Article

BIM-oriented working within the (road) construction sector

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Abstract: The AEC sector faces a large-scale shift from a traditional (road) construction process to a construction process based on the Building Information Modelling principle. BIM is a promising new development that has received considerable attention in recent years. The aim of this study is to investigate the advent of BIM-oriented working within the (road) construction sector in Belgium in order to determine Belgium's position in this transition towards a building process with BIM. To support this research, an online survey based on an impact analysis was distributed to 122 employees active in the AEC sector. The results indicate that most companies already made the transition from a traditional building process to a building process using the BIM principle. In addition, the research demonstrates that the results mainly apply to employees active in civil engineering. A small group, mainly active in the road construction sector, has not made the transition due to several obstacles. Overall, the transition started later in the road construction sector, unlike other sectors. Based on this it is recommended that sufficient attention is paid to this group, who have not yet been able to realise this transition, as they constitute an obstacle to the further development of BIM.

Keywords: BIM; digitisation; (road) construction sector

1. Introduction

Recently, there has been a large-scale shift from a traditional (road) construction process to a (road) construction process based on the BIM principle. BIM is a very broad concept that has multiple interpretations and definitions, making it difficult to merge them into a single unambiguous definition **[1,2]**. The acronym BIM stands for **Building Information Modelling**, i.e. the process of sharing digital data between the different partners of a project through a common exchange platform in order to support the roles of the various stakeholders **[3-7]**. Moreover, BIM can also imply **Building Information Model**, the digital 3D display of the project. Today, in addition to these two meanings, the abbreviation is also used in the sense of **Building Information Management**, namely the intelligence contained in the BIM model and the ability to manage and query that information **[3-7]**. The reason for these different meanings is due to the fact that the applications have evolved over time and that the potential of BIM is much larger than initially foreseen **[2]**.

Several studies in the AEC sector have already investigated the difference between a traditional construction process and a construction process based on the BIM method in order to identify the advantages and disadvantages associated with the BIM process. This was usually done by means of surveys, which were carried out at various functions active in the construction sector **[7-16]**. The use of surveys makes it possible to determine the state of affairs and to analyse the users' attitude towards the BIM concept. In addition, many studies are carried out on the basis of case studies in order to evaluate the benefits and limitations of BIM **[1,2,4,10,17]**. These studies show that the main benefits of using BIM are improved information flow, improved profitability, lower costs and better time management. However, it is undeniable that the implementation introduces a number of new problems, such as the high cost and training associated with the implementation, lack of trained staff and the required scale of cultural change **[1,2,7,15,16]**.

The research usually takes place within the construction sector, where comparisons are made between different functions, projects, companies, countries or even continents **[12,18,19]**. In contrast, the focus on the road construction sector is still absent. Less research has been done in this field compared to the construction industry **[9,20,21]**. Moreover, it is remarkable that in most studies, where a comparison is made between different European countries or continents, very little is mentioned about Belgium. This is due to the low number of studies in the Belgian construction sector.

In this paper, an attempt is made to fill this gap in the existing literature by investigating the advent of BIM-oriented working within the (road) construction sector. The aim is to examine the transition from the traditional construction process to the construction process with BIM for (road) construction companies in Belgium. Additionally, the possible causes behind this slow evolution are a part of this research. The will to digitise is strongly present within the sector, and stimulated by the government, but translating this will into practise is usually very difficult due to the presence of some certain barriers. This research is carried out by the Agency for Roads and Traffic, in collaboration with the University of Antwerp, as part of a master's thesis.

The data for this study were collected by means of a survey, which was conducted among employees of various companies active in the (road) construction sector. It was very important for this survey to approach various functions, companies and sectors in order to create the best possible picture of the current situation. Moreover, the surveys were distributed in two ways. Firstly, the questionnaire was distributed by bachelor students during their internship at various (road) construction companies within Belgium. In addition, the digital questionnaire was also distributed via social media.

This paper is organised in the following way: firstly, the research methodology of the paper is explained, in which the survey and its associated analysis are fully described. In addition, a general description of the BIM concept is formulated, where the difference between BIM and the traditional construction process is emphasised on the basis of its advantages and limitations. In parallel, the current state of affairs in Belgium in relation to the other European countries is also discussed in the same section. In the third section, the results of the research are analysed and linked with previous work in this field. Finally, in part four, a conclusion is formed that provides an answer to the main research question.

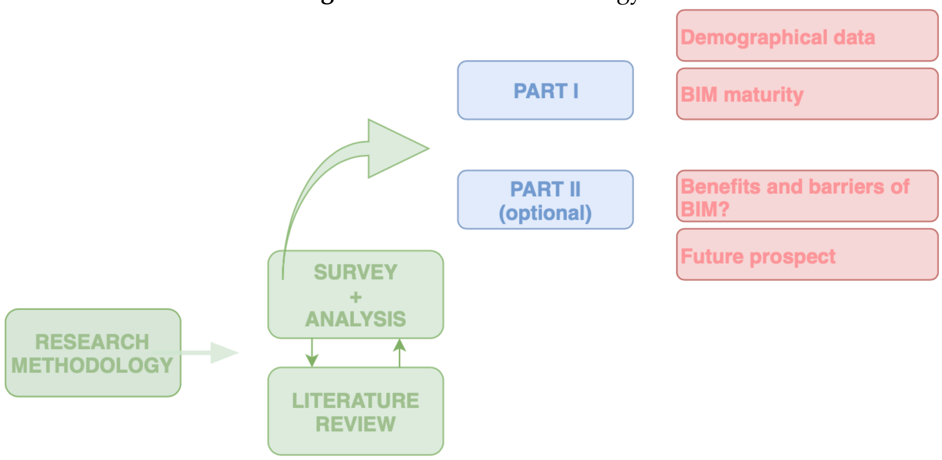
Figure 1. Word cloud

2. Research methodology

This section discusses the method used to investigate the advent of BIM-oriented working within the (road) construction sector, by answering the main question: "In which way is BIM implemented within the (road) construction sector in Belgium and where do they currently stand in this transition between the traditional building process and a building process with BIM?".

First the survey is discussed, followed by an overview of the current state of affairs, which can be compared with the results of this analysis.

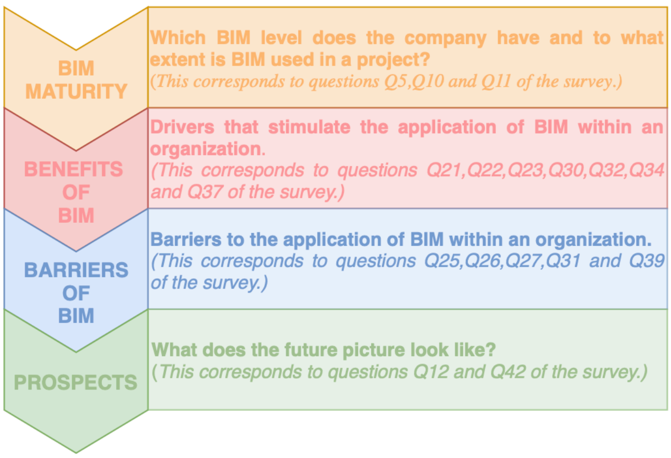
Figure 2. Research methodology



2.1. Quantitative study: Survey

In order to determine the current state of affairs of the (road) construction companies in Belgium, in this transition to a digital company, a survey was prepared on the basis of an impact analysis, consisting of four different main topics in the survey. These main topics are also the research topics of this study to formulate an answer to the main question:

Figure 3. Research topics and corresponding questions



The survey was divided into two parts. The first part was completed by all 122 participants, as opposed to the second part, which was optional, and was completed by only 42 participants.

In the first part, the participant's profile is determined to see which company profiles are involved and to grade the BIM maturity of the respondents. The company profile consists of the company size, the function and the sector. With this profile correlations and cross tables can later be carried out to check the degree of digitisation. Subsequently, additional t-tests can be made to compare the averages of two variables and to test whether these differences are statistically significant. In the second part of the survey, several aspects from the first part are examined in more detail in order to get a better picture of certain points of view.

The questionnaire was distributed in two ways. First and foremost, by the bachelor students, who were requested to have this questionnaire completed by several employees at their internship company. These were mainly construction companies active in Belgium. In addition, the questionnaire was also distributed via LinkedIn and by mail in order to reach people mainly within the road construction sector.

Finally, this survey will also be used by an associate student, Robin van Riet, who will focus on the results of Lantis. Within her master's thesis, she will investigate the use of BIM for Information management in a large-scale infrastructure project and make comparisons between Lantis and the rest of the companies that participated in the survey.

2.2. Benefits and disadvantages of BIM

"A BIM is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle from inception onward ***[22]****."*

2.2.1. Why BIM?

"BIM is the future"[1]

In recent years, the pressure to digitise has been increasing in the society. By means of digital technologies an attempt is made to change the business model in order to realise the process towards a digital company **[8,11,23]**. This transition is also happening in the construction sector in general and more specifically in the road construction sector **[9]**. One of the most important developments that facilitates this transition towards a digital company, is the BIM concept **[3]**. The BIM approach revolves around an intelligent data rich 3D model that is shared by team members and that becomes a collaborative centre during the entire life cycle of an asset, be it a bridge, a road or a building **[24]**. It helps people to visualise what needs to be built in the simulated environment to identify possible problems and errors in advance, using the clash detection, which is one of the most known benefits of BIM **[1,2,7,8,24]**. Besides supporting the design and development of a project, BIM is also used for the continuous management and maintenance of assets **[3,4,25]**.

2.2.2. The benefits of BIM

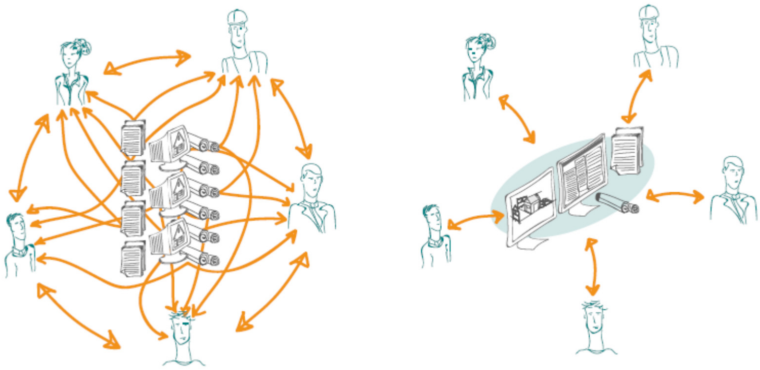
The advantages of BIM integration are multifaceted and benefit all teams involved. One of the most important gains, is the optimisation of the information exchange between the construction actors. Here, information exchange does not only mean the transfer and receipt of information, but much more the consultation and coordination of information that is of common interest **[1,2,26,27].** This improved communication resulting in a much faster and more efficient delivery of a better product **[2,8]**.

The most important difference between a traditional building process and a building process with BIM is the way the information is shared between the different actors involved. In a traditional building process, communication takes place on the basis of 2D drawings, plans and documents, which are printed out or passed on by mail. Each actor in this process draws up its own plans with its own improvements and interpretations based on the previous plans of the other actors involved **[28].** Since the process is not based on an integral approach, each actor works on its own and the passing on of information is quickly omitted. As a result, they work with plans that are not up to

[1] According to one of the respondents

date, which increases the chance of errors and miscommunication **[28,29]**. These errors may lead to unforeseen costs, delays and possibly even to court cases between the various parties **[25,30]**.

Figure 4. The way of communication during the traditional building process and the BIM process **[28]**.



The BIM practise, on the contrary, works in a very structured way. The construction process that normally takes place in a linear way is omitted and replaced by a process in which the entire project team has to work together from the beginning **[28].** The various sources of information are shared with all teams participating in the process, allowing for fluent collaboration and progress **[3].** However, the BIM should not be seen as one all encompassing joint 3D model or database, but as a shared data model **[5,25].**

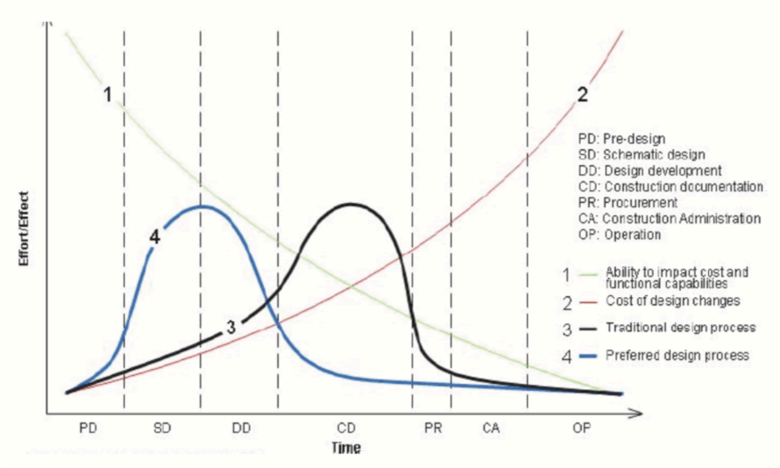
After all, everything revolves around the fluent collaboration of the various disciplines, where everyone can immediately process their information into the models and then share it with the other links in a faster and more efficient way. It is in this way much easier to obtain the necessary information because everything is made available and the various links are aware of the current changes **[5,25]**. Improved communication also usually comes first when asked about the main benefits of BIM **[4].** This is also the case in the paper by Aranda-Mena et al. (2009), where a comparison is made between five case studies, in which there is consistent agreement with the propositions that BIM: improves information management and information exchange, efficiency, coordination, buildability and the design itself **[4].**

Another comparable study by Salman Azhar (2011), which also compares several case studies, shows that the use of BIM can greatly improve the predictability of building performance and operation **[2].** As the use of BIM accelerates, collaboration within project teams will increase as well, leading to improved profitability, lower costs, improved time management and a more efficient customer-client relationship **[2].** Moreover, a study conducted by the University of Twente into BIM maturity, based on a survey, shows that the main drivers of BIM are the following aspects: working more efficiently, reducing failure costs and processing time, improving information management, increasing cooperation with other partners and strengthening the competitive position **[7,8,17].**

As a result of the fluent communication and cooperation, the BIM process enhances time saving, allowing the project to be completed earlier than with a traditional construction **[4].** However, this might not always be the case. The preliminary phase of a construction process with BIM is much more labour intensive than with a traditional construction process, because all the information first has to be digitised one by one **[4,6].** However, once all the information is in the model, the BIM principle can save time. If an error is discovered during these stages, it can easily be changed in one go in contrast to the traditional building process, where each link has to adjust the error to the different plans **[2,7,31].** The work intensity at the beginning of the process can in this way be compensated for by a time saving during problem solving in the subsequent stages **[4,6]**.

In a paper by Aranda-Mena et al. (2009) this equation is represented by a diagram with time-intensity distribution curves, in which a comparison is made between a building process with BIM and a traditional building process **[4]**. This diagram is similar to Patrick MacLeamy's graph, which also shows this comparison graphically **[6]**.

Figure 5. Patrick MacLeamy's effort-time distribution curve **[6]**.



In the graph, MacLeamy plots effort/effect against time to illustrate the difference of the effort/effect graph over time in a pre and post BIM scenario. There are four different curves, with the green descending line showing the possibility to influence costs and quality and the red ascending line showing the cost of design changes. The black curve then represents a traditional construction process and shows the main efforts in pre-BIM times. This is in contrast to the blue curve, which represents a building process with BIM **[6]**.

When using BIM, the curve shifts to the left, to the earlier design phases, where changes are easier and less costly to process **[1,2,4,30,31].** At a later stage of the design process, where the pre-BIM scenario mainly takes place, costs increase much faster when changes need to be made. From this it can be concluded that the use of BIM makes it possible to deal with errors much faster and cheaper in the process as opposed to the traditional process where a change at the end of the process is very costly **[1,2,4,30,31].** According to studies, 85% of the life cycle costs of a facility occur after the completion of the construction, and around $10 billion in the US alone is lost annually due to insufficient access to information and interoperability problems during the operation and maintenance phases **[1].**

This graph represents what can be achieved with BIM and highlights the inefficiency of pre-BIM working methods **[6]**. In conclusion, throughout the life cycle of the project, the BIM principle will save time, with the savings not occurring in the initial phase, but only in the final phase **[4]**.

A second important benefit of BIM is risk reduction and clash detection **[4,7,8,10,16,17,25,27,31].** The implementation helps to gain insight into existing conditions for both the safe construction and maintenance of, for example, an infrastructure facility **[24].** With the help of clash detection, potential conflicts are brought to light at an early stage by merging the models of different disciplines and checking them for clashes. Where the different parts of models interfere with each other, a conflict is detected **[4,7,8,10,16,17,24,25,27,31].** These conflicts are then reported and followed up in further stages. In this way, communication becomes more transparent and failure costs at the construction site are greatly reduced by identifying where the conflicts with the existing environment will occur [19]. In a traditional construction process, however, 2D plans are usually used, which do not make it possible to trace overlaps immediately. Such errors are then only discovered during the construction of the project, where in some circumstances drastic delays and costs can be incurred **[7,8,31].**

The Centre for Integrated Facility Engineering (CIFE) at Stanford University in the United States conducted a survey in 2007 to analyse the use of Virtual Design and Construction (VDC) and BIM technologies in the AEC sector **[10].** The survey was completed by 171 respondents representing a broad mix of business size, technical disciplines and project types. They are active throughout the

US and the rest of the world, and often provide services at multiple stages of the design and construction process. The data suggests that BIM could reduce unforeseen financial changes by up to forty percent as opposed to a traditional process. Construction costs were reduced by ten percent, through faster tracking of any design errors, and construction time by seven percent **[10].**

These benefits of BIM were also polled in the survey for this research to see if there are similarities between the different studies.

2.2.3. The current barriers preventing the use of BIM

Today, there are still a few important pitfalls and drawbacks to the BIM concept, which must be considered. First and foremost, the financial aspect of BIM should not be underestimated **[6-8].** It requires a certain investment that cannot be recouped in the short term. It often involves new processes and a new working method that requires considerable effort and time to implement the switchover. The relevant software and hardware must be purchased, and staff must be trained in the use of that software. In addition, at the beginning of the switchover the knowledge is usually not present within the office or company, which means that for many things external people have to be called in. This reduces, especially in the beginning, the productivity and the speed with which the switch is realised **[2,14,15,16,30,32].** Moreover, it must be taken into account that BIM software packages need to be updated periodically, which is an additional cost item **[33].**

Further, there are also a number of legal issues that can cause problems when working with BIM **[7,8,27].** An example of these are copyright issues. Since the cooperation and exchange of information are central to BIM, this can in some cases cause confusion as to who owns the copyright. Additionally, it is also possible that various parties may request payment for sharing their information, which leads to unnecessary costs. In order to avoid these issues, it is encouraged to make good arrangements between the various parties involved at the beginning of the process and to set out ownership rights and responsibilities in the contract document **[27].**

The abovementioned drawbacks are also usually the most important barriers that recur when asked about the disadvantages associated with the BIM method. According to the research carried out by the University of Twente, the main barrier that most people face is the lack of knowledge and experience, which hinders the speed of implementation and expansion of BIM applications **[7,8].** Another barrier that is considered important is that not all partners can participate in the BIM process. However, it is expected that this barrier will diminish with an increase in BIM maturity in the construction sector. Differences in BIM maturity between the partners also underline the importance of making a good estimate of a partner's BIM capacity before a project starts **[7,8].**

Another study based on a survey of 31 construction companies in the United States found that the main obstacle to BIM is the lack of trained personnel **[34].** The second obstacle was the high cost of implementation followed by the reluctance of the other project partners, interoperability and the lack of legal and contractual agreements **[34].**

In a study by Robert Eadie et al. (2014), information was collected through a web-based survey conducted among the top 74 UK-based contractors in the construction sector **[15].** The findings here showed that the barriers after the introduction of BIM are less important, as the main obstacle to the initial investment has been overcome and the "fear" factor has been reduced. The two main barriers to the implementation of BIM in general are "scale of culture change required / lack of flexibility" and "lack of procurement in the supply chain" **[15].** Implementing new processes in an organization means that the culture of the organisation changes, which entails risks and challenges that are not limited to financial considerations, but also involve the flexibility or diversity of the organisation's people and systems **[15,16].** In addition, contractors striving to deliver a BIM project also expect their subcontractors to be "BIM-literate". It is to this end essential that the BIM software packages used by the various project participants are "interoperable" in order to achieve the benefits of better collaboration. Without this, the concept of collaboration is a sham and, instead of streamlining communication in the supply chain, BIM will act as a barrier **[1,2].** Furthermore, it should not be forgotten that if the investment in BIM software is a financial burden for large main contractors, it is also likely to be financially out of reach of their subcontractors **[15].**

These barriers of BIM were also polled in the survey for this research to see if there are similarities between the different studies.

2.2.4. Current situation in Europe

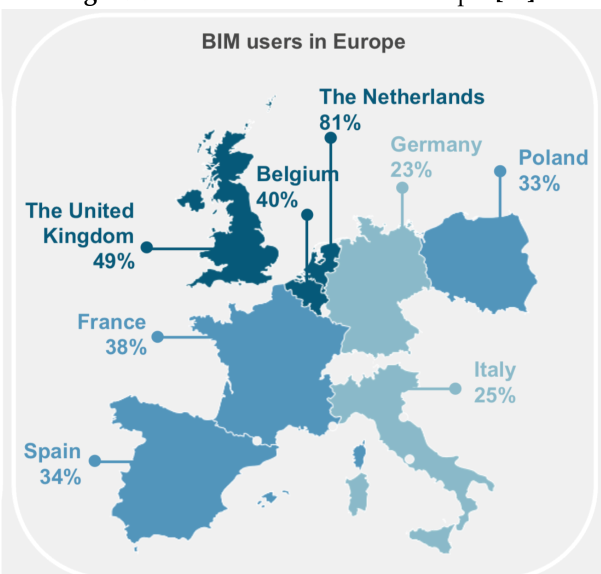
The BIM concept has attracted a great deal of attention in the past few years. However, for many it is still a novelty. The ideas and technologies behind the BIM concept have in fact been evolving for more than fifty years **[35].** In this respect, the concept was first initiated in the 1970s, but only received due attention when Autodesk released the "Building Information Modelling" guide in 2002. Since then, BIM has been deeply rooted in various areas of research and development. Conversely, implementing BIM in practise is a different story **[35]**.

The Belgian construction industry is lagging behind in this digital transition compared to other European countries, such as France, the Netherlands and the United Kingdom **[11,19]**. In January 2014, the EU Public Procurement Directive (EUPPD) entered into force, which, among other things, recommended modernising European public procurement rules through the use of electronic tools, such as BIM, for public procurement **[36]**. The adoption of the directive meant that all 28 European member states had to encourage, specify or oblige the use of BIM for publicly financed construction and building projects in the European Union by 2016 **[36]**. Today, the use of BIM for publicly funded construction projects is already mandatory in the United Kingdom, the Netherlands, Denmark, Finland and Norway. In contrast to these countries, the use of BIM for public procurement is not yet mandatory in Belgium but is increasingly being prescribed by government and semipublic authorities **[36]**.

Certain countries have set themselves ambitious targets, even before the European directive was adopted **[11]**. The United Kingdom has embarked on a thorough modernisation of the construction sector since 2011, mainly through digitisation. The aim was to achieve a 20% reduction in construction costs, execution times and building management costs. Other countries in the Union had already imposed the use of BIM in their public building contracts. Finland did this in 2007 and the Netherlands in 2011 **[11]**.

From the moment BIM was investigated in Europe, the Netherlands has always been at the forefront of BIM implementation **[19]**. This is also visible in the report of the USP's European Architectural Barometer, which shows longterm trends in the use of BIM by architects **[19]**. The report is based on a quantitative market survey in which between 150 and 200 telephone interviews with architects were conducted in eight European countries (Spain, Italy, France, Belgium, the Netherlands, Germany, Poland and the United Kingdom) **[19]**.

Figure 6. The use of BIM within Europe. **[19]**.



If the use of BIM among architects is analysed by country in Europe, it is clear that the Netherlands has a leading position by far, with 81% of architects already using BIM. This is twice as high in contrast to Belgium, which probably has to do with business culture. In the Netherlands, the market is more digitised and is more used to cooperation between the various stakeholders in the construction industry **[19].** For these reasons, it is interesting to look at how the implementation of BIM is taking place in the Netherlands and how they are positioning themselves in relation to it.

In the Netherlands, the Bouw Informatie Raad (BIR) has always played a very important role during the introduction of the BIM concept. They stimulate companies in the construction industry to become more proficient in the use of BIM and thus to grow to a higher BIM level **[37].** In order to better steer the construction sector, various studies were carried out to find out the state of affairs**.** A good example of this is the BIM Maturity Sector Analysis **[7,8].** In May 2014, commissioned by the BIR and Nederlandse Vereniging voor Inkoopmanagement **(**NEVI**)**, the University of Twente launched a two year study into BIM maturity in the Dutch construction sector **[7,8].** As the first part of the study, a sector analysis was carried out among fifty companies **[8].** In addition to the previous sector analysis conducted in 2014, an online survey was conducted among 105 organisations at the beginning of 2016 **[7].** The aim was to form a better picture of the differences and similarities between subsectors with regard to BIM maturity. The results showed that the highest average maturity score across all subsectors was achieved on the 'strategy' criterion. This shows that, on average, the management of the interviewed organisations values the application and development of BIM. Furthermore, many organisations in various subsectors indicate that the greatest challenges lie in the area of "people and culture". The BIM managers and BIM drivers claim that working habits cannot be changed overnight. This is a gradual process that needs to be supported by good information, training and guidance **[7,8].** According to this study, 3D clash detection is at the top of the list of the most important BIM applications, because it provides the greatest added value by reducing failure costs. The following main benefits are: increasing efficiency and reducing lead time, optimising processes, strengthening the competitive position and improving information management. Moreover, the main barrier that emerged in this research was the lack of knowledge and experience about BIM that slowed down the implementation and expansion of BIM applications **[7,8].**

Similar investigations were also carried out in Belgium. At the beginning of 2017 the Confederatie Bouw carried out a survey **[11].** Until then, there were hardly any reliable statistics available on the digitisation of the Belgian construction sector. That is why the Confederatie organised a survey among its members in the runup to its BouwForum 2017 **[11].** It was a thorough attempt to find out the degree of digitisation among Belgian construction companies and their attitude towards it. 272 contractors took part in this survey, distributed across the four major subsectors of carcass construction, installations, finishing and civil engineering reflecting a good existing distribution in the sector. The results showed that BIM was still little known and that, on average, a small 30% of contractors were familiar with digital technologies and only 5% of them used them properly. The inhibiting factors here were mainly the lack of usefulness for the production process because it was not seen as necessary for the functioning of the company and the limited demand for these technologies. The other reasons quoted are (in descending order of average frequency) cost, lack of time and lack of staff with the necessary background. For BIM, however, the lack of time was cited as one of the biggest barriers. Nevertheless, this delay was not very worrying as the BouwForum 2017 proved that the sector was interested and wanted to actively prepare for the digital transition. The large majority of the construction companies that had knowledge of the digital tools but were not yet using them declared that they were ready to apply them in the very near future **[11]**.

A more recent study was carried out by the Belgian Research Centre, which developed an online tool, the Digi-Barometer, to benchmark Belgian road construction companies in terms of digitisation **[9].** This is an online self assessment tool that uses a series of detailed questions to measure the degree of digitisation of companies. The first edition of the analysis report, highlighting the results of the Digi-Barometer for Road Construction, showed that all types of companies, from small to large, at least intend to digitise their business processes. They are driven by an urge for efficiency and the question of how they can continue to distinguish themselves from the competition. A total of sixty construction companies took part in the benchmark exercise because of their intention to work more efficiently and digitise their business processes **[9]**.

In practise, despite its multiple benefits, the implementation of BIM has been very slow. This form of digitisation is not obvious to everyone and people deal with it in their own way. It is important that sufficient attention is paid to the weak links in the process. This is because the collaborative process within BIM is like a chain. If one link in the chain does not cooperate effectively, it hinders the others from performing their function optimally and properly. The presence of these weak actors is currently holding back the further evolution of BIM due to the presence of some certain barriers.

3. Results and discussion

In this section the results of the survey on the occurrence of BIM-oriented working within the (road) construction sector are reported and discussed.

The survey was completed online in the early part of 2020 by 139 respondents. However, the number of valid surveys is equal to 122. Table 1 shows an overview of the dataset and how it is subdivided. It is striking that most respondents work in a large company and are active in the road construction sector.

After part I, respondents were given the choice to finish the survey and only 42 respondents completed the questionnaire. For these reasons, a new overview of the demographics of the remaining respondents is also given in Table 1. Again, most respondents work in large companies, but in contrast to part I, most of them are active in civil engineering.

Table 1. Demographical data of the respondents

Company size	**Part I (n=122)**	**Part II (n=42)**
Self-employed	5,7%	0,0%
Small enterprise (< 50)	20,5%	24,4%
Small to medium-sized enterprise (≥ 50 and < 250)	19,7%	14,6%
Big enterprise (> 250)	54,1%	61,0%
Sector		
Road construction	27,9%	12,2%
Residential	8,2%	9,8%
Industrial	5,7%	9,8%
Commercial	10,7%	12,2%
Civil engineering	27,9%	39,0%
Other	19,7%	17,1%
Function		
Architect/designer	13,1%	17,1%
Management (senior management + project director)	29,5%	24,4%
Site management (project manager + technical assistant + site manager)	28,7%	26,8%
Engineering offices (stability engineer + technical engineer)	9,0%	7,3%
BIM function (BIM modeler + BIM manager + BIM coordinator)	13,9%	14,6%
Other	5,7%	9,8%

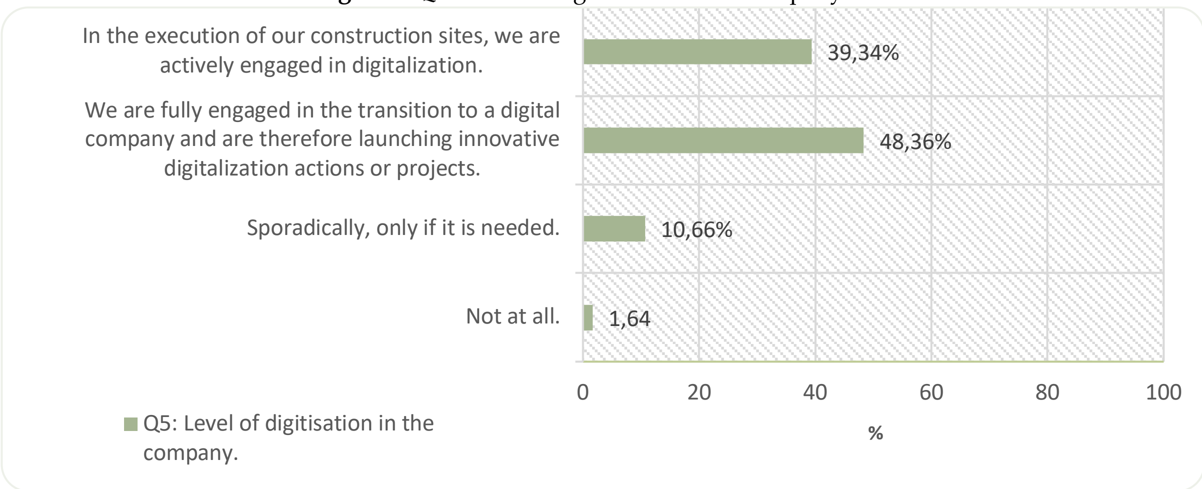
3.1. Part I

3.1.1. Results digitisation

Belgian (road) construction companies all face the same challenge: digitisation is a must, but at the same time a time consuming and intensive process. Most people realise that technological developments need to be kept up to date, but how are the first steps taken?

The analysis of the survey shows that 48% of the participants are already fully engaged in the transition to a digital company and have already started innovative digitisation actions or projects. Only 39% are fully digitised and are actively engaged in digitisation in their construction sites. What is striking in Figure 7 is that a large part has already realised the transition within their company, but that there is still a small 13% within the (road) construction sector, which is hardly or not at all involved with digitisation. It is important that this minority receives the necessary attention, because they are usually the cause of the slow transition.

Figure 7. Q5: Level of digitisation in the company.



Looking at the company profile of these respondents, who are sporadically or never involved in digitisation, it appears that 58% of them are active in the road construction sector, 21% in the residential sector and 21% in civil engineering. The majority of respondents who have already made the switch and are actively digitising their business processes are active in civil engineering with 29%.

An important aspect of this switchover is the way in which communication and cooperation between the various links takes place. Taking a look at the results in Figure 7, it is expected that most of the people in the (road) construction sector communicate using 3D digital files or even via a collaboration platform, because the majority has realised the transition to a digital company. However, on the question "Q6: How do you process, obtain or share your plans during a collaboration" it appears that in practise during a collaboration 42% of the processing, obtaining or sharing of the plans is still done on the basis of 2D digital plans and even 13% on the basis of paper plans or scanned PDF. Only 21% of all respondents uses 3D digital plans and 24% uses a 3D building information model on a collaboration platform. This is also one of the reasons why certain problems, such as high failure costs, still occur today.

Digitisation is a broad concept in which the ways of collaboration and communication also have to undergo a digital transformation in order to obtain an optimal result. This optimal result can be achieved by striving for opportunities to reduce project costs, increase productivity, reduce lead time and improve quality **[38].** In order to achieve these goals, the costs of failure must first and foremost be reduced, which is a major problem within the (road) construction sector. Most of these failure costs occur during the execution and delivery of a construction project and are estimated at 43% of the total failure costs during a project **[26]**. The main cause of this is the weak communication and information exchange at the construction site, which occurs during all phases. In addition, it is not always easy to clearly communicate observed deviations to the responsible (sub)contractor. This description must contain sufficient and clear information so that it can be rectified. In practise, however, this is not always possible due to the high time pressure, resulting in relevant information being omitted **[26]**.

Looking at the respondents' company profiles, regarding to the communication between the different links using a 3D building information model on a collaborative platform, reveals that 38% is active in civil engineering and only 7% in road construction. Within road construction, 50% of the communication is still based on 2D digital files and 18% on 3D digital files. In addition, it appears that 26% in the road construction sector still communicate on the basis of paper plans or scanned PDF.

In the transition from 2D to 3D, a 3D visualisation of the building is displayed without any additional properties being linked to the objects. Only when switching to BIM, a digital building model is created that makes use of architectural, intelligent objects. Additional properties are then linked to all these objects (e.g., the choice of materials and dimensions) **[7,8,30,31]**. In this process, all information is only entered once, so the chance of errors is much lower than in a traditional building process. In addition, there are several possibilities to add extra dimensions such as planning and costs to these digital building models **[7,8,30,31].**

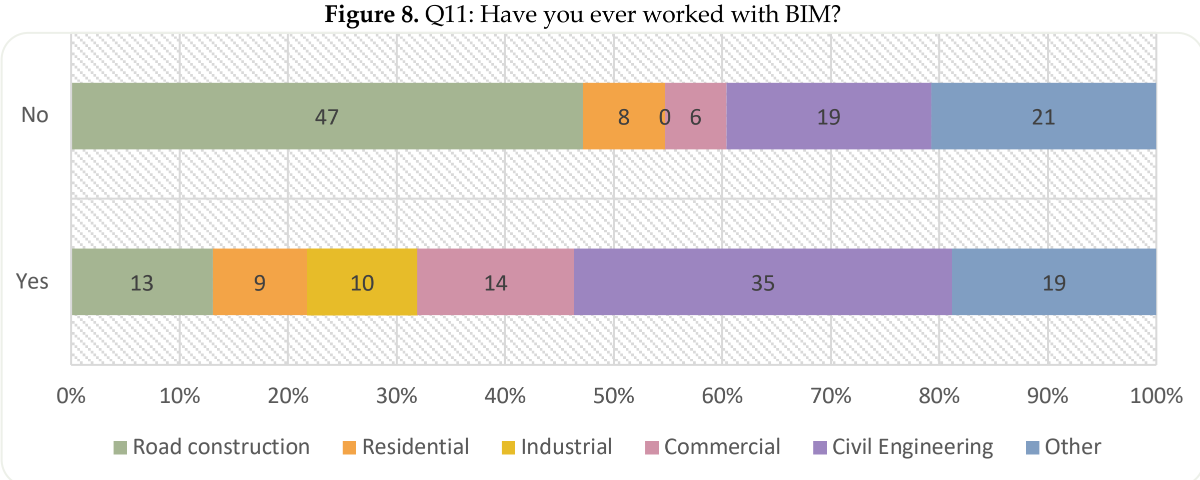
3.1.2. Results BIM

BIM plays a very important role in the digitisation process of the (road) construction sector **[1].** It is one of the most important developments that help realise the transition to a digital company **[1,2].** As mentioned earlier, BIM has the potential to lead to better results, time savings, a reduction in failure costs, fluent management and maintenance of a construction. In this respect, communication forms the basis and it is possible to perform a clash detection at an early stage and to align the various aspect models. This means that conflicts and differences can be detected at an earlier stage and can be resolved at a lower cost **[11,31]**.

Thanks to these advantages, it has been very popular in the past few years, which is noticeable in the analysis. 55% of the respondents know in general how it works and 32% have a broad knowledge of BIM. However, there are still a small number of people, 13%, in this sample who know nothing about BIM or have never heard anything about the BIM concept. This mainly concerns people active in the road construction sector.

The enormous attention that has been attached to working with BIM in recent years has subsequently ensured that most of them also have been able to make the switch from a traditional building process to a building process with BIM. This is also visible in the results which show that 57% of the respondents have worked with BIM before. Looking at this in more detail and examining the company profiles of these respondents, it is remarkable, as shown in Figure 8, that most of the respondents who answered yes are active in the civil engineering sector and only 13% in the road construction sector. Among the respondents who have never worked with BIM, on the contrary, it is striking that those who are active in the road construction sector take the lead with 47%. This is very high compared to the other sectors.

Figure 8. Q11: Have you ever worked with BIM?

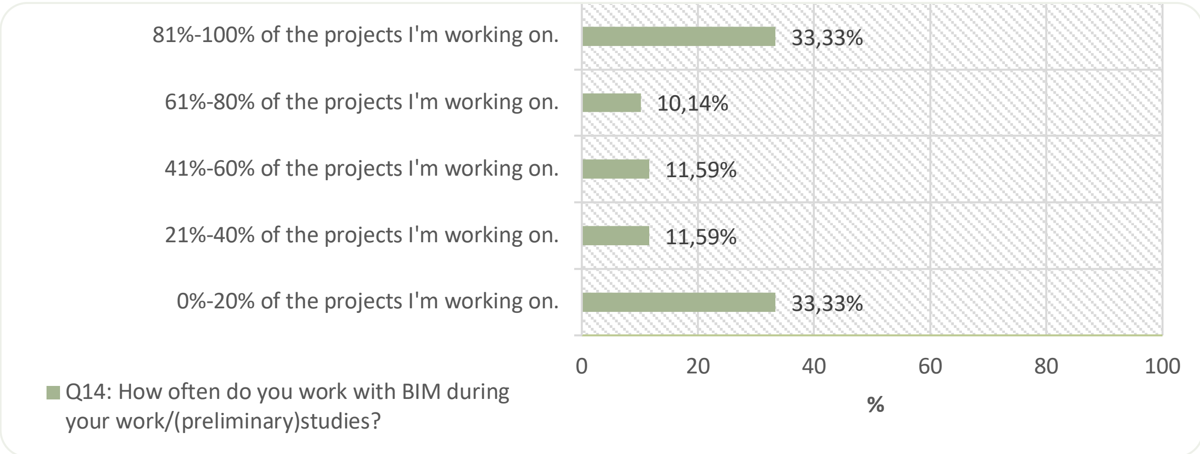


The main reason why most respondents in this research, who do not use it, have not been able to take this step yet, is the lack of knowledge and experience. This relates to the fact that this has almost never been requested by the client or due to lack of time. The implementation of BIM requires a substantial investment in hardware and software, which requires constant training and investment. After the training, staff will also have to familiarise themselves first with that, which will reduce the productivity and speed of designs in the first phase **[30]**.

However, for this group it is clear that there are opportunities to make the transition in the near future. If the necessary management support and investments are involved, 43% of the participants are prepared to use BIM in the future. In addition, 40% of the respondents see many benefits and would therefore like to make the transition as soon as possible. Again, there are a number of respondents who are turning their backs on the whole BIM story. 13% would like things to stay the way they are and do not see a switch to BIM as necessary.

It is also striking that within the group of respondents, who have already had to work with BIM, not everyone is equally active with BIM. Figure 9 shows that the use is very widespread and that only 33% of these participants have been able to realise the switch almost completely and very often use BIM during the construction processes. The respondents in this group are mainly active in civil engineering. Respondents who work the least with BIM (0%-20%) are mainly active in the road construction sector.

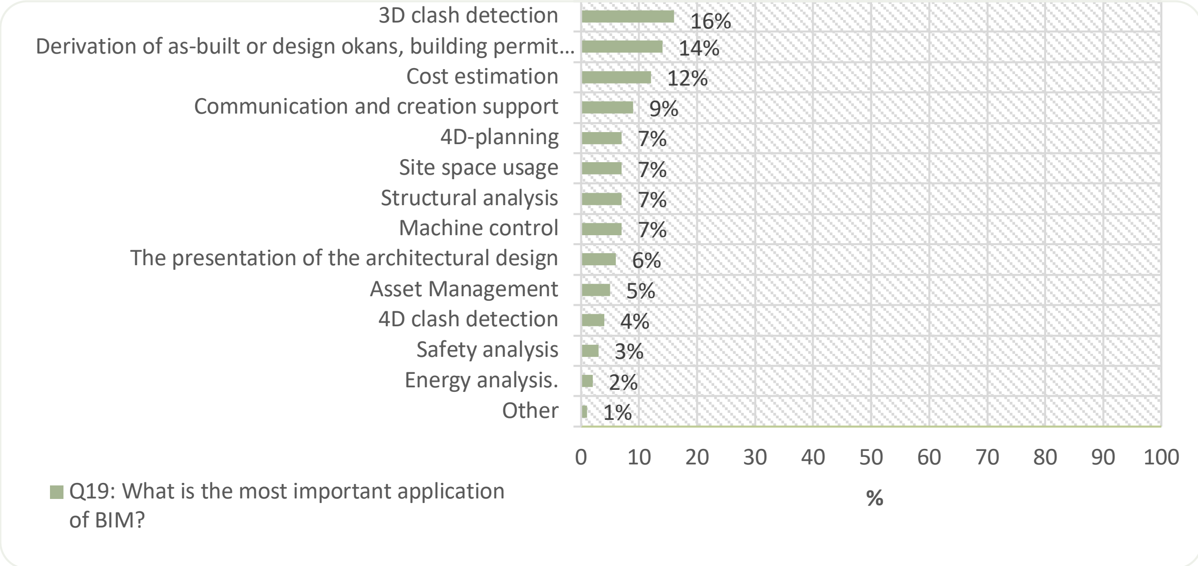
Figure 9. Q14: The frequency of BIM



During certain construction phases, the BIM process can lead to remarkable benefits. The study shows that these advantages arise mainly during the construction phase and in determining quantities and costs. In parallel, an analysis of the main benefits revealed that most respondents experience an increase in productivity, an increase in the involvement of project staff and a reduction in unpredictable costs in a construction process with BIM. This is in line with Salman Azhar's (2011) research, which reveals that the integration of BIM mainly improves communication and cooperation between the different project partners, which in turn leads to an increase in efficiency, productivity and quality of the product and a reduction in failure costs **[2].** Moreover, these results are consistent with the research carried out by the University of Twente, which shows that the main drivers of BIM are working more efficiently and reducing failure costs **[7,8].**

The study by the University of Twente showed that the most important application of BIM was the 3D clash detection, which, due to its presence, can reduce failure costs by filtering the errors at an earlier stage **[7,8].** This is in line with the results of this study. As shown in Figure 10, most respondents agree that the 3D clash detection is the most important application of BIM, followed by the possibility to derive as-built or design plans and the cost estimation.

Figure 10. Q19: The most important application of BIM

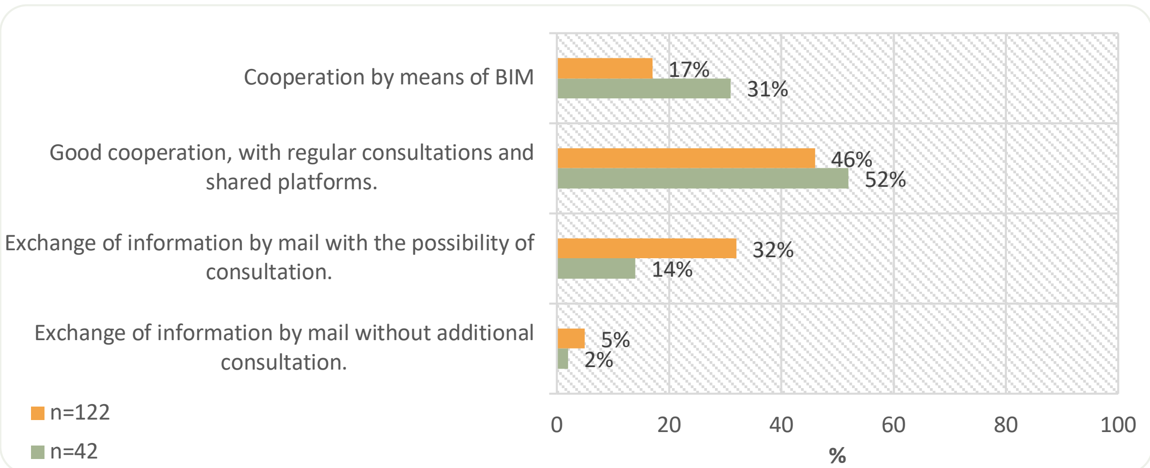


3.2. Part II

In order to get a better idea of the respondents' position on the BIM concept, a number of statements were drawn up in the survey. This part of the survey was nonbinding and was only fully completed by 42 respondents. A demographic comparison has already been made in Table 1. In addition, it is also important to know how these 42 respondents position themselves against the BIM concept in order to draw conclusions and generalise them to the entire sample. Therefore, it must be proved that this group does not differ from the total respondents in terms of their attitude towards BIM. This excludes the possibility that the remaining respondents all happen to be BIM adherents or not, as this could strongly influence the interpretation of the results. This comparison is shown in Figure 11, comparing the attitudes of the two different groups, i.e. all participants and those who completed part II, towards the BIM concept.

It is striking that there are relatively more BIM adherents in the remaining group of respondents. It is important that this is taken into account when interpreting the results. In both groups the majority of respondents are in category 3, i.e. good information exchange with regular consultations and shared platforms, and only a small minority in category 1, i.e. information exchange via mail without additional consultations. In addition, there are also relatively less people in category 2, where there is an information exchange via mail with the possibility of additional consultations.

Figure 11. Q7: How does the communication and cooperation between the different project partners take place?



3.2.1. The benefits of BIM

It can be deduced from various sources that working with BIM has many advantages **[1-5,7,8,10,11,16,17,25-27].** The previous literature study showed that the integration of BIM primarily improves communication and cooperation between the various project partners. This transparent exchange of information in turn leads to an increase in the efficiency, productivity and quality of the product. In addition, good communication leads to a reduction in failure costs because most errors can be filtered early on in the process. In this section, these benefits are analysed on the basis of various statements.

It is very clear that the results from the survey are in line with the literature study. 88% of the participants fully agree that BIM facilitates information management, the flow of information and the sharing of this information between the different project partners. In addition, the opinions on the increase in productivity, efficiency and quality are similar. Table 2 shows that the majority of respondents experience these benefits when using BIM during the construction process, but that there are also respondents who do not agree with this. This is most probably due to the fact that not everyone within the company has sufficient knowledge about BIM, which means that external people have to be called in for considerable things. As a result, in some cases, productivity and the speed of the transition is reduced **[7,8,14].** In addition, the labour intensity at the beginning of the BIM process by adding all the available information, deters some, which quickly slows down the transition **[4,6].** However, once the transition has been made and users are more familiar with BIM, the labour intensity at the beginning of the process is recovered in the following phases **[4,6].**

In Tables 2 and 3 an additional overview is given of the benefits and barriers that were questioned in this study.

Table 2. The benefits of BIM (n=42)

Corresponding question in survey	Benefit	I agree	I partly agree	I disagree
Q21	Increasing efficiency	76,2%	14,3%	9,5%
Q22	Facilitates the flow of information and the exchange of information.	88,1%	9,5%	2,4%
Q23	Improves the quality of the design	78,6%	16,7%	4,8%
Q24	Improves coordination between the different parties	88,1%	9,5%	2,4%
Q30	Clash detection ensures that construction conflicts can be filtered much earlier in the process.	92,9%	7,1%	0%
Q32	Positive impact on the productivity.	76,2%	11,9%	11,9%
Q33	Improves project results.	81,0%	11,9%	7,1%
Q34	It is a good source of information to realize the project without many problems and additional costs.	71,4%	19,0%	9,5%
Q37	Cost estimation and planning can also be estimated, which reduces failure costs and material wastage.	64,3%	21,4%	14,3%
Q38	Changes can easily be adapted to the different plans because everything is linked together.	71,4%	21,4%	7,1%
Q42	The bill of quantity, drawn up on the basis of a BIM model, contains fewer errors.	54,8%	23,8%	21,4%
Q44	Enables a more accurate price offer.	52,4%	28,6%	19,0%
Q45	4D-planning based on BIM shows clearer availability of resources (people + machines).	52,4%	38,1%%	9,5%

Table 3. The barriers of BIM (n=42)

Corresponding question in survey	Barrier	I agree	I partly agree	I disagree
Q25	Sufficient knowledge is not always available within the company, so external people have to be called upon. This reduces productivity and the speed with which the switchover takes place.	50,0%	21,4%	28,6%
Q26	Introduces new problems related to the payment of certain information and ownership of information.	35,7%	35,7%	28,6%
Q27	It requires too much effort and time.	42,9%	16,7%	40,47%
Q31	Requires a high economic investment (software, training...), which cannot be recouped in the short term.	50,0%	23,8	26,2%
Q39	The cooperation process within BIM is like a chain. If there is one link that does not cooperate, the BIM concept disappears.	61,9%	19,0%	19,1%

In Part II, the clash detection, which is the most important application of BIM **[4,7,8,10,16,17,25,27,31]**, was questioned anew in Q30 and again, 92.9% of the respondents agreed that this application ensures the detection of errors when the different aspect models of the different chains are overlaid. When using BIM during a construction process, the problems and additional costs are much lower compared to the traditional construction process.

Finally, it is very important that the participants, who do not experience the BIM process very positively, are given the necessary attention. They are the links that ensure that the cooperation process within BIM does not always run very smoothly.

3.3. Correlations and t-tests

In order to further analyse the results and to be able to generalise them to the population, correlations are drawn up. This involves checking whether the company profile (company size and sector)[2] of the respondents has a statistical connexion with the digitisation process and use of BIM. Only the significant results are discussed here. This means that for these results, the null hypothesis, which states that the results from the sample cannot be generalised to the entire population, may be rejected. The significance limit of $p < 0.05$ is used for this analysis. In this case, it can be stated that when the probability that the null hypothesis is valid is less than 5%, it is rejected and thus the results can be generalised.

For the purpose of these analyses, the variable sector is recoded to an ordinal variable. The recoding is shown in Table 4. The variable business size is already coded in an ordinal way.

Table 4. Recoding sector

Actual coding	New coding
Road construction	1
Residential	2
Industrial	3
Industrial	4
Civil Engineering	5

In addition, t-tests are also carried out in order to compare the averages of two different groups. In these tests a comparison is made regarding the company size and a recoding of this variable is made

[2] The variable "function" has been omitted as it gave no significant results.

to small companies (≤ 50 persons) and large companies (> 50 persons). Furthermore, a comparison is made by sector in which this variable is recoded into the road construction and the construction sector (residential, industrial, commercial and civil engineering).

3.3.1. Digitisation

The lack of budget and other resources is usually cited as one of the reasons for delaying the digitisation of companies **[7,8,14-16].** In addition, there must also be people available in the company who can initiate the transition to a digital company through various training courses **[7,8,14-16].** Making sure these people are available and making a budget available is not easy for every company. In general, it can be expected that larger companies will have more people available and have more budget to start the digitisation in the company **[20].** When looking at the results of the t-tests in Table 5 and Table 6, it is clear that there is a significant difference in the variance between small and large companies.

Table 5. Group statistics

	Company size	n	Mean	Std. Deviation	Std. Error mean
Digitisation	Small companies (≤ 50 persons)	32	3,12	,91	,16
	Large companies (> 50 persons)	90	3,30	,63	,07

Table 6. Independent t-test

		Levene's Test for Equality of Variances		t-test for Equality of means		t-test for Equality of Means	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
Digitisation	Equal variances assumed	4,48	,036	-1,20	120	,233	-,18
	Equal variances not assumed			-1,01	41,98	,319	-,18

When the relationship between the sector and digitisation is subsequently examined, there is a significant correlation value of 0,237. This indicates a weak positive linear dependency. Since the variable sector has been recoded, this can be interpreted as follows: the sector has a moderate positive correlation with digitisation, with civil engineering making more use of digitisation than road construction.

3.3.2. BIM

The results of the t-tests give a significant difference in variance for the coherence between the knowledge of BIM and the sector. The respondents active in the road construction sector have a mean of 2,94 on a scale from 1 to 4, where 1 represents 'no knowledge of BIM at all' and 4 represents 'I have an extensive knowledge of BIM'. This means that on average these respondents lean towards category 3 of 'knowledge BIM' which says they broadly know how BIM works. The respondents active in the construction sector (residential, industrial, commercial and civil engineering) have a mean of 3,41. This means that on average these respondents are between category 3 and 4 of 'knowledge BIM' which means they are in between a broadly knowledge of BIM and an extensive knowledge of BIM. To conclude, this group has a significant higher mean than the respondents active in the road construction group and thus they have more knowledge of BIM. However, the standard deviation shows that the difference in mean is not that large.

Table 7. Group statistics

	Sector	n	Mean	Std. Deviation	Std. Error mean
Knowledge BIM	Road Construction	34	2,94	,55	,09
	Construction sector	64	3,41	,58	,07

Table 8. Independent t-test

		Levene's Test for Equality of Variances		t-test for Equality of means		t-test for Equality of Means	
		F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**
Knowledge BIM	Equal variances assumed	9,99	,002	-3,84	96	,000	-,47
	Equal variances not assumed			-3,91	71,26	,000	-,47

3.4. Future vision

The respondents' vision of the future gives a prediction of what the (road) construction sector will look like in the coming years. The majority, 67% of the participants (n=122), believe that the use of BIM will add value to their organisation, because in addition to avoiding the costs of failure and the problems, it also allows them to derive measurement and progress statements from the BIM model and then link this to logistical and/or accounting systems. However, 17% of the respondents believe that BIM will only offer added value in terms of failure costs and problems on site due to the presence of the 3D class detection. There are also participants, 5% (n=42), who are not equally optimistic and do not believe that BIM can provide added value for their organisation. These people, who still have to be convinced of the benefits that BIM has, are present within the road construction and industrial sector.

The awareness that BIM will gradually take over the (road) construction sector and that there is a need to evolve together is high. This was also remarkable in the analyses which showed that 97% of the respondents will develop further in the future. A number of reasons for this, stated by the respondents, were for example: "BIM is the future", "There is no way back", "Too many benefits to ignore" and "standing still = going backwards".

The biggest challenges at the moment are to ensure that each link, including the smaller ones, is persuaded to pull the same rope to bring the BIM process to a successful end. This mainly concerns people who are not used to using software on site, let alone 3D models. Only if all partners are involved in the BIM principle and follow the same rules, it will be possible to really work together **[1,2].** Nowadays, it is usually one part that is already further ahead and wants to take the rest with it. In addition, managing and sharing the information is also an important challenge. Several large companies can sometimes request a payment in exchange for sharing their information, which leads to unnecessary costs and difficult cooperation **[15].** As a solution to this, it is necessary to make good agreements between the various parties involved at the beginning of the process and to be sure of the good will to cooperate. It is very important that the cooperation process is described in a structured and clear way, so that each stakeholder knows what the expectations are and what their responsibilities are for providing information **[15].**

5. Conclusions

In the past few years the development of BIM has progressed strongly, due to its increasing use in the sector. As a result, the challenges associated with its implementation are also becoming broader as well. This implementation is not obvious to everyone and each company deals with it in its own way. In order to create a better picture of what these challenges are and what limitations are experienced today in the (road) construction companies in Belgium, a survey was carried out. The survey was based on an impact analysis, consisting of 4 different phases: the demographic background of the respondents, the BIM maturity of the respondents, the benefits and drawbacks of BIM and the respondents' vision of the future.

The questionnaire showed that 55% of the respondents are broadly familiar with the BIM process and 32% have a broad knowledge of the BIM method. However, there are still a small number of people in the sample who have never heard anything about the BIM concept. When focusing on this group of respondents, it appears that most of them are active in the road construction sector. In addition, 57% of the respondents have been able to make the transition from a traditional building process to a building process with BIM and have already worked with BIM. It is striking, when looking at the company profiles of these respondents, that most of those who have been able to make this switch are present in civil engineering and that in the group of respondents who have never worked with BIM, the road construction sector is at the top with 47%. It is essential that this group, who are turning their backs on BIM, receive the necessary attention because they constitute one of the barriers that make the implementation happen gradually. The main reasons for this reluctance in this research are the lack of knowledge and experience, insufficient demand for BIM by the customer and the lack of time to realise the switchover. This is in line with the research of the University of Twente, where the lack of knowledge and experience was also at the top of the list of barriers blocking the implementation of BIM **[7,8].**

Furthermore, the implementation of BIM in the (road) construction sector is receiving a great deal of attention today because it goes hand in hand with various advantages. The main benefit experienced in the use of BIM in this study is first and foremost increased productivity, followed by an increase in project staff involvement/increased cooperation and less unforeseen costs. This is consistent with Salman Azhar's (2011) research which showed that the integration of BIM primarily improves communication and cooperation between the various project partners, that in turn leads to an increase in the efficiency, productivity and quality of the product and a reduction in failure costs **[2].** Moreover, the research carried out by the University of Twente is also in line with this, which showed that the most important drivers of BIM are working more efficiently and reducing failure costs **[7,8].** Reducing failure costs can be achieved by the presence of a clash detection, where the errors are already filtered at an earlier stage. For these reasons, the clash detection is one of the most important applications of BIM in this study, which is in line with several similar studies **[1,2,7,8,11,15].**

In order to further analyse the results and to be able to generalise them to the population, correlations were drawn up and t-tests were carried out in order to compare the averages of two different groups. When assessing whether there is a relationship between the sector and the degree of digitisation, a significant correlation is found, which is interpreted as follows: the sector has a moderate positive correlation with digitisation, with civil engineering making more use of digitisation than road construction.

It can be concluded that most companies have already made the switch to a digital company or are in the process of preparing to do so in the near future. It is remarkable in this respect that, unlike the other sectors, the road construction sector has experienced a certain delay. In addition, there is also a difference between the degree of digitisation of large and small companies. The small companies, who are less digitised, hinder the further evolution of BIM. They are less able to make the switch due to a lack of money and resources, but are obliged to go along with the rest because it is almost impossible to do otherwise. However, the fact that many small companies have yet to make the switch means that the further evolution of BIM is hampered, as the BIM process only works if all links, including small subcontractors, cooperate **[1,2,7,8,31].**

One of the limitations of this investigation was the period in which it took place. The appearance of the COVID-19 virus caused most companies to have their staff working from home, resulting in most potential respondents not having time to complete a survey. The survey was finally completed by 122 participants, which is still a low number. In addition, it is undeniable that there have been a considerable number of surveys on this subject lately, which has led to a decline in interest in completing the survey. Finally, the second part of the survey, which gives a broader picture of the respondents' point of view, was only completed by 34% of the participants and compared to the first part these respondents had a more positive view on the BIM story. This was then taken into account when interpreting the results.

The BIM concept is something that is constantly evolving and always offers new challenges. In further research it is therefore possible to outline the evolution of BIM on the basis of previous studies. A wider public can be attracted to obtain even more significant results. In addition, it is also possible to conduct in-depth interviews in order to better understand the respondents' points of view.

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Appendices

The following appendices can be found in the digital portfolio, in the appendices folder:

- **Appendix A:** Survey in English
- **Appendix B:** Survey in Dutch
- **Appendix C:** Rapport Qualtrics
- **Appendix D:** Output Analysis SPSS

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