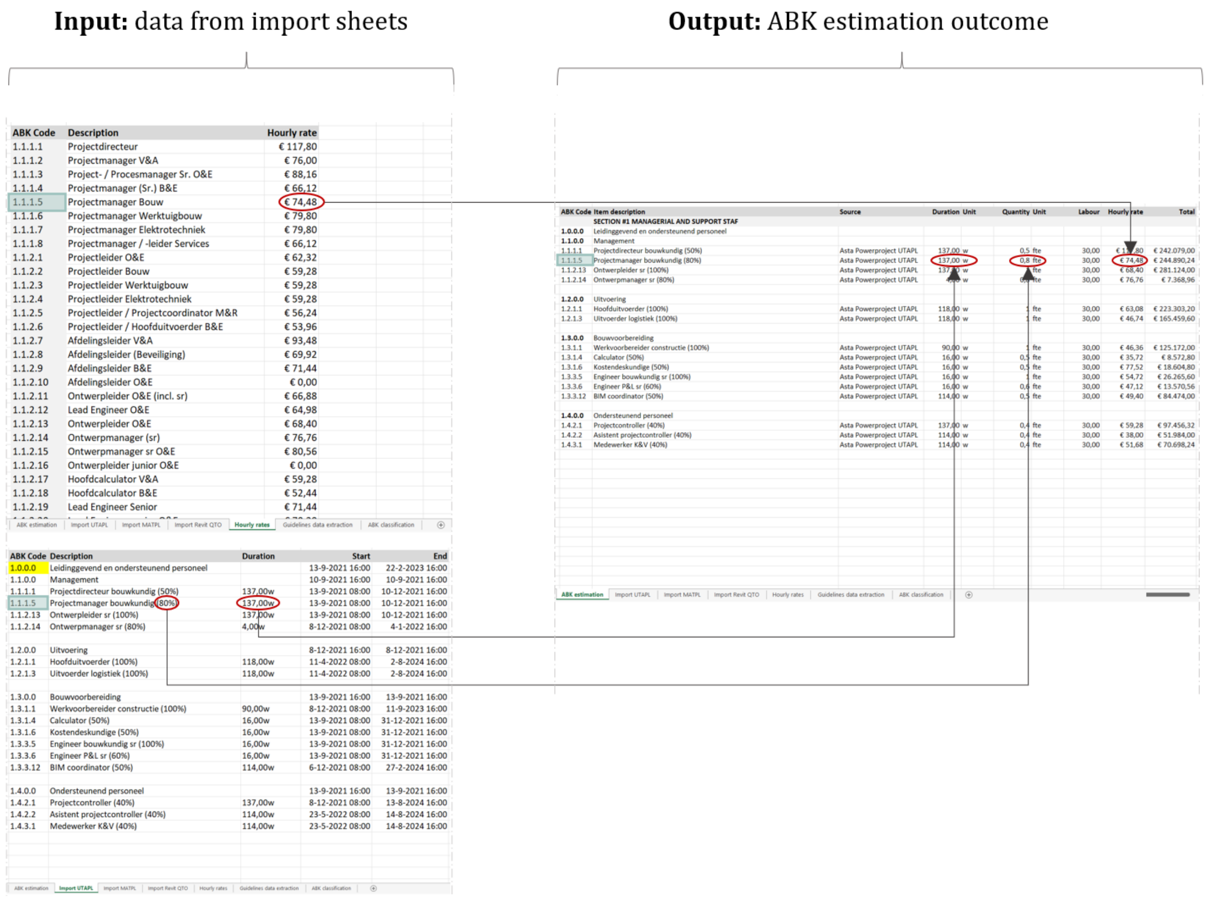


Figure 19: Processing of imported data to generate the outcome of the ABK estimation

After changes have been made within the planning or construction site model, the data extraction step can be repeated. Data can be re-imported into the import sheets which will allow the tool to automatically generate an updated outcome of the ABK estimation.

A pre-requirement for using BIM solutions for indirect cost estimates concerns the fact that automation by the estimation tool is only possible if the information models are created according to the standards set by the cost estimator. If not, the tool might give incomplete values, or parts of the final ABK estimate are impossible to obtain. Therefore, the outcome of the developed ABK estimation tool strongly depends on the completeness of the input data from the information models. Related to this precondition, the tool requires the use of a 3D construction site model for extracting quantities for the input of cost item parameters in sections 2-7 of the ABK model. In case a 2D construction site layout is still used, a complete estimate of the cost items can not be accomplished by the tool.

4.3 VERIFICATION

The process of verification evaluates whether the tool is operating as intended without failures or mistakes. By making use of data from a reference project within Heijmans N.V., a step-by-step verification of the data operations of the tool is conducted. This way of verification assesses if the tool complies with the technical requirements as identified in paragraph 4.1.

The technical requirements are evaluated in an objective way. An assessment matrix is set up in table 7, which allows assigning scores to each of the requirements. A scale bar with scores from 1 to 3 is applied to indicate the level of satisfaction. A score of 1 represents no satisfaction of the requirement and asks for redesign of the tool. When a requirement gets assigned a score of 2, this requirement is partly satisfied. It will be considered whether an incomplete satisfaction restricts the functioning of the tool or is found acceptable. A score of 3 indicates full satisfaction of the requirement by the tool. The subsequent paragraphs will elaborate on the assigned scores for each of the technical requirements.

Table 7: Verification of technical requirements

Development needs		Technical requirements	Score
Consistency	1.	The tool facilitates a structured description for obtaining cost item data from the information models.	3
	2.	Cost items in the information models Powerproject, Revit and Excel are provided with an ABK code in accordance with the classification of the ABK model 2018.	3
Interoperability	3.	The tool exchanges data from Powerproject to the estimation tool in Excel. The amount of information received by the tool is in accordance with the amount of information required.	3
	4.	The tool exchanges data from Revit to the estimation tool in Excel. The amount of information received by the tool is in accordance with the amount of information required.	3
	5.	The tool generates an outcome of the ABK estimation based on the extracted data from Powerproject, Revit and Excel.	3
Adaptability	6.	In every phase of the construction process, cost data can be extracted from the information models and imported in the estimation tool.	3
	7.	Any new or adapted cost items, obtained by changes in the information models, such as schedule changes or changes in the construction site layout, are directly visible in the ABK estimation overview.	2
	8.	Change in the final ABK estimation outcome is directly noticed after adjustments are made in the linked information models.	2

4.3.1 CONSISTENCY

The use of different estimation methods can lead to inconsistencies in the outcomes of the ABK estimation. A structured process description for quantity take-offs and the classification of cost items will have to contribute to the improvement of consistency and audit trail of the ABK estimation outcome. Related to the consistency of the process, technical requirements 1 and 2 are evaluated.

1. The tool includes guidelines for extracting and importing data from the information models. The required steps to obtain data from the UTA and equipment planning in Powerproject and from the construction site model in Revit are described in the "Guidelines data extraction" sheet of the estimation tool.

2. The tool applies a classification of cost items in accordance with the ABK model drawn up by the NVBK and Bouwend Nederland (2018). The coding ensures that the right input for the cost items in the ABK estimation outcome can be extracted from the import sheets. Application of this cost item classification and the described format of the tool makes it possible to process comparable data from other construction projects in the same way.

4.3.2 INTEROPERABILITY

The quality of interoperation refers to the interconnection of the different sources of information and can be measured by the quality of exchange and the quality of use. The quality of exchange draws up if the exchange is correctly performed i.e. if information sent to another program succeeds. The quality of use represents the amount of information received by a partner in comparison with the amount of information requested (Ducq & Chen, 2008). Technical requirements 3-5 are linked to the quality of interoperability.

3. The exchange of data between Powerproject and the ABK estimation tool succeeds without any problems. No data is lost when exporting the UTA or equipment planning to a CSV file. The tool is able to load the data in the designated import sheets. The amount of data received by the tool is in accordance with the amount of data required. Data extraction from Powerproject fully satisfies the third technical requirement.

4. The exchange of data from Revit is executed in the same way as is the case for Powerproject. The extraction is performed without any problems or errors. Besides, the amount of data exchanged is in accordance with the amount of data required for the ABK estimation. The data extraction from Revit fully satisfies the fourth technical requirement.

5. The extracted data in the import sheets provide the right input for the tool to generate an ABK estimation outcome. After importing the data, no further actions need to be taken. Data from the various information models is used to automatically fill the cost item parameters and calculate the corresponding costs. The tool summates the costs of all imported cost items and shows the outcome of the final ABK estimate. Technical requirement 5 is therefore fully met.

4.3.3 ADAPTABILITY

Construction schedules are dynamic and often require to be updated with different changes which is reflected in the time-consuming process of planning and renewing. Achieving a higher level of automation in construction scheduling needs quantitatively assessed up-to-date information. It is desirable for the ABK estimation tool to be able to incorporate these changes without excessive manual programming. Therefore, technical requirements 6-8 should be met.

6. In any desired phase of the construction project, the described step of data extraction can be performed. There are no phases during the construction project that restrict the use of the estimation tool, which leads to full satisfaction of the sixth requirement.

7. Any additional or modified cost items that result from changes in the information models, can be connected to the estimation tool. After re-importing the adjusted data from the information models, the tool is able to automatically update the overview of the ABK estimation. However, due to the intermediate step of re-importing the data, the requirement for direct visibility in any new or adapted cost items is therefore not fully met. A score of 2 is considered acceptable within the scope of this research on account of the achieved reduction in manual tasks.

8. Besides updating the overview of the ABK estimation, the tool is also able to regenerate an outcome of the ABK estimate. Financial consequences of project changes are hereby noticed. Although the tool features an appropriate degree of adaptability, there is no function to continuously gain automatic updates from the information models. This can be explained by the semi-automatic character of the data extraction step. The requirement for direct visibility of consequences of project changes within the outcome of the ABK estimation is therefore not fully satisfied. However, due to the obtained reduction in manual tasks, a score of 2 is found acceptable within this scope of research.

In this chapter, the identified development needs served as the basis for the formulation of tool requirements. General requirements were set up to define the overall intended functioning of the tool which was required to address the needs for development. A more detailed specification of technical requirements was set up and served as the starting point of the development process. Here, five development steps could be defined: identification of cost item parameters, locating data, cost item classification, data extraction and processing data. Based on a coding structure, the tool was able to semi-automatically extract and process cost item data from information models. By amalgamating this data, an outcome of the ABK estimation could be generated.

Development of the tool was followed by the process of verification. Scores were assigned to the technical requirements by making use of an assessment matrix. The tool fully complies with the technical requirements related to consistency and interoperability. The functionality of the tool was not restricted by the incomplete scores related to the adaptability requirements. The next chapter will focus on the process of validation, which will determine if the development of the estimation tool provides the right solution to the needs for development within the ABK estimation process.

IV
OUTCOME

5 | TOOL VALIDATION

The focus of the previous chapter was on the development of the ABK estimation tool. The various development steps were described and the working of the tool was eventually assured by reflecting the technical requirements during verification. This chapter will evaluate the validity of the developed tool. The validation process will determine if the needs for development in the ABK estimation process are satisfied by the implementation of the tool. Paragraph 5.1 will elaborate on how this process was set up, whereafter paragraph 5.2 will describe the validation results.

5.1 VALIDATION APPROACH

The validity of the ABK estimation tool is assessed on the basis of data from a reference project of Heijmans N.V. within the institutional and commercial sector. The ABK estimation process of this project will be compared with a redesigned process where the developed tool is applied. Validation is performed under optimal conditions, meaning that any necessary learning curve for using the tool and any additional task duration for the one-time step of encoding the cost items within the reference project have not been taken into account. The focus will be on tasks within two sub-processes of the ABK estimation (dotted area in figure 20) where problems related to obtaining cost item data have been identified (paragraph 3.2). It will be determined whether these needs are met and, accordingly, whether the tool positively affects the efficiency of the ABK estimation process. For each of the development needs it will be described how validation is performed.

The need for improvement in consistency was based on the lack of guidelines to obtain quantities in the ABK estimation process. To validate the tool in terms of consistency, it is required to let multiple advisors estimate the ABK of the same project by making use of the tool. The outcomes can be compared in order to determine whether the tool contributes to the process consistency. This method of validation was not applied within this research. It will therefore not be possible to substantiate this part of the validation. Instead, this need for development will be qualitatively reflected based on literature findings.
The aim of improving interoperability is to reuse project data and thereby eliminate time-consuming tasks. Tasks within the sub-process of drawing up ABK estimation are related to the development need for improvement of interoperability. The need for improvement in adaptability is focused on the speed at which insight in financial consequences of project changes can be

obtained. Tasks within the sub-process of technical completion are related to the development need for improvement of adaptability. For both needs, the elimination of manual intervention in order to reduce the duration of tasks is the main requirement. Fulfilment of these development needs can be measured in units of time and will therefore be quantitatively validated. The applied process in the reference project and redesigned processes are compared concerning their duration of tasks.

5.2 VALIDATION RESULTS

In the applied process in the reference project, a total of 271 hours was spent in order to obtain the final ABK estimation outcome. The two sub-processes, drawing up ABK estimation and technical completion, took 54,2 and 27,1 hours respectively (figure 20). The tool was able to perform tasks within these two sub-processes by making use of the available schedules and 3D construction site model from the reference project.

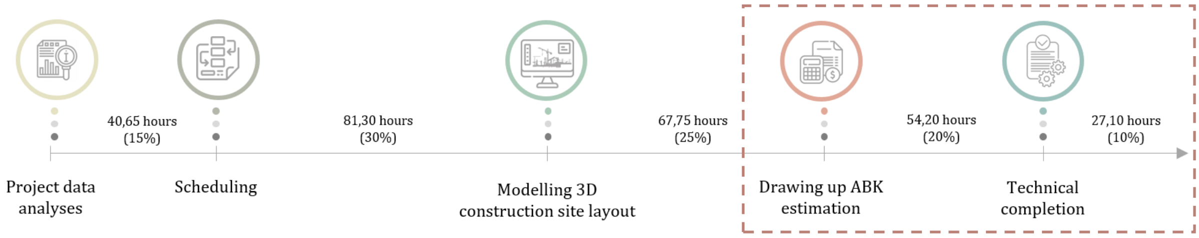


Figure 20: *Duration of sub-processes ABK estimation based on reference project data*

5.2.1 VALIDATION CONSISTENCY

A consistent approach and format to cost estimation contributes to a similar outcome of the estimate even when performed by different advisors (Edwards, Jensen & Haug, 2007). This is ought to ensure uniformity and enables standardised comparisons between the ABK estimates. It is assumed that when different advisors apply the same structured guidelines for extracting quantities from the information models, more consistent outcomes will be achieved among the indirect cost estimates.

In the development of the tool, consistency was supported by the implementation of a coding classification system. In general, coding can help to operate computerised cost accounting and facilitates the process of allocation of indirect costs (Rai, 2016). It is therefore assumed that the use of the ABK coding classification system will support the functioning of the tool and makes it possible to track the data used for indirect cost estimation.

5.2.2 VALIDATION INTEROPERABILITY

The estimation tool replaces three tasks related to quantity take-offs in the drawing up ABK estimation sub-process: data extraction from Powerproject, data extraction from the construction site layout and data extraction from the hourly rates table. Instead, the tool requires the preparation of a QTO schedule in Revit and the extraction of data from the information models to the tool in Excel.

Data extraction from the UTA and equipment planning in Powerproject was performed in 1 minute and 2 seconds and in 1 minute and 16 seconds respectively. The drawing up of the QTO schedule in Revit was performed in 1 minute and 4 seconds. The subsequent task of extracting the data from the 3D construction site model in Revit was performed in 53 seconds. The final outcome of the cost items generated by the tool was compared with the outcome of these cost items in the reference project. Without detecting any discrepancies between these outcomes, the tool was able to reduce the duration of the sub-process of drawing up the ABK estimation by 59,87%. Table 8 shows an overview of the reduction in task times after implementation of the ABK estimation tool for each of the sub-processes.

Table 8: *Task time of quantity take-offs before and after implementation of the ABK estimation tool*

Sub-process	Tasks	Duration	Tasks estimation tool	Duration
Drawing up ABK estimation	Data extraction from Powerproject	5,42 hours	Data extraction from UTA planning Powerproject to ABK estimation tool	01:02 minutes
			Data extraction from equipment planning Powerproject to ABK estimation tool	01:16 minutes
	Data extraction from construction site layout	16,26 hours	Drawing up quantity schedule 3D construction site model Revit	01:04 minutes
			Data extraction from construction site model Revit to ABK estimation tool	00:53 minutes
	Data extraction from hourly rates table	10,84 hours	Extraction hourly rates data from Excel	00:00 minutes (Automatically)
	Other	21,68 hours	Other	21,68 hours
	Total:	54,20 hours		21,75 hours
	Time reduction sub-process:			**59,87%**
Technical completion	Processing of adjustments from Powerproject	1,36 hours	Processing of new or adapted cost items in UTA planning in the ABK estimation outcome	00:45 minutes
			Processing of new or adapted cost items in equipment planning in the ABK estimation outcome	00:45 minutes
	Processing of adjustments from construction site layout	1,36 hours	Processing of new or adapted cost items in construction site model in the ABK estimation outcome	00:51 minutes
	Other:	24,38 hours	Other	24,38 hours
	Total:	27,10 hours		24,43 hours
	Time reduction sub-process			**9,86%**

5.2.3 VALIDATION ADAPTABILITY

The estimation tool replaces two tasks in the technical completion sub-process: implementation of adjustments from Powerproject and implementation of adjustments from the construction site layout. To perform these tasks, the tool requires semi-automated re-extraction of new or adapted cost items in the information models. Adjustments in cost item parameters concerning the amount of fte's in the UTA planning, the duration of deployment in the equipment planning and the amount of deployed equipment in the construction site model were used to simulate project changes.

After the adjusted data in the information models was extracted, the tool was able to process these adapted cost items. The task of assimilating changes from the UTA and equipment planning was performed in 45 seconds. Implementing changes from the construction site model was performed in 51 seconds. Here too, the final outcome of the cost items generated by the tool was compared with the outcome of these cost items in the reference project. Without detecting any discrepancies between these results, the tool was able to reduce the total duration the technical completion sub-process by 9,86%.

Figure 21 shows the redistribution of duration of the ABK estimation sub-processes, resulting from the implementation of the estimation tool. The sub-processes concerning project data analyses and scheduling now cover a larger part of the total ABK estimation process duration than before.

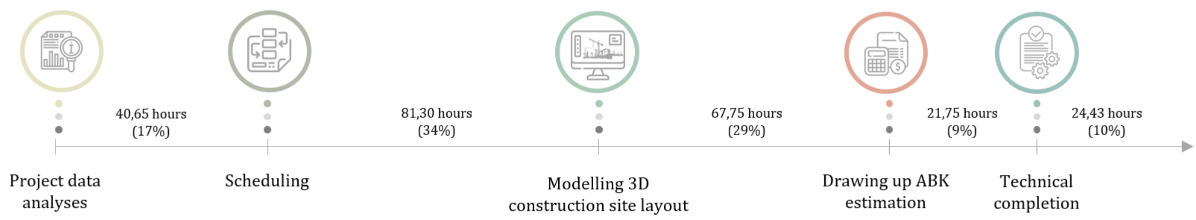


Figure 21: *Duration of sub-processes after implementation ABK estimation tool*

5.2.4 VALIDATION EFFICIENCY

Task time, determined as one of the ISO standards for usability, is used as a measure to determine the impact of the estimation tool on the efficiency of the ABK estimation process. It can be concluded that in accordance with this reduction in task time, the implementation of the tool contributes positively to the efficiency of the ABK estimation process by a reduction of the total process duration of 12.96% (table 9). Although not quantitatively assessed within the reference project, it is assumed that the transition from manual to semi-automated tasks can positively contribute to the reduction of unnecessary actions and the amount of human errors.

Table 9: Total impact of the tool on ABK estimation process efficiency

ABK estimation process	Duration
Current practice	271 hours
Implementation estimation tool	235,88 hours
Reduction in duration	**12,96%**

The results of the validation process have been discussed with practitioners. It was confirmed that the achieved reduction in task time was a satisfactory result. The developed tool was hereby found to contribute to the more efficient and faster implementation of changes, which in many cases take place at the end of the tender process. Furthermore, the application of the tool was valued as a means to generate more consistent outcomes from the different advisors.

The implementation of the estimation tool within the reference project gave insight into the effects on current practice. As a result of the validation process, an answer can be given to the third research question: *How can efficiency be improved in the indirect cost estimation process?* It is assumed that by providing structured guidelines for the extraction of indirect cost data, greater uniformity can be achieved among the indirect cost estimates. By making clear which data sources are used, the audit trail of the estimation of indirect cost items can be improved.
Improving the interoperability between BIM software by the tool resulted in a reduction of task time within the process of ABK estimation. Hereby, a more direct link was created between the information models and the outcome of the ABK estimate. Compared to current practice, new and adapted cost items can be assimilated in a shorter period of time. The implementation of the tool contributes positively to the efficiency of the ABK estimation process by a reduction of the total process duration of 12.96%. From practice, this was found a satisfactory result. In conclusion, main benefits of the tool are the structured guidelines for quantity take-offs, a reduction in time for QTO tasks and implementation of project changes within the outcome of the ABK estimate.

6 | CONCLUSION AND DISCUSSION

This chapter provides the conclusion and discussion of this research. In paragraph 6.1, answers will be given to the main and sub-research questions. Thereafter, the research results will be discussed and linked to possible limitations (6.2). Finally, recommendations will be made for practical implementation of the research outcome (6.2.1) and for future research (6.2.2).

6.1 CONCLUSION

In this research, it was aimed to improve the efficiency of the process of indirect construction cost estimation. Redesign of this estimation process demanded for a more systematic description to understand the weaknesses of present procedures and to identify new processes. The first sub-question of this research focussed on: *How is the current process of indirect cost estimation set up?*

In the Netherlands, the ABK model, which is used for the determination of the indirect construction costs, defines and categorises the indirect construction costs according to project and cost characteristics. In the current process of the ABK estimation within Heijmans N.V. five main sub-processes could be identified: project data analyses, scheduling, drafting construction site layout, drawing up ABK estimation and technical completion. Within these last two sub-processes, problems were identified related to the lack of consistency, interoperability and adaptability. To estimate the indirect cost items of the ABK model, data can be extracted and processed from building information models. How these information models are put in use is answered by the second research sub-question: *How can BIM be used to estimate the indirect cost items of the ABK model?*

By integration and coordination among building components and their scheduling data, BIM can be used in cost and quantity estimates. BIM has the ability to visualise construction projects from the design phase and integrate this visualisation with project cost estimation and control. In the process of ABK estimation within Heijmans N.V., several BIM applications were applied. Revit was used for modelling the physical elements of the ABK, which were located on the construction site. In Powerproject, the schedules for UTA personnel and equipment were set up. Both information models contained data for estimation of the cost items of the ABK model. However, these BIM solutions did not automatically generate indirect cost estimates by any means. The absence of automated links between the BIM software and the outcome of the ABK estimation resulted in a lack of visibility of variations in planning and changes in design. Manual quantity take-offs led to time-consuming tasks for the advisors. Therefore, the third research sub-question was defined as: *How can efficiency be improved in the indirect cost estimation process?*

A proof-of-concept tool was proposed to reduce manual interventions in the estimation process of the ABK. Based on a coding structure, this ABK estimation tool semi-automatically extracted and processed cost item data from the information models. By amalgamating this data, an outcome of the estimate was generated. A more direct link was created between the information models and the outcome of the ABK estimate by replacing manual tasks in the sub-processes of drawing up ABK estimation and technical completion. The tool was tested within a reference project whereby improving interoperability between the BIM software resulted in a reduction of task time within the sub-process of drawing up ABK estimation by almost 60%. Compared to current practice, improvement in adaptability was achieved by assimilating new and adapted cost items in a shorter period of time. A reduction in task time by nearly 10% within the sub-process of technical completion was achieved. Implementation of the tool contributed positively to the efficiency of the ABK estimation process by reducing its total duration from 271 hours to 235 hours. From practice, these results were determined as a satisfactory outcome.

To conclude, a computer-based tool was developed to semi-automatically extract quantity take-off-related data from building information models and process this data to estimate the indirect cost items of the ABK model. The proposed ABK estimation tool reduced manual tasks in the final completion of the ABK budget which will eventually allow the cost estimators to use their time more efficiently. Besides the gained reduction in time, it is assumed that the more standardised application for the estimation of the ABK will improve the consistency within this process.

6.2 DISCUSSION

From literature it was concluded that BIM software can be used for allocating and linking the required quantities for direct construction cost estimates. It was expected that by means of these features of BIM, improvements in terms of efficiency could as well be made within the process of indirect cost estimation. In this research, a method for interoperability between building information models that are put in use during the ABK estimation process was incorporated in a proof-of-concept tool. The tool was able to accelerate the quantity take-off process by replacing manual interventions with semi-automatic tasks. The implementation of the tool resulted in the fulfilment of the development needs and the goal of this research to increase the efficiency of indirect construction costs management. The expectations based on the literature review have therefore turned out to be true.

The achieved results of this research can also be related to the linking of BIM dimensions. By connecting the 3D construction site model and a 4D planning to the ABK outcome, a shift took place from a manual 2D estimate to a semi-automated 5D estimate. This transition adds possibilities for the ABK estimation such as the ability to provide data in real-time, visualise costs and improve the decision-making process. More direct insight in financial consequences of project changes or the use of alternative construction methods can be obtained due to the developed links between the information models and the ABK estimation tool. In addition to the resulted reduction in process duration, the expected improvement in process consistency by providing guidelines and process steps for drawing up the ABK estimate can be seen as another satisfactory result of this research.

Besides the mentioned possibilities the ABK estimation tool provides, a couple of limitations are present. According to Azhar (2011) information models for indirect cost estimation are more detailed than in the case of a traditional designing process, including the possibility of adjustment to changes during the construction project. Moreover, the automation of the quantity take-off process enables a faster analysis of the costs and variants of the construction. However, it should be noted that while information models provide adequate measurements for quantity take-offs, they do not automatically generate indirect cost estimates by any means. Advisors perform a critical role in the construction process far beyond that of extracting counts and measurements. The process of estimating involves assessing conditions in the project that impact cost, such as unique assemblies and difficult access conditions (Assaf, 2001). There are still intangibles, such as site conditions or general requirements, that can not be incorporated in the information models and require the expertise of the advisors. Automatic identification of these intangibles is not feasible by the tool.

Another limitation concerns the fact that the development of the estimation tool is designed for the use of predetermined BIM software programs. Its implementation could be limited when potential end-users apply other programs in their estimation process than in this research.

It must be noticed that validation was performed by the developer of the tool, which creates optimal conditions. It enabled the validation steps to be carried out correctly in one go. This might have tended to more positive results than would have been the case when potential end-users without full knowledge about the tool would have performed these validation steps. The time required for the task of coding the cost items was also not included. This task is seen as a one-time investment which, once completed, can be benefited from.

During the validation phase, conclusions regarding improvements in consistency could not be fully substantiated. Therefore, this part of the validation had to be worked out on the basis of assumptions. This can be seen as a limitation of the findings within this study.

To validate the tool in terms of adaptability, adjustments of single cost items within each of the information models were taken as a starting point. In practice, following project changes, it will take longer to manually implement more than one cost item adjustment in the ABK estimation outcome. When applying the estimation tool, regardless of the number of changes, only one task is required to implement the adjustments in the ABK estimation outcome. The tool's contribution to the process adaptability will therefore increase as more changes occur throughout the construction process.

6.2.1 RECOMMENDATIONS PRACTICAL IMPLEMENTATION

Building information models do not automatically generate indirect cost estimates by any means, but they can offer advantages over traditional based methods by minimising manual quantity take-offs. Estimators should therefore consider using the concept of the ABK estimation tool in addition to BIM solutions to facilitate the laborious task of quantity take-offs in the ABK estimation process.

For practical use, in order for the ABK estimation tool to be effective, adjustments of process steps will have to take place. This includes the classification of cost items in the information models and the replacement of manual tasks by semi-automatic tasks for quantity take-offs. Redistribution of the duration of the ABK estimation sub-processes, will free up time to spend on, for example, the identification of alternative construction methods and factoring of risks which will contribute to high-quality cost estimates. To achieve this, there has to be more focus on the completeness with which the planning and construction site model are drawn up in order to maximize the added value of the tool. Cost items in the construction site model can hereby be supplemented with cost information in addition to their ABK code. It is assumed that coding the cost items will take some time, but once applied will provide a clear structure to support the functioning of the tool.

Besides making use of the tool during the tender phase, benefits can also be gained of its use during realisation of the project. Over time, financial consequences of real life adjustments can be reflected in overviews of current indirect costs when construction is underway.

6.2.2 RECOMMENDATIONS FUTURE RESEARCH

Besides the recommendations for practical implementation of the estimation tool, suggestions can be made for future studies. One of the main challenges with this type of integration is how to develop the optimization tool so that it would be generally applicable.

Within this research, the two BIM software programmes Powerproject and Revit are used. To increase the support for implementation of the tool further study can be made on a wider range of software. Besides, this research focused on a process for projects within the institutional and commercial construction sub-sector. Here too, in future studies a step could be made towards broadening the scope of research. It would be interesting to look at similarities and differences within indirect cost estimation processes in other sub-sectors such as the infrastructure or residential construction sector and to determine what influence this has on the application of the tool. In addition to broadening the scope of the research it is recommended to investigate the actual use of the tool in practice. By doing so, the proof-of-concept tool can be developed to a level suitable for practical implementation by construction companies.

Besides the ability of extracting cost item data, it could be of value to add a level of intelligence to the tool. Recognizing outlier values and other irregularities or even automatically estimating costs based on project data can possibly help the advisors to improve the quality of their estimates. However, when steps are taken towards automation or eventually even the addition of artificial intelligence within the ABK estimation process, it should be kept in mind that verification of outcomes based on knowledge and experience will always be required.

REFLECTION

This section will reflect on the research process. An evaluation on how the different components of this process have been personally experienced and possible alternative approaches for following research will be worked out. First, the literature review will be reflected, followed by a reflection on the research methodology and finally on the research results.

The literature review was of importance at the beginning of the research process to provide the basis for the design of the research. Looking back on this phase, it was difficult to define the scope of the study and therefore to determine which parts of literature should be included and which should not. Although in this phase there was still a search for the correct formulation of the problem definition, the theoretical background provided the knowledge needed to define the research key concepts. In particular describing the possibilities within BIM provided insight into the expectations of the research end result.

The actual applied research methodologies were in some cases experienced differently from the expectations at the beginning. As the research progressed, it was found that the conversations with the advisors could have been set up in a more efficient way. Doing so could have allowed data to be collected and required knowledge to be obtained in earlier phases of the research. This could possibly have been helpful to get a clearer picture of the required steps to reach the research objective. Besides, it was found challenging to formulate the content of the interview results in a scientific format. The scientific substantiation of findings and conclusions was experienced as a difficult part of this process, which at times resulted in less enthusiastic moments. However, these moments could often quickly be turned back in positivity once the solution came into view.
Although the first approach was to validate the tool qualitatively by conducting a second round of interviews, obtaining additional data in the last phases of the research provided the possibility to quantitatively approach the results of the validation.

By making use of the findings from literature and the results from the interviews, sufficient insight has been obtained to develop a tool that can improve the efficiency of the ABK estimation process. It was enlightening to eventually show in a quantitative way what improvements could be achieved by making use of the tool. Actually putting it in use by the advisors would have been a great additional step to fully test its practical implementation. The final research results eventually met the expectations of a proof-of-concept tool and the expectations based on the literature review.

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APPENDIX

A. CLASSIFICATION COST ITEMS IN ACCORDANCE WITH ABK MODEL 2018

ABK code	Description	
0.0.0.0	**Section 0: General project data**	**(Section)**
	General data (no costs)	
0.1.0.0	**Project data**	**(Cluster)**
0.1.1.0	Total m² gross floor area	(Item cluster)
0.1.2.0	Built surface … m²	
0.1.3.0	Façade surface … m²	
0.1.4.0	Number of residences	
0.1.5.0	Maintained design documents, planning and construction site layout (incl. date)	
0.2.0.0	**Duration of execution**	
0.2.1.0	Engineering/design phase: …	
0.2.2.0	Start: …	
0.2.3.0	Project completion: …	
0.2.4.0	Substructure: …	
0.2.5.0	Superstructure: …	
0.3.0.0	**Contract form**	
0.3.1.0	UAV 2012/UAV-GC/D&C/E&C	
1.0.0.0	**Section 1: Managerial and support staff**	
1.1.0.0	**Management**	
1.1.1.0	Project directors	
1.1.2.0	Project management	
1.2.0.0	**Execution**	
1.2.1.0	Execution	
1.3.0.0	**Construction preparation**	
1.3.1.0	Work preparation	
1.3.2.0	Contract monitoring	
1.3.3.0	BIM modelling/engineering/coordination execution phase	
1.4.0.0	**Support staff**	
1.4.1.0	Facility/secretarial support	
1.4.2.0	Project administration	
1.4.3.0	KAM-coordination	
1.4.4.0	Systems engineering	
2.0.0.0	**Section 2: Facilities for construction site personnel**	
2.1.0.0	**Temporary accommodations**	
2.1.1.0	Construction sheds, facility units	
2.1.2.0	Structural layout	
2.1.3.0	Inventory	
2.1.4.0	Washing and changing rooms	
2.1.5.0	Temporary toilet facilities	
2.1.6.0	Installation-technical layout	
2.1.7.0	Painting, upholstery, awning	
2.1.8.0	Paving for construction sheds and units	
2.1.9.0	Canteen use, coffee supply/coffee machine	
2.1.10.0	Cleaning construction shed	
2.1.11.0	Usage costs, for example office supplies	
2.2.0.0	**Communication and data management**	
2.2.1.0	Communication equipment	

2.2.2.0	Data processing equipment
2.2.3.0	Multifunctional/copier/printer
2.2.4.0	Copy and printing costs
2.3.0.0	**Provisions for OSH (safety, health, welfare and environment)**
2.3.1.0	Collective safety provisions such as toolbox meeting, safety instruction
2.3.2.0	Safety consultancy costs
2.3.3.0	Safety and health plan implementation phase
2.3.4.0	Personal protective equipment for staff and visitors
2.3.5.0	Safety Coordinator
2.3.6.0	First aid facilities

3.0.0.0	**Section 3: Layout and management of the construction site**
3.1.0.0	**Construction site layout and clearance**
3.1.1.0	Permit for construction site
3.1.2.0	Klick-notification
3.1.3.0	Construction site: set out, set up
3.1.4.0	Main dimensions
3.1.5.0	Construction sign (advertising)
3.1.6.0	Temporary drainage facilities
3.1.7.0	Restore public property
3.1.8.0	Protection trees
3.1.9.0	Clearing and cleaning during construction
3.2.0.0	**Construction site segregation**
3.2.1.0	Construction site segregation such as construction site fence, gate, fence with fall protection
3.3.0.0	**Construction roads**
3.3.1.0	Construction roads incl. groundwork
3.3.2.0	Temporary bridges/culverts, etc.
3.3.3.0	Restoration final pavement
3.3.4.0	Loading, unloading crane positions
3.3.5.0	Parking facility staff
3.3.6.0	Walking routes
3.4.0.0	**Traffic facilities**
3.4.1.0	Signs/traffic lights outside construction site
3.4.2.0	Construction site signs
3.4.3.0	Signs in buildings
3.4.4.0	Traffic controller
3.5.0.0	**Facilities environment**
3.5.1.0	Safety environment
3.5.2.0	Permits for environment (e.g. entrance/exit, road closure due to large landfill)
3.5.3.0	Cleaning public roads
3.5.4.0	Precario use of public terrain
3.5.5.0	Walk-through container
3.6.0.0	**Construction waste**
3.6.1.0	Waste containers (own and third parties) incl. landfill costs
3.6.2.0	Garbage chute
3.7.0.0	**Space for storage and preparation of goods**
3.7.1.0	Levelling terrain for storage areas
3.7.2.0	Storage containers and warehouse storage sheds
3.7.3.0	Warehouse manager
3.7.4.0	Saw shed
3.8.0.0	Monitoring construction site/accommodations
3.8.1.0	Security construction sheds and construction site incl. alarm follow-up
3.8.2.0	Access control/surveillance (e.g. passport, attendance, security film, container control, personnel administration)
3.9.0.0	**Safety features**
3.9.1.0	Construction safety: e.g. floor edge protection, stairwells, fall protection,
3.9.2.0	Visit Aboma (inspection)

3.9.3.0	Security officer
3.9.4.0	Fire extinguishers, stretchers, first aid kits, etc.
3.10.0.0	**Special travel and accommodation costs**
3.10.1.0	Parking costs
3.10.2.0	Travel costs (e.g. from hub transport to inner-city construction site, bus transport)
3.10.3.0	Accommodation costs
3.11.0.0	**Climate facilities**
3.11.1.0	Climate screens
3.11.2.0	Temporary facade seals
3.11.3.0	Heating installation building
3.11.4.0	Temporary work facilities
3.11.5.0	Replacement lighting ornaments and air treatment filters by using final installation
3.11.6.0	Drying the building for progress in the work
3.11.7.0	Covering material
3.12.0.0	**Cleaning before delivery**
3.12.1.0	Final cleaning
3.12.2.0	Cleaning façade in relation to warranty
3.12.3.0	Maintenance period
3.12.4.0	Aftercare and warranty during the maintenance period
4.0.0.0	**Section 4: Transport and logistics**
	Incl. labour, usage and inspection costs
4.1.0.0	**Horizontal transport**
4.1.1.0	Tractors
4.1.2.0	Platform trailers
4.1.3.0	Wheelbarrows etc.
4.1.4.0	Telehandlers
4.1.5.0	Shovel/forklift
4.1.6.0	Gantry crane on rails
4.1.7.0	Transport crew
4.2.0.0	**Vertical transport**
4.2.1.0	Construction elevator
4.2.2.0	Passenger/goods lifts incl. lift controls
4.2.3.0	Temporary use of final lifts incl. inspection and protection of the final lifts
4.2.4.0	Façade mounting system
4.3.0.0	**Stationary cranes**
4.3.1.0	Tower cranes
4.3.2.0	Lifting equipment
4.3.3.0	Lifting supervisor
4.3.4.0	Crane operator
4.4.0.0	**Mobile cranes**
4.4.1.0	Telescopic cranes
4.4.2.0	Crawler cranes
4.4.3.0	Folding cranes
4.4.4.0	Lifting equipment
4.5.0.0	**Climbing equipment**
4.5.1.0	Ladders
4.5.2.0	Temporary stair tower
4.5.3.0	Mobile scaffold
4.6.0.0	**Temporary structures**
4.6.1.0	Temporary (auxiliary) constructions incl. engineering
5.0.0.0	**Section 5: Temporary connections**
5.1.0.0	**Design temporary connections**
5.1.1.0	Design costs temporary installations (calculations and drawings)
5.1.2.0	Groundwork and klick report
5.2.0.0	**Electricity**

5.2.1.0	Connection costs
5.2.2.0	Distribution network construction site and building object
5.2.3.0	Consumption during construction (incl. fixed fee)
5.2.4.0	Provisorium (temporary transformer room)
5.2.5.0	Aggregate
5.2.6.0	Lighting installation
5.2.7.0	Light towers
5.3.0.0	**Water**
5.3.1.0	Connection costs
5.3.2.0	Distribution network construction site and building object
5.3.3.0	Consumption during construction (incl. fixed fee)
5.3.4.0	Water meter box
5.3.5.0	Pressurized water installation
5.3.6.0	Materials for distribution network
5.4.0.0	**Gas**
5.4.1.0	Connection costs
5.4.2.0	Distribution network construction site and building object
5.4.3.0	Consumption during construction (incl. fixed fee)
5.4.4.0	Materials for distribution network
5.4.5.0	Inspection and permit costs
5.4.6.0	Propane or natural gas installation and facilities
5.5.0.0	**Sewage**
5.5.1.0	Construction sewerage
5.5.2.0	Connection costs
5.5.3.0	Septic tank
5.5.4.0	Discharge costs temporary sewage
5.6.0.0	**Data**
5.6.1.0	Communication and/or data distribution network
5.6.2.0	Trunks
5.6.3.0	Internet connection

6.0.0.0	**Section 6: Use of small equipment**
6.1.0.0	**Processing tools**
6.1.1.0	Small tools: from electric drills, screwdrivers, jigsaws to electric saw tables
6.1.2.0	Operating materials: e.g. saw blades, drills
6.1.3.0	Repair and maintenance of small equipment
6.1.4.0	Small equipment inspection costs
6.1.5.0	Concrete processing equipment: e.g. poker vibrator and sander
6.1.6.0	Stone processing equipment: e.g. grout mill, stone wheelbarrows
6.1.7.0	Wood processing equipment: e.g. table saw, circular saw
6.1.8.0	Metal processing equipment: e.g. welding plant, metal cutting tools
6.1.9.0	Glass processing equipment
6.2.0.0	**Measuring instruments**
6.2.1.0	Measuring instruments: e.g. spirit level, theodolite

7.0.0.0	**Section 7: Special ABK's (specials)**
7.1.0.0	Transition area (HUB) including fences, precario, security, energy (incl. accommodations)
7.2.0.0	Central project organisation for combination works (umbrella)
7.3.0.0	Self-climbing building shed
7.4.0.0	Construction site equipment on surface water
7.5.0.0	Deployment transport helicopter
7.6.0.0	Extreme security commitment
…	

B. INTERVIEWS ADVISORS

B.1 INTERVIEW STRUCTURE AND QUESTIONS

Background information:

1. What is your position within the company?
2. What activities are part of this position?

Process steps:

3. Which process steps can be identified and which products are required for the final completion of the ABK estimation?

Required information:

4. What type of information is required for the ABK estimation and from which software programs is this information obtained?
5. What share do the ABK have in relation to the total project costs and how much time and manpower is required to obtain an ABK estimate?

Adaptability:

6. In the case adjustments take place within the design or planning, what steps are taken to implement these adjustments in the ABK estimation?
7. How is the ABK estimation process currently perceived in terms of efficiency with regard to issues such as efficacy, reliability, time investment, manpower and costs? Do you see opportunities for process improvement?

Topic	Description	Problems	Development needs
Process steps	Analyses of project data and the construction site environment are the starting points of the ABK estimation process. From these analyses, an execution schedule can be set up. The execution schedule serves as the basis for the determination of construction site drawings, the UTA, equipment and crane planning. Situation, architectural and installation drawings combined with information from the 3D model of the building, if present, serve as input for the development of the construction site layout plan. All obtained project documents are amalgamated and used to extract the required quantities for the ABK estimation. Advisors have to manage these various sources of information to determine the quantity related information of the cost items.	There is no singular checklist referenced to build out the contents of the estimate, which leads to inconsistent outcomes. The amalgamation of various information sources diminishes the audit trail of the final ABK estimate.	Guidelines to obtain quantities from various project documents in order to improve the consistency and audit trail of the process..
Required data	The required information for the estimation of the ABK is contained by the project documents developed during the ABK estimation process. Asta Powerproject is used to develop the execution, personnel and equipment schedules. Fte's and deployment durations of cost items are extracted from these schedules and are required to determine the corresponding costs. Revit is used to generate 3D models of the physical ABK elements on the construction site and contains quantity and cost data of these elements. An external database in Excel contains data about the hourly rates of managerial and support staff.	There is a lack of interoperability between the various used BIM software programs. The missing link between these programs leads to time-consuming tasks. The quantity take-off of ABK data is seen as a step that can be set up in a faster and more consistent way.	Improvement of interoperability between BIM software in order to reuse project data and eliminate time-consuming tasks.
Adaptability	Within a project, some design or planning adjustments can take place. When changes occur within the project design or planning, these have to be manually adjusted and re-entered within the ABK estimation.	Current practice does not effectively manage the dynamic change in an ABK estimate once the estimate is finalised and construction is underway. The task of manually taking over project changes is time-consuming and prone to errors.	Direct visibility in consequences of project changes without full dependence on manual intervention.

B.3 ADVISOR 1

Q	Answer	Open coding	Axial coding
1	Senior advisor planning and logistics	Senior advisor planning and logistics	-
2	Roughly speaking, there are two cost items. Indirect costs and direct costs. Direct costs are calculations, then it is simply calculating the building, the quantities and then units. So basically the what. We are actually looking at the indirect costs, how something should be built. What is needed for the direct, what actually is needed for the building, what do you need to be able to make that. That's kind of the variable. This includes the staff costs, the shed layout is included, the construction site layout is included, the horizontal and vertical transport, so the cranes, transport, mobile cranes and elevators. Then we have the construction flow we need. Besides, a small amount of equipment that you need in general. With the construction site layout, shed park, we calculate all that. For planning we also look at the length of time, which is required. We also look at the aspect of how the transport is going, but that is mainly at the construction site, because in itself the route to the construction site is determined at a given moment, we also look at how the flows can be equipped in a safe way. Taking into account the planning and the speed you need, deployment is also decisive at a given moment. Do you build something with one or two cranes? Do you use one construction lift or two construction lifts, because at some point you also need transport of persons. Once we have collected all this data, we enter it once, in an ABK budget, also named general construction site costs. These are always the kind of indirect costs, which cannot always be related to a specific part of the building object. We fill in these kinds of costs and that will eventually become our end product. We make a schedule, UTA occupation and derived schedules and a construction site drawing or we put it in a model. Sometimes it can be done just as quickly if we have not that much data available. Then we just do it sketchily on a PDF. We just grab the location from Google ourselves, draw the building in the right place and then we get to work with that. But if there is a model, then we put it into a 3D construction site model. If you take a look within the phases of the project preparation, you can distinguish SO, VO, DO, etc. We can already be involved in different phases. Usually we try as much as possible, once we get involved at the beginning of a project, we also stay involved until the end. What we are now noticing more and more is that we increasingly want to be involved during realisation. Previously, we budgeted up to our DO pieces and then handed it over to the production department/realization team. What we do notice is that we want to keep an eye on a kind of 'stick to the plan' of what you are doing now. And you also notice that on the construction site they also need our knowledge and “know how” more and more in the sense that we know what we have planned and how we want to make it, that you will also convey that much more. Because you can't transfer that in an hour. We as a department also see that we are sometimes involved for a longer period of time. We are at the frontside, especially to bring in tenders and works, but we also assist in the realisation a lot these days.	Indirect costs, variables, staff costs, shed layout, what is needed for the building, calculate construction site layout, planning, deployment of materials, ABK budget, UTA occupation, 3D construction site model, Involved in different phases, more during realisation, construction site needs knowledge of advisors, convey what is planned, frontside bringing tenders and works, assist realisation	-

3	Firstly, when we receive documents, we assess these documents. What should you build? What kind of building is it? These documents are called the project data. Based on the plans of the architect, constructively and technically. We then analyse the environment. That is a kind of location scan. Then we always start with, okay, we have to build this building, then a rattle goes through our head about what we need and what we have to deploy. Usually a very quick thought about the largest components, which are the cranes and such. The moment you have that, you have an idea of what type of work it is. Then we do the analysis and set up a planning. We write out the activities of the planning and their sequence. I always call that the mast route, how are we going to build it. We plan that at some point. We then make a corresponding construction site budget. If it really takes time, we even do analyses on what we have come up with ourselves. For example, if I have planned two tower cranes, and I link them to my schedule, what is then our capacity movement. So looking at the occupation of your tower cranes, is it overloaded or is it well occupied. The moment we look at it again, we say okay, that's good. We then consulted with the equipment department to set up the construction site. They always want a template of the crane locations, where are the sheds, where do you want fences, where do you want swing gates, you name it. They also make a plan for that. We get a budget from them. Then when we deploy tower cranes, we also look at the capacity of those tower cranes. What can you lift and what is needed to lift. Then you have to think in terms of weights. I have a crane somewhere in a position and from that position we will look at the different flights. The flight is the distance from the mast to the element where you have to lift. Then we say, for example, on that flight we must have 30 tonnage. We have table booklets for that to see which type of crane it should be. This is always discussed with the equipment department. This is often substantiated with a quotation. If we don't have enough information, we'll get it from old data. The moment the planning, the construction site and the whole thing is ready, we already have an occupancy rate in the back of our minds. What do we need in terms of guidance, project management, project leaders. That is in particular the control mechanism. Then you get the executive staff, those are the executers. We then have an idea about that, which will be the occupancy rate. We then translate that into fte staffing. fte in the sense of, 100% is 1 fte. If we say 80% then it is 0.8. When we just talk about the products. That's actually the planning, derivation of plans and the construction site drawing. We then make a budget, but that is all a collection of the mentioned products. So all the input goes into the ABK budget. Those are actually the three main items. It is also always stated which assumptions the products contain.	Assess documents, project data, analyse environment, what is needed, what to deploy, set up a planning, write out activities, how to build it, construction site drawing, revision, equipment department, construction site budget, table booklets, occupancy rate, control mechanism, fte, deriviation of plans, collection input to ABK budget, assumptions	Project data analysis, environmental analysis, execution schedule, construction site drawing, crane planning, UTA planning, quantities, request pricing, collection of products,
4	We mainly use the deployment from the schedules, so we use the ftes for that. What do we think we need. So those are the numbers of personnel and their duration. To make the planning, we take quantities or we determine quantities ourselves if we really don't have enough information available. We mainly use quantities. At a certain point we know what the tempo per day will be approximately or how long the production of a part will take. That also determines the duration at a given moment. What we then do is establish a relationship at some point, when we have to finish something, only then the next part can start. We call this the critical path. What we mainly get out of the planning are durations. Because we have made the planning of the object, the building, I can also extract the needed equipment from my planning that I have to enter in my ABK. So the moment I know that I have deployed a crane, I know when I need that crane, the start moment and I determine in my planning the end moment when that crane can leave. This duration can be seen in a duration time bar. With the type of crane determined, following from that, I know the cost of that crane per week. Then I also know the duration, the number of weeks, which ultimately determines the occupation. At a certain point we know which tools are linked to a certain product, for example for the crane we need a crane operator, a traffic controller, a lifting supervisor or whatever. Then we fill it all in. We also do the same with the sheds. Sheds are the easiest, because they are usually needed from start to finish. We determine the amount and type of shed again on the basis of our UTA occupation. The moment we look at the UTA occupancy, we see a certain graph arise that shows a peak at certain moments, which represents the capacity that has to come into a shed. A shed is something that you often place once. This includes installation costs and a rental component. Or we take a look at the duration and say that it's better to buy the shed and make use of a buyback. Then we buy it from a company and after the project the company will take it back for a residual value. That can sometimes be more interesting than a rental component. A more expensive concept that we also sometimes look at are units, depending on the size of a project. You can scale up with a unit. At shed, for example, you see in your peak that you need 20 men, so I you have to base your amount of sheds on that number. The prices of	Deployment from schedules, fte, personnel and durations, determine quantities, critical path, equipment cost and occupation, UTA planning, request prices equipment department, yearly scanned prices, Asta Powerproject, IBIS-TRAD, Revit, BIM360, IFC, Solibri	Asta Powerproject, Revit, IBIS-TRAD

	materials are in line with the market. We usually request these prices from the equipment department. So we say to the equipment department: we need this type of crane. What they do, because they constantly request those prices, they do a check if it is correct what you are doing. They look at boom lengths. If they turn over each other, they take a look at how close they are to each other. Next, we have a type of crane. What we often do internally is to see who has most recently requested crane prices. Then we dare to use that price. Otherwise it is the market forces. For example, you now see scarcity. You can see that the price is going up quite a bit. The equipment department checks whether the estimated price is correct. In principle, these prices are scanned every year. Not with every project. When we hear that some price has changed, we will make a change for a specific project. The schedules are made in Asta Powerproject. That's our planning program. That is what we work with as standard. For the budget it is IBIS-TRAD. The modelling is done in Revit. We have derivatives of this program in which we can look at the Revit model. The Revit model is a heavy file and everyone works centrally in it. And we get opportunities within BIM360. The Revit model is uploaded there and from there we can look into the model. We can look at it in Solibri via an IFC. So there are different means of looking at the model. It would be nice if data could be extracted from the Revit model to eventually use in the ABK budget. That must be the future. But to be able to do that, you must be able to model something that, at the moment you are going to determine the crane for example, you need to indicate what type of crane it will be, the number of mast parts you have to put in it and also the boom elements. They determine the cost of that crane. You should also know if you are going to put that crane on an undercarriage or on a foot or on a foundation beam. These are all additional aspects. You also have to start thinking right away about the crane operator. How do I select this. So that must be linked somewhere. That crane must also be assembled and disassembled. Imagine you have a crane with a boom length of 40 meters, then the boom is built on the ground. So there has to be a space on the construction site where we can lay out those 40 meters. Then it must be determined where the mobile crane to lift the boom should be placed. That also determines a certain cost item. I think you eventually have to analyze each object in the ABK model to determine what items it consist of. When we are modelling something in a smart way and the model has also been developed in such a way that it immediately takes into account what type of crane is used, it should be possible to determine the crane costs. You have to start thinking about the foundation and what costs are involved. Can you have that modelled and calculated by the construction department? Because then you could automatically include it in the model and therefore have it automatically entered in the ABK budget. Then you would eventually have all the components together in your model.		
5	In 9 out of 10 cases the share of ABK will be somewhere around 20-22% in relation to the total project costs. It is a big cost item, from which people always think they are too high and still sometimes calculate with 10%. We are increasingly aware of what needs to be done for the realization of the project that its share tends much more towards the 18, 20 and 22%. Every project is unique. When we zoom in on the ABK, the staff costs are approximately between 40 and 50% of the total ABK. So the moment you know this item, you usually are able to estimate what the final amount of costs can be. This again depends on the duration of a project. Do you have a project that can be build in succession, or do you have a project where you notice that you actually need half occupations, but from which you know it will not happen. The moment that we fill in the budget is at the end. Then everything is collected. We set up a schedule, made a construction site drawing, looked at the cranes, all the facets that we first had to do in this process. When you look at these products I think you are talking about 90% and 10% of the products contains the completion of the ABK budget. If you have to make an estimate, you do a quick analysis. Then nothing in-depth is asked from the client. If you really want to have a serious budget, we will also make the planning much more extensive. That's 6 lines, 10 lines, 20 lines, or even 1000-line schedules. The question is, how deep do you need to go. When you roughly know that a floor lasts 10 days, you can quickly say that 4 floors equals 40 days. You can also plan those 10 days in more detail. Then we talk about making walls, putting the stamps, building the floors, the installation on top and then it is, for example, not 10 days but 9 or 11. Then one line of planning might become 8 lines. If I put that together and I have 20 floors, the rules will naturally increase quickly. Sometimes we have to go that deep to find speed in the construction process. For example in a foundation, where are we doing the pile driving. When I take a look at the drawings, I can say roughly from my experience based on an estimate, this takes about 4 months. I think what you want to look at now are all the	Tends to 20% of total project costs, staff costs 40-50% of ABK, budget is filled in at the end after collection of products, 90% of product is research, 10% is product ABK budget, dependent on level of detail, ABK automization will pay off	Around 20%, differentiation in projects,

	products we prepare, all products that are needed for entering the ABK, how can I do that smarter, because you have already provided a product in such a way that I can link something in between and make sure it can be filled in automatically in the ABK. That will certainly pay off. Every P&L advisor carries out a project and each one of them fills in the ABK of their project. Sometimes a colleague checks whether a high number can be adjusted based on key figures and their feeling, for example.		
6	Adjust manually. For example, the moment I have all products ready, there is the moment of a technical completion. The planning and construction site drawing are then entered into the budget. So my ABK is discussed. When the staff looked through the budget, the main thing that is looked at is the amount of fte. They also know that they have to reduce costs from here because this is the largest cost item, this is where the most money is spend to. You can look somewhere halfway through the budget at an item that includes 1500 euros, but if you are talking about a total of 10 million, what difference does that 1500 euros make. By linking staff deployment levels to the planning, we can also show who does what during the execution of the project. It can happen that some tasks need to be done by a subcontractor and the fte needs to be adjusted. When we are finished with the technical completion, we are now only talking about the staff, first we have to adjust the staff within Powerproject in the planning. When this adjustment is about the duration I logically have to adjust the duration. I then need to shorten my duration bars. If it's in text I'll have to adjust the occupation. When we have said about some staff member instead of 100%, he will get 60%, I have to adjust that too. So that's an extra step I have to take. Then I have to implement the adjusted amounts in my ABK budget. What you usually see is that we first save the ABK budget of the technical completion. We call that our base, because that was our truth. Then we will look below that and we have to manually go through the lines of the occupation and we have to enter the time again. So when, for example, in the budget there is an occupancy of 100%, then that has to be 0.6 and I have to adjust the weeks. The moment we really notice that we are for example moving from prefab elements to cast-in-place elements, the weights will also be lower, so the crane occupation will be different and the lifting capacity will be less, so it will be a different type of crane. This can then have consequences for the duration. I'll have to adjust that again in the schedule. Adjusted weeks will come out and I have to adjust those again in the budget. And I have to manually adjust the costs of the crane type again in consultation with the equipment department. For example, because you have adjusted the staffing level, something will also happen to the shed, so for example the shed becomes smaller, I have to request a new quote again and we have to adjust it manually in the ABK budget. By continuously adjusting the duration and costs, we also have to do a lot of things manually. What we have already tried in IBIS-TRAD is to use measurement statements. In IBIS-TRAD I have already linked a lot of things. So if the duration of the total project changes from 100 weeks to 90 weeks, all I have to do is enter 90 in 1 spot and then the program changes everything associated with adjusting that 100 to 90. We also do that with square meters. We work a lot with BVOs. There are also many key figures associated with these BVO's. If the building changes as a result of an adjustment, i.e. the square meters are adjusted, I only have to click on it in one place. People are enthusiastic about that speed. We are looking for these kind of improvements. We once talked about going to an Excel file. If we can link things in Excel, then you only have to adjust something in one place and the rest will change automatically. I call IBIS-TRAD a knock-in tool. Because the program only calculates what you enter, but you cannot make derivatives of it.	Manual adjustments, technical completion, focus on fte, time-consuming, incapability IBIS-TRAD	Manual adjustments, time-consuming

7	I don't think it's efficient. Because you go through the budget manually you know what is being filled in, but there is always a chance of errors. Because you always have to re-enter numbers that are placed somewhere else. And tapping a zero behind it can happen just like that. The danger with automation however, is where will the data be placed and is it in the right place. At a certain point if you would fill something in without knowledge and you have it linked to a budget, then what comes out of it does not always have to be true, despite the fact that you think everything is linked. Someone who has knowledge still has to go over it. The knowledge and experience can be used after filling in to see where clever adjustments can be made. But I think you can get the information much faster. The costs of a part are usually already filled in. Then it is usually only the adding of the units and duration. Transferring those properties immediately is going to reduce time, 100%. We now continuously obtain these properties from the products we have made. With fences, for example, I need the amount of fences, so at some point I will first look at my drawing. With modelling I can very quickly see the linear meters. Based on these linear metres, I know how long a type of fence is, how many pieces it should be. We then enter that manually into the ABK budget. We need the linear meters for installation. For the rent we need the number of pieces. We look at the duration in the planning. So I need several products to be able to come up with a number for that fence. We now use Powerproject for the staff deployment, because this program is where the realization is located. In Powerproject you can collapse the planning and then you will only receive it in a few lines, instead of something like 1000. It can for example also only show the main items, foundation, the skeleton, structural work, facade closure, roof, finishing and delivery and in between technology . Those are usually the main items of the schedule. And from there we will link to the workforce. I think there is a lot to be gained from time reduction. But you have to keep the knowledge. That's really what we're aiming for. Don't underestimate it. It cannot be that a generated schedule is all you need. There is also a need to check whether it is really correct. You always need someone who can look at such a planning with experience. When a building that is linked to a parametric planning, we can not say: this is immediately the construction site that belongs to it. Perhaps for certain parts, but knowledge is still needed. Digitization is a tool but still needs to be verified by someone with the necessary knowledge and experience. If manual transfers can already be completed for us and we can only use our knowledge on what we are good at, we can look at a planning much faster and make it even tighter, look even better at the occupancy and even better at the budget. Now, we first have to make a lot ourselves before we actually use our knowledge. More time would be freed up to use our knowledge when other manual tasks are taken away. Then we will be empowered more, I have that feeling. But I am hesitant that people then think at a certain point: I know that I have to fill in these parameters because then the planning will do something. A planning will be produced, which lasts for example 14 months, while advisors could immediately say that 14 months is not realistic. But we can see why those 14 months are indicated. We can look at where the efficiency is present, but you cannot blindly accept it as the truth. I think when you talk about the bigger picture you are talking about a time reduction. When I have a model that is correctly completed and for which the correct parameters are known, and I have already linked 60%, for example, then I only have 40% left to do. But again, you do need knowledge. The moment I can link all the data to an Excel file, and you can come up with something smart so that all numbers are generated in Excel, and the ABK budget can be drawn up from there, that will also reduce in time. Then all I have to do is check what I've come up with, but the data take-over is already done. For example, instead of having to work on a project for 5 weeks, I may now be ready after 3 weeks and can therefore pick up another project. If these manual tasks are already done, efficiency and productivity can be increased.	Inefficient, manually adjustment, errors, danger of automization, need of knowledge, time reduction, several products to come up with one number, Time reduction, keep knowledge, digitization as tool, need for experienced verification, take away manual tasks, increase of productivity	Need of knowledge, right division of time, increase amount of time for experienced verification

B.4 ADVISOR 2

Q	Answer	Open coding	Axial coding
1	Senior advisor planning and logistics	Senior advisor planning and logistics	-
2	With the entire process of integrated planning, logistics and ABK. We determine ABK from the planning and logistics.	Planning, logistics, ABK determination	-
3	As soon as we receive the project data, we make an inventorisation. We perform an analysis. From there we divide the building into elements. We then determine the quantities within the design of the project. From there we make the first start of an execution schedule, based on the first analyses as we have done them. From this execution schedule, possibly linked to a design schedule if a design component is involved, we determine the crane planning to see if not too many cranes have to run in a very small spot. The planning may need to be slightly adjusted based on the crane analysis. We therefore already have looked a bit at the construction site layout. The planning may also have to be adjusted, because it does not fit completely due to the available spaces at the construction site, so there are a kind of loops every time. Then we have the base ready. We may be need to request quotes for certain parts. From construction site parts and cranes and the like. Then we can translate that into the construction site costs. The quantities are taken from the construction site layout, in terms of meters of fencing, meters of pavement and in terms of number of sheds. Then we can add that to the construction site costs. The moment we really start to fill in the construction site layout, we usually go on site and do an environmental analysis to determine where we can park or where we can get the electricity for example. Usually you have to look on the spot as well. Whether there is one-way traffic and what access points are available. Because these are also components that must be included in the construction site costs. We determine the support staff after we have determined the execution schedule and after we checked it in relation with the crane schedule. If we have a more definitive execution schedule, we link a staff occupation to it. A number of products can be identified that are necessary for the ultimate estimation of the ABK budget. And there is actually a sequence in those products. You can't do one before you can start another. You only know how many cranes you have to set when you know what speed you have to run to be able to achieve the delivery int time. We also have a template for the estimation of the ABK itself. It contains a lot of basic prices of standard products. You can as well have very specific parts, just like a construction site installation. You are very sensitive there with daily prices. These prices are then usually requested on the market. Also in terms of the shed layout, it is often price sensitive. There are many different variations in cranes, in terms of set-up and how easily you can reach them for assembly and disassembly and how high they should be and how long should the boom be. There are so many different specifications which makes us usually check with a number of suppliers. So we request some parts directly from the supplier and other parts, such as a construction site installation, are done by the equipment department. The hourly rates for staff are fixed rates per function as standard. These rates are already included in the ABK base and they are re-established every year and, if necessary, adjusted again in the ABK base.	Project data, inventory, analyses, execution schedule, crane analysis, construction site layout, quotation request, quantities, staff occupation, products, template, basic prices,	Project data analysis, environmental analysis, execution schedule, construction site drawing, crane planning, UTA planning, quantities, request pricing, collection of products,
4	Powerproject from Asta is used for the execution planning. The crane planning is usually made in Excel. We also usually put the personnel planning in Powerproject, which we link to the execution planning. The construction site drawing, depending on the level that is requested, is put one time in a PDF and the other time in AutoCAD and another time we model it completely in Revit. We actually have the objective to do everything in Revit. The client's question or the way in which you want to present it, the time aspect, the accuracy with which you have to budget and the templates that you do or do not have at your disposal determine the form in which the construction site drawing is executed. If no Revit model is available, then it is of course quite cumbersome to work out the construction site drawing in Revit. Eventually, the ABK budget is worked out in IBIS-TRAD.	Powerproject, Excel, PDF, Revit	Asta Powerproject, Revit, IBIS-TRAD

5	That will differ per project. Compared to the direct construction costs, it will be between 15 and 30%. This also includes aspects of how parking is arranged, is it in the middle of the city centre, do you possibly need a hub that you have to build somewhere, the demarcation between what the client pays and what should be included in our price. Sometimes the client pays the precario, the other time we have to include the precario in our own price. So that can make a difference in that sense. Normally, one advisor works on the elaboration of the ABK. It may also be the case that the two advisors support each other. It depends a bit on the size of the project. You may have to do a small job in 2 weeks and a large one that takes 3 months.	15-30%, one advisor, size of the project, 2 weeks, 3 months	Around 20%, differentiation in projects,
6	Firstly, you don't wait until the end to deliver products. During the entire tender phase, you try to seek support and commitment from those directly involved, so that you are not confronted with all kinds of unexpected changes in the end. So the moment the technical completion starts, most of the products have already been completed. Then it is more about explaining to the management what you have come up with, rather than having completely different views. If so, then we did something wrong. After a technical completion, the UTA planning can in some cases be adjusted which leads to manual implementation of that change in the ABK estimation. That is a matter of an adjustment of 1 or 2 days. This is then taken over manually. First a manual adjustment within Asta Powerproject and then manually in IBIS-TRAD.	Manual adjustments, time consuming	Manual adjustments, time-consuming
7	Only a limited number of people still have the knowledge. The knowledge of drawing up schedules and deriving the construction site layout and personnel planning from this and deriving an ABK budget from this. As a result, you have to look at everything more coarsely than is actually desirable. Then sometimes you can't take a view at the variants that are desirable. It would be a good thing if there was a way so that it takes less time, but also that more people can get along with it. I think that a lack of knowledge is the case now and that it certainly will be in the future. If simple manual tasks could be removed, there would be more space and time left to use the knowledge for, for example, looking at alternatives that may be desirable. Within a project, there can be some small or larger design adjustments. It takes quite a lot of time to keep up with those design adjustments every time, or to answer the client's sub-questions: and what if we do this, and what if we do that, what effect will that have. One floor level more, one floor level less, the building becomes a bit wider or a bit longer, a different installation. If you can also provide an answer to these questions a lot faster via a step towards automation, you will save a lot of time. This frees up capacity to focus on other things.	Shortage of knowledge, division of time, time for working out alternatives, savings of time	Need of knowledge, right division of time, increase amount of time for experienced verification

Q	Answer	Open coding	Axial coding
1.	Senior advisor planning and logistics	Senior advisor planning and logistics	-
2.	Making schedules, setting up logistics and determining ABK.	Planning, logistics, ABK determination	-
3.	The first thing you do is making the execution plan. You read into the project data, and you look through the project drawings. Then you set up the plan. As soon as you have done that, you will look at the construction site, which is needed to be able to realize this planning. Then you gradually fill the ABK model and request quotations that you need, if necessary. The first thing you need is the planning, because a lot of things are time-bound, of course. Then we are talking about the execution schedule. The staff planning depends on the execution schedule. You set up the main planning as well as the crane planning, to see whether the main planning can be realized with the number of cranes you have determined. At the same time, you actually make a UTA planning, which contains executors, project leaders and the entire staff. You will also need this to complete your ABK. In general, every advisor does this in the same way. You will fill in your text when going through the project drawings. You will enter everything that is on the drawings in the text column. You determine the quantities roughly from these drawings. Of course these quantities differ per project. You can look up a lot of key figures in books, but most of it is in your head. If you don't know something, you can ask someone else who you know has worked on the same item before. But most of it is in my head already.	Execution plan, project drawings, look at the construction site, staff planning depends on execution schedule, crane planning, UTA planning, determine quantities through the products, key figures	Project data analysis, environmental analysis, execution schedule, construction site drawing, crane planning, UTA planning, quantities, request pricing, collection of products,
4.	Asta is used for planning. Asta Powerproject I think it is called these days. I still set up the crane schedule in Excel. In the future it might be possible to do this in Powerproject as well, but we are still looking into that. We build up the ABK in IBIS-TRAD. Quantities of fencing and the like depend on the construction site that you have at your disposal. We extract the quantities from the project drawings. The construction site layout drawing. Usually we receive a template from the client stating the boundaries of the construction site. From this template we set up the construction site including construction roads, etc. If you need more information about the completion of the construction site, you can contact the municipality to ask for confirmation of the choices that are made. If you have the UTA occupation, you can roughly determine the amount of sheds that are needed. It also happens more often that the construction site layout is modelled in 3D. That should actually happen even more often, but it's not happening yet. Certainly not in the tender phase. In the implementation phase usually it is. It often depends on whether there is time, whether it is complicated and whether you have a draftsman at your disposal. We often make a 3D model ourselves in the implementation. IBIS-TRAD contains a number of data that are necessary for the preparation of the ABK budget. These are data on quantities, labour and duration. The specification code in the budget corresponds to the classification of the ABK model drawn up by the NVBK. In IBIS, the hourly wage is also stated in a column behind the staff items.. We get that hourly wage from the hourly wage table. These will all be updated at the beginning of January. So you can see, for example, for an executive, 2 days a week is equal to 0.4 FTE, for 30 weeks, 32 hours a week on average, so that gives a certain number of hours in those 30 weeks, which is then multiplied by the hourly wage from the hourly wage table. IBIS can perform those multiplications itself. Once everything has been entered in IBIS, the end product of the ABK budget is finished. The added value of a Revit model in which the construction site layout can be modelled, in my opinion, shows itself when you have to explain to the client how certain parts of the project will be carried out. Then you can show what it will look like. Some things in the case of a complex construction cannot be shown properly without linking the planning to a BIM model. Only then can you clearly see the sequence.	Asta Powerproject, Excel, IBIS, 3D models	Asta Powerproject, Revit, IBIS-TRAD
5.	Depending on the project and whether the installations are also included, this will often be between 15 and 20 percent of the direct costs. Usually the budget of a project is worked out by one person. One advisor is involved in the elaboration of the ABK for each project. For very large projects I sometimes want to ask someone else to figure out something together. But we usually work it out ourselves. If I had to make an estimate, we would be working on that for an average of four months. That depends on the specification of the project.	15-20%, one advisor per project	Around 20%, differentiation in projects,

6.	The change is typed into the schedule. Often the adjustment within IBIS occurs at the same time as the adjustment in Powerproject. The adjusted quantities are now obtained from the products we have established. When something in the planning needs to be updated, an additional step needs to be taken. The planning must first be adjusted, and then the matching line item in the ABK budget must be changed.	Typing adjustments, time-consuming	Manual adjustments, time-consuming
7.	The reliability is 100% of course. In terms of time, it just depends on how many projects you are working on at the same time. It would be easier if you get quantities delivered to safe time. But on the other hand, if you determine the quantities yourself, you also know how the work is put together. It would be easier if there was a BIM model with all the quantities included. Depending on how you organize your planning per floor or per building section or per phase. But often when you start you don't know whether you are going to build in phases. It would be easier if those amounts were already known. The danger when you start automating things, is that at some point you stop thinking about it. Then you assume what is in the model to be the truth, while it often is not. You should always keep thinking about it. The danger with automation is, and I notice that very often, that it is full of errors because there is no more reasoning. You have to keep thinking about it to get a feel for it. That is the same with the quantities, it takes some work, because often you are working on it for a number of days, but then you also have a sense of what the work entails. I think the younger generation will think about it more easily than the older generation. Knowledge and experience are still needed. Some consultants are not yet sufficiently skilled in the Revit models of the construction site, so that the 2D drawings are still used to extract quantities. It's really a matter of doing it and just getting started. But you should not have the illusion that in the end you can only draw up an ABK budget based on the square meters for example. There its tricky business. If you have a construction site model available that you can link to IBIS-TRAD, then in theory the number of lifts and cranes, square meters of chain and the like could be regulated.	Delivery of quantities, BIM model, automation danger, knowledge and experience still needed, regulate quantities from information models	Need of knowledge, right division of time, increase amount of time for experienced verification

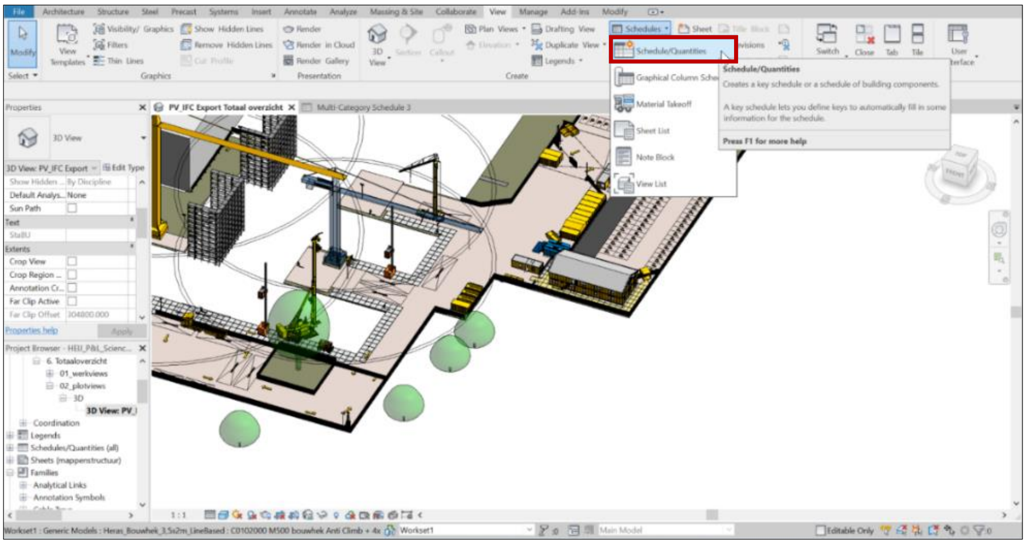
C. RESEARCH DEVELOPMENT STRUCTURE

Topic	Problems	Development needs	General requirements	Technical requirements
Process steps	There is no singular checklist referenced to build out the contents of the estimate, which leads to inconsistent outcomes. The amalgamation of various information sources diminishes the audit trail of the final ABK estimate.	Guidelines to obtain quantities from various project documents in order to improve the consistency and audit trail of the process.	The tool provides insight into the steps that should be taken to obtain cost item data for the ABK estimation. The tool substantiates choices in use of cost item data.	The tool facilitates a structured description for obtaining cost item data from the information models. Cost items in the information models Powerproject, Revit and Excel are provided with an ABK code in accordance with the classification of the ABK model 2018.
Required data	There is a lack of interoperability between the various used BIM software programs. The missing link between these programs leads to time-consuming tasks. The quantity take-off of ABK data is seen as a step that can be set up in a faster and more consistent way.	Improvement of interoperability between BIM software in order to reuse project data and eliminate time-consuming tasks.	The tool links BIM software to the outcome of the ABK estimation. The tool reuses once entered project data for the estimation of the ABK. The tool reduces the task time of extracting cost item data from BIM software.	The tool exchanges data from Powerproject to the estimation tool in Excel. The amount of information received by the tool is in accordance with the amount of information required. The tool exchanges data from Revit to the estimation tool in Excel. The amount of information received by the tool is in accordance with the amount of information required. The tool generates an outcome of the ABK estimation based on the extracted data from Powerproject, Revit and Excel.
Adaptability	Current practice does not effectively manage the dynamic change in an ABK estimate once the estimate is finalised and construction is underway. The task of manually taking over project changes is time-consuming and prone to errors.	Direct visibility in consequences of project changes without full dependence on manual intervention.	The tool shows changes within the project in terms of consequences for the final ABK estimate. The tool is able to reduce manual tasks for obtaining cost item data for the ABK estimation.	In every phase of the construction process, cost data can be extracted from the information models and imported in the estimation tool. Any new or adapted cost items, obtained by changes in the information models, such as schedule changes or changes in the construction site layout, are directly visible in the ABK estimation outcome. Change in the final ABK estimation outcome is directly noticed after adjustments are made in the linked information models.

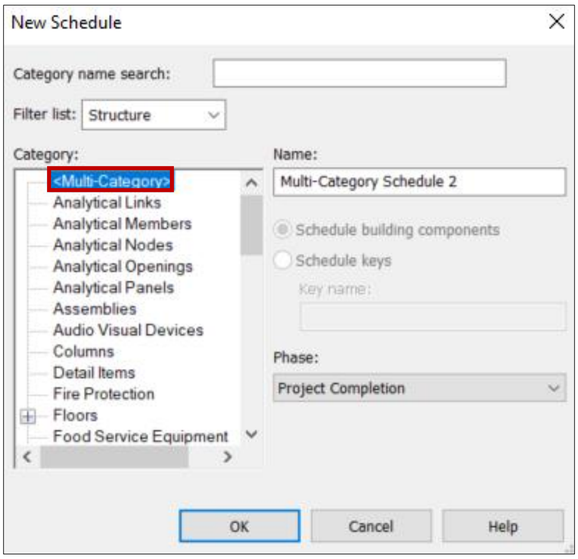
D. DATA EXTRACTION STEPS REVIT

A quantity take-off schedule must be set up first in order to extract data from Revit and export it to the ABK estimation tool. The Revit schedules will complete the QTO of cost items in the Revit model of the construction site according to a predetermined set of parameters. The steps to draw up the schedule and export the containing data are elaborated upon here.

1. After opening the file containing the construction site model in Revit, click the "View" tab, select "Schedules" and click on "Schedules/Quantities".

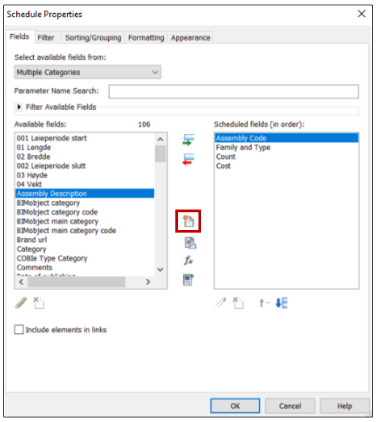


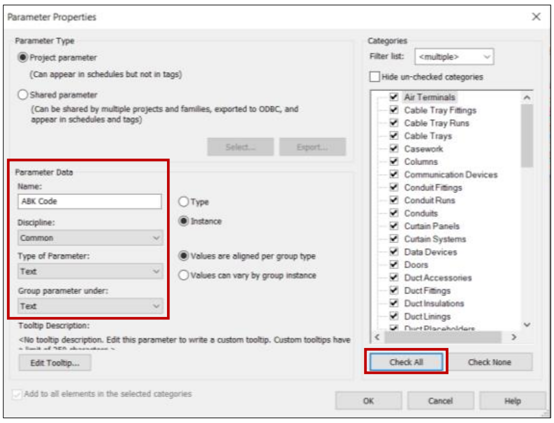
2. In the New Schedule dialog, click the "Multi-Category" category and click OK.



3. In the Schedule Properties dialog under the Fields tab, click the "New parameter" button. For "Name" fill in ABK Code, for discipline select "Common", for "Type of parameter" select

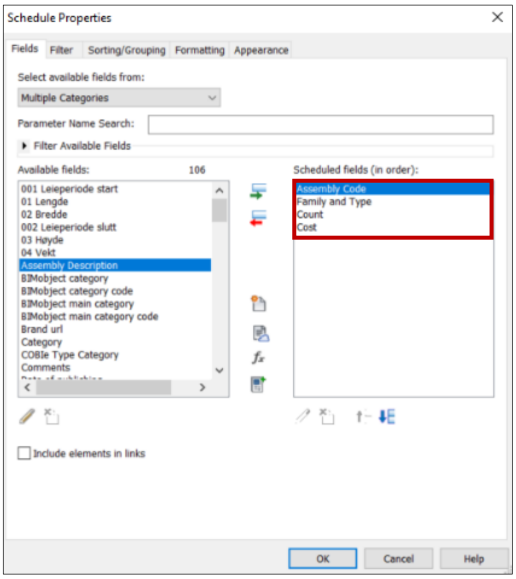
“Text” and for “Group parameter under” also select “Text”. Select the “Check all” button and click OK. The ABK code parameter has now been created.

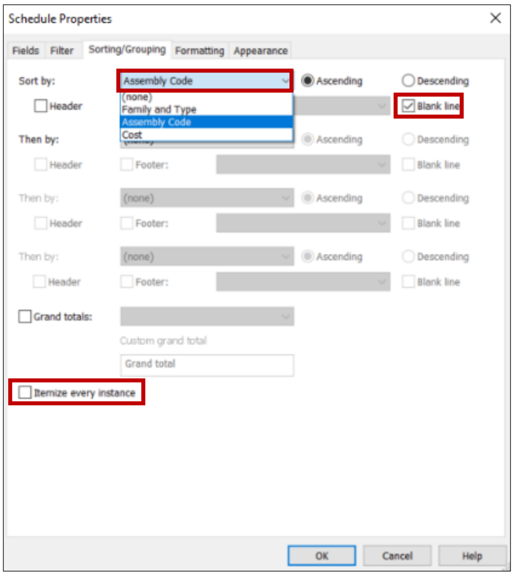




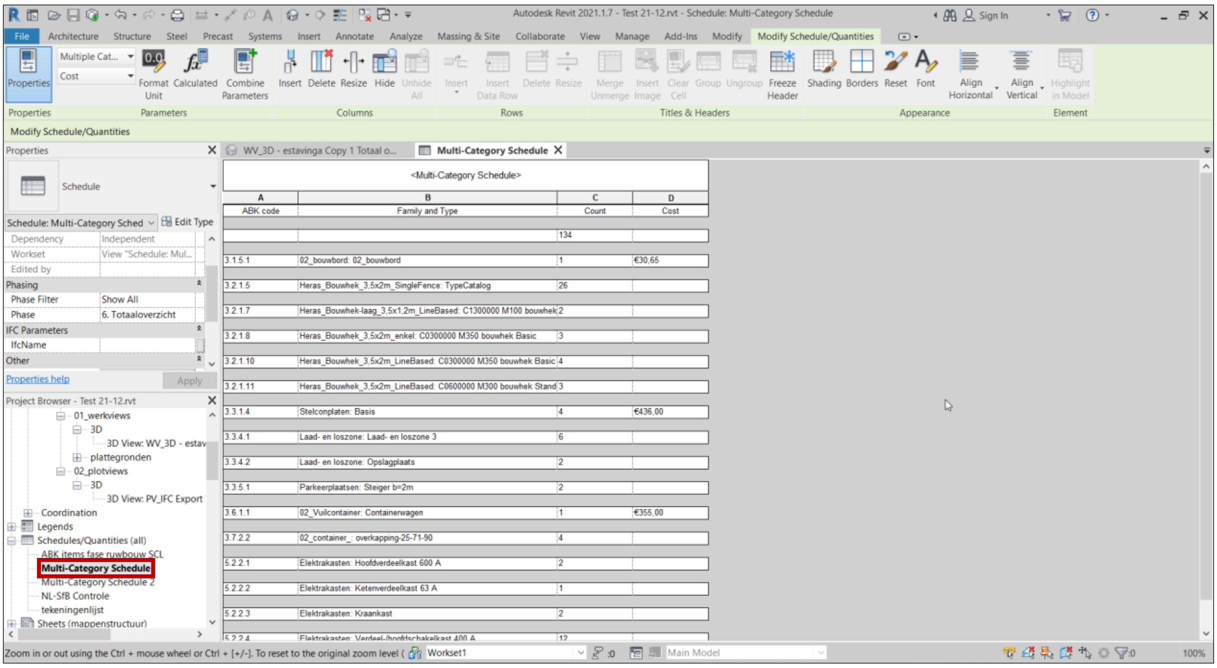
4. In the Schedule Properties dialog, for Available fields, select the following parameters and click OK:
   - ABK code
   - Family and type
   - Count
   - Cost

   In the same dialog, select “Sorting/Grouping”. In the Schedule Properties dialog, sort by “ABK Code” and check the “Blank line” box. Make sure the “Itemize every instance” box is unchecked. Click OK.

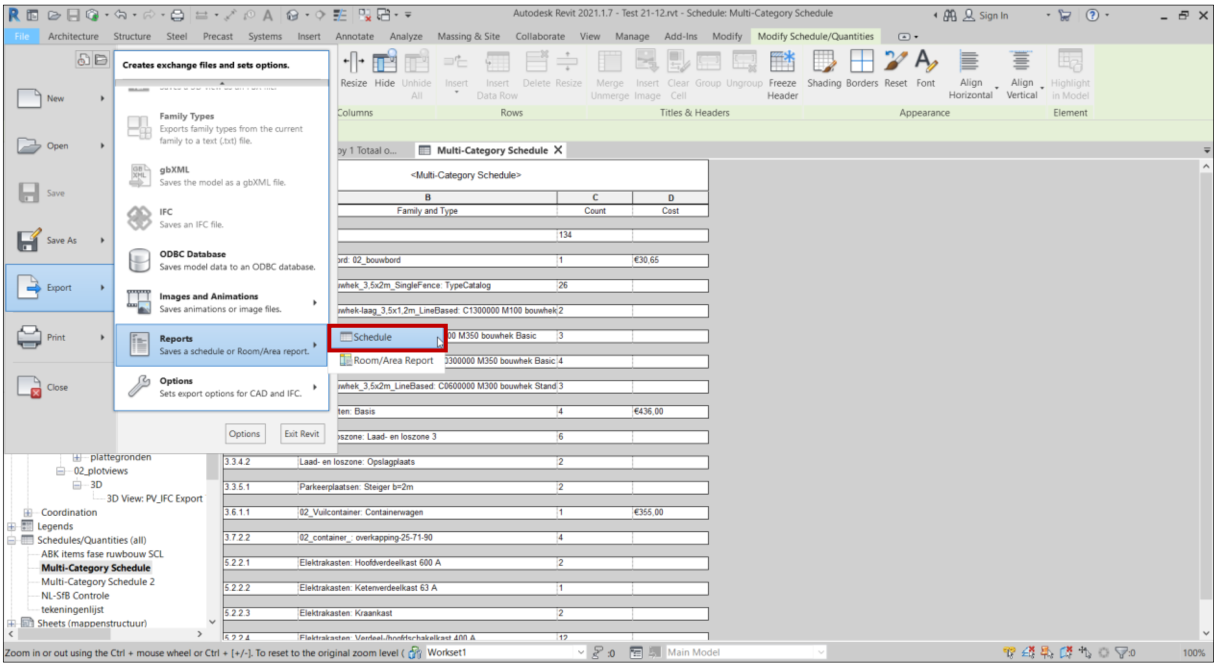




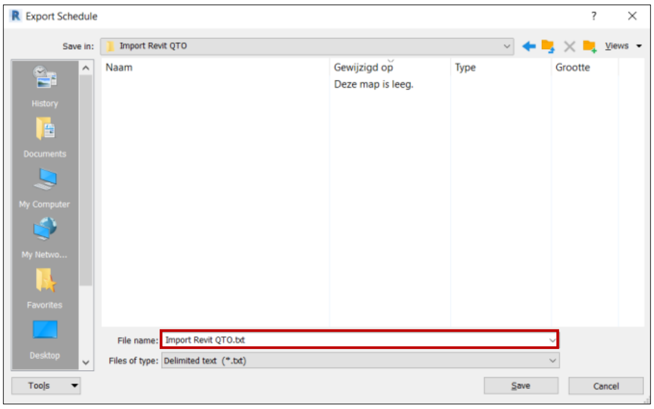
5. The quantity take-off schedule displays, and the view is listed in the Project Browser under Schedules/Quantities. Once the schedule is set up, the data can be exported to Excel.

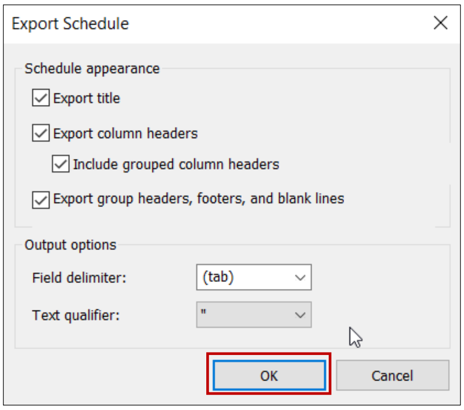


6. In the opened schedule window, select “File” > “Export” > “Reports” > “Schedule”.

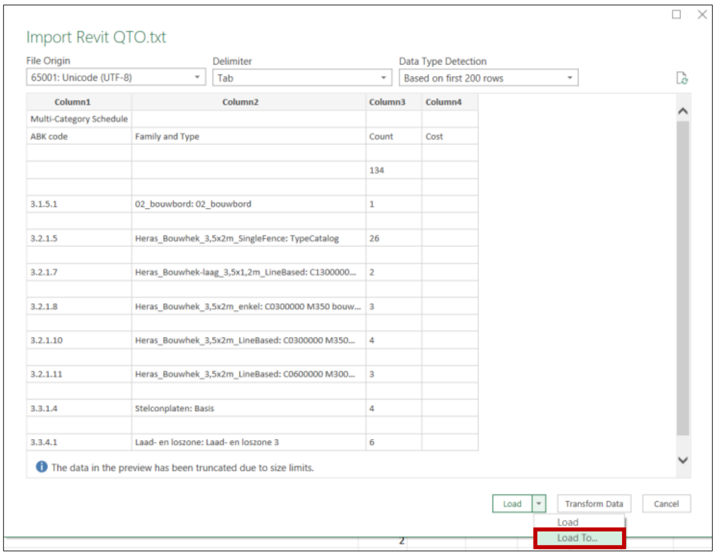


7. Save the schedule as an .txt file (Delimited text file type), and check the options.





8. Open the ABK estimation tool in Excel. Open the "Import Revit QTO" sheet and select the yellow marked cell. Select "Data" > "From Text/CSV". Import the .txt file of the saved Revit Schedule. Click on "Load to…"



9. Check the "Existing worksheet" bullet as location to load the schedule. Click OK. The ABK estimation tool is now able to extract the imported data from the Revit Schedule.