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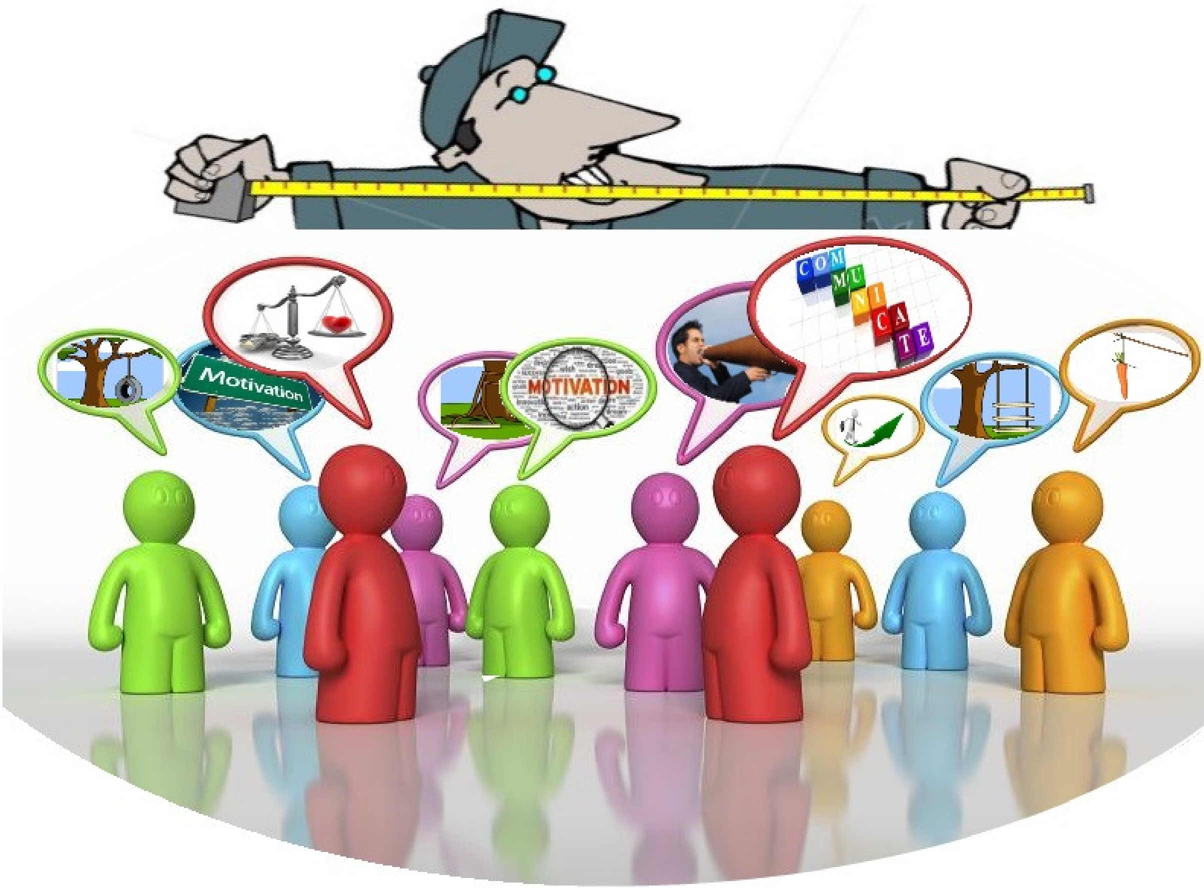
Benchmarking Communication and Motivation in Engineering Projects



Development of a benchmark instrument for communicational and motivational aspects in engineering projects in order to provide quantitative evidence of the impacts of BIM

Thomas Snoep, July 2013

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Preface

This research is the final proof of competence for obtaining my Masters degree and the closing piece of my two year study 'Construction Management and Engineering' at the University Twente. The report is the result of my work executed at Grontmij between October 2012 and July 2013.

I've started working on my thesis with two very enthusiastic goals in mind, to provide evidence for the impacts of BIM and aid Grontmij with the implementation of BIM in their work processes. During the study I discovered that these goals where a bit overstretched for a master thesis and had to narrow my scope. Consequently, I focused my research on the impacts of BIM on communication and motivation and developed a tool which is capable of measuring those two concepts in projects. I'm very happy with the end result. I have experienced my ups and downs in this process as well, and learned not only much more about BIM communication, motivation and implementation process, but also something new about myself.

I've spend most of my time at Grontmij, first in Waddinxveen and next in Rotterdam and would like to thank all the employees of the teams engineering and project management for their kind welcome. I especially like to thank Bart van Oosterhout for all his time, effort and support by reading all my lengthy chapters thoroughly and asking me the right questions at the right times. I really enjoyed our weekly meetings.

I would also want to thank my first supervisor from the university, Timo Hartmann. Even though your comments would sometimes drop my motivation to an all-time low, a little night sleep would always reveal their true meaning and provided me with a push (or kick) in the right direction, like good comments should. I also greatly appreciated the possibility of meeting long distance via web meetings. In this context I would also really like to thank my second supervisor Hans Voordijk. You thoughts, comments and level of involvement sometimes gave me the impression of having the fortune of two first supervisors.

I would like to thank my parents and sisters for listening to my progress, reading & commenting on my report and supporting me when things weren't going as smooth as I would have liked. And finally, off course, my girlfriend Bertine who allowed me to relax and put my mind on other things than the thesis when I wanted, but was also prepared to be a discussion partner and provide me with her thoughts on my research. Finally a thanks to you, reader. If you read this line you have at least read one page of my report, so thank you for that.

Thomas Snoep

July 2013

Summary

Introduction and background

Until recently, *Building information modelling*(BIM) was almost only used in the *Architecture Engineering & Construction*(AEC) industry, but the reported positive perceived impacts have caught the attention of civil industry. A frequently mentioned and large barrier for implementation of BIM is the lack of empirical evidence on the perceived benefits of BIM. There have been qualitative efforts to provide project actors with the empirical evidence, but the perception of great value in such qualitative methods can be described as a by-product of the complex nature of the construction process, in the face of a general lack of quantitative data. This study focuses on developing a benchmark instrument, which is capable of measuring communication and motivation potential in a civil engineering firm quantitatively. The philosophy behind the development is that the data from the instrument should be able to provide quantitative evidence that BIM impacts these concepts

Main results

I developed the benchmark instrument based on two well established measurement tools from the respective theoretical fields and gathered data via a survey study at Grontmij. With the gathered data, I was able to determine that the instrument provides valid and reliable quantitative results on the communicational concepts. I also determined that instrument requires revision of the motivational concepts before it can provide inconclusive quantitative evidence for the impact of BIM. Furthermore, the data showed that BIM had not yet impacted the respective concepts at Grontmij, and provided findings that were not anticipated based on the literature which indicate synergy effects between the communication and motivation potential concepts.

Wider Implication

The benchmark instrument can be used to measure communication aspects and provide quantitative evidence of an impact of BIM. The instrument also provides new and currently unavailable benchmark scores for both communication and motivation potential concepts in civil engineering consultancy firms. These scores can be used by companies in the industry to assess their performance and guide improvement processes. The instrument has also shown synergy effects between communication and motivation potential concepts, which can provide the basis for future research on that subject.

Samenvatting

Introductie en achtergrond

Tot op heden werd bouwwerk informatie modellering(BIM) voornamelijk toegepast bij projecten in de woning en utiliteitsbouw. Positieve geluiden over de impact van BIM hebben echter ook de civiele techniek sector bereikt, waardoor BIM nu ook in deze sector wordt geïmplementeerd. Een veel genoemde barrière voor het implementeren van BIM is het ontbreken van empirisch bewijs van de impacts van BIM. Er zijn kwalitatieve onderzoeken geweest die de impacts aantonen, maar het grote waardegevoel over BIM uit dit soort onderzoeken kan ook veroorzaakt worden door de complexiteit van het bouwproces met het oog op ontbrekend kwantitatief bewijs. In dit onderzoek is er een meetinstrument ontwikkeld waarmee het mogelijk is om de communicatie en het motivatie potentieel in projecten bij civiele consultancy bedrijven, kwantitatief te meten. De filosofie achter deze ontwikkeling is dat het instrument ook gebruikt kan worden om kwantitatief bewijs te leveren voor de impact van BIM op deze concepten.

Resultaten

Het ontwikkelde meetinstrument is gebaseerd op twee gerenommeerde instrumenten uit de respectieve theoretische velden en gebruikt in een enquête bij Grontmij. De data laat zien dat het instrument valide en betrouwbare kwantitatieve resultaten kan leveren voor de communicatie aspecten. De data laat ook zien dat het instrument herzien moet worden voordat het mogelijk is om onomstotelijk kwantitatief bewijs te leveren voor een impact van BIM op motivatie aspecten. Ook blijkt er uit de data dat BIM op dit moment nog geen significante impact heeft gehad op de communicatie en motivatie potentie in projecten van Grontmij. Wel zijn er onverwachte indicaties van synergie effecten gevonden tussen de twee theoretische velden, wat een positieve impact van BIM kan versterken.

Bredere implicaties

Het meetinstrument kan gebruikt worden om communicatie aspecten te meten en daarmee kwantitatief bewijs voor een impact van BIM te leveren. Verder levert het instrument ook nieuwe en tot op heden niet beschikbare referentie punten op voor zowel de communicatie als het motivatie potentieel in civiele consultancy bedrijven. Deze punten kunnen gebruikt worden door bedrijven om hun eigen prestaties te meten en hun verbetertrajecten te structureren. Het instrument heeft ook synergie effecten laten zien tussen communicatie en motivatie, wat gebruik kan worden als basis voor toekomstig onderzoek naar deze effecten in combinatie met BIM.

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Chapter 1: Introduction

1.1 Context of the study

Until recently, *Building information modelling*(BIM) was almost only used in the *Architecture Engineering & Construction*(AEC) industry, but the reported positive perceived impacts have caught the attention of civil industry. Large contractors and engineering firms, as well as clients and knowledge institutes, all present their wish to implement BIM. One of these firms is Grontmij (see appendix A for a company profile).

A frequently mentioned and large barrier for implementation of BIM is the lack of empirical evidence on the perceived benefits of BIM (Adriaanse, (2007); Becerik-Gerber & Rice (2010); Barlish & Sullivan (2012)). Project actors “know” that there are positive impacts, but are unable to predict or measure them. This frustrates further implementation of BIM. A clear knowledge of the perceived benefits appears to be one of the key mechanisms which influences the way actors use ICT like BIM (Adriaanse, 2007). Without that knowledge actors are left with implementing BIM based on only speculative benefits and causes dilemmas for users on the decision to utilize BIM or not (Barlish & Sullivan, 2012).

There have been qualitative efforts to provide project actors with the empirical evidence on the benefits of BIM such as improved communication, improved productivity and improved quality (see for example: FMI (2007); McGraw Hill Construction (2009); Becerik-Gerber & Rice (2010)). Gilligan & Kunz (2007) suggest that the perception of great value by BIM users in such qualitative methods is a by-product of the complex nature of the construction process, in the face of a general lack of quantitative data (Gilligan & Kunz, 2007, p. 13). The general lack of quantitative data and the accompanying difficulty to provide evidence on the benefits of BIM was also identified by Barlish & Sullivan (2012). Both authors independently developed an instrument which measures benefits of BIM quantitatively. However, these are based on AEC and Industrial industry processes respectively and only describe more substantial phenomena like time reduction and cost reduction. A similar instrument for the civil engineering industry or insubstantial phenomena is unknown, which is the starting point of this study.

In an exploratory literature study (see appendix B), the impacts of BIM found in AEC literature are linked to the goals of Grontmij. This resulted in five distinct perceived impacts of BIM in a civil engineering firm; namely the impact on project duration, communication, design deliverables, cost estimation, motivation. From these five, the impact on communication and the impact on motivation where selected for the benchmark instrument, because time and scope constrains (see appendix B) but also because the impact of BIM on motivation has received very little research attention and the impact on communication is, when measured at all, only measured qualitatively. Furthermore, both impacts lead to rather insubstantial benefits like higher understanding and higher motivated personal. An instrument which measures these concepts would therefore provide a great contribution to both Grontmij and the scientific community.

1.2 Structure of the report

First basic BIM concepts and key project actors were used to determine the perceived impacts of the implementation of BIM. The result of this step is the list of five expected impacts of the use of BIM mentioned earlier. Next the selected impacts of communication and motivation where confronted to performance measurement theories and BIM impact measurement theories. This analysis provides methods on how the impacts are measured and how the validity and reliability is tested. This is found in chapter two. After that, the appropriate research method and data collection method where investigated. The found methods of measuring the concepts of communication and motivation where also adapted to the goals and scope of this study. The result of this section is the evaluated benchmark instrument and is represented in chapter three. The developed benchmark instrument was then implemented at Grontmij and confronted with Grontmij employees which resulted in a data set concerning the current level of communication and motivation potential at Grontmij. The results of the instrument were analysed to test the validity and reliability of the instrument with the underlying theoretical constructs. The data was also explored in order to identify unanticipated relationships. These sections are elaborated on in chapter four. Finally, the conclusions and recommendations for this study are explained, and a discussion on the process and instrument is presented.

2

Chapter 2: Theoretical background of the study

The main method used in the literature study was the snowball method, where new sources were identified from reference lists of initial sources. The complete literature study of this research is provided in appendix B. In this chapter the summary of the study is presented. The perceived impacts are assessed, followed by a determination of the validity and reliability tests and finally an analysis into the statistical testing methods which are required in this research is made. Before the assessments are performed, a clear definition of BIM for this study is presented, as such a definition is important in view of the philosophy of the development and is used in assessing what concepts should be measured.

There is no definition in the literature that fully fits the research goal, so a definition specific for this research is described below. The definition is based on the COINS (2010) definition, and the definition of Woo et al. (2010).

"BIM in this research is an intelligent, 3D, virtual model that represents functional and physical characteristics of an object or group of objects. This model will then be used to assist activities, and improve processes which are undertaken during the design and engineering phase of a project life cycle"

The definition displays my point of view about the three critical features of BIM; namely, 1) the use of a 3D model as the representation of objects or a group of objects, 2) the attachment of functional and physical characteristics to this model, and 3) the use of the model to assist activities, and to improve processes. The definition can be criticised as being narrow as some authors claim that BIM does not require a 3D model, but only an active and two-way link between a database and analysing software (Jernigan, 2008). Nevertheless, the use of 3D visualization is often mentioned as a benefit of BIM and therefore this feature is seen as a critical part of BIM in this research.

2.1 Impact on Communication

2.1.1 Theoretical foundation

The impact of BIM on communication is a frequently mentioned impact. The use of BIM would improve communication in all phases of the project (Eastman et al. (2011); Barlish & Sullivan (2012)) as it allows information to be easily shared (Azhar, Hein, & Sketo, 2008). It can improve communication during project meetings as it allows for more dynamic views (Wu & Hsieh, 2012). Sacks et al. (2010) and Eastman et al. (2011) state that effectively communicating design intent to professionals and non professionals is one of BIM's key functionalities, and Kymmell (2008) mentions that in theory a BIM could include all the needed information and makes 2D drawings obsolete. To better understand how BIM influences communication, the communication process is investigated

Communication theory describes that communication follows a basic pattern: First a sender has a message (for example a 3D design), which he then encodes using symbols, words or expressions. Next, he transmits the coded message via a medium. The encoding is done based on assumptions made by the sender on the decoding capabilities of the receiver. The receiver decodes the message from the medium, and the message is "communicated" from sender to receiver (see Figure 1). Understanding comes from how well the receiver is able to decode the message he receives via the medium, and interpret it.

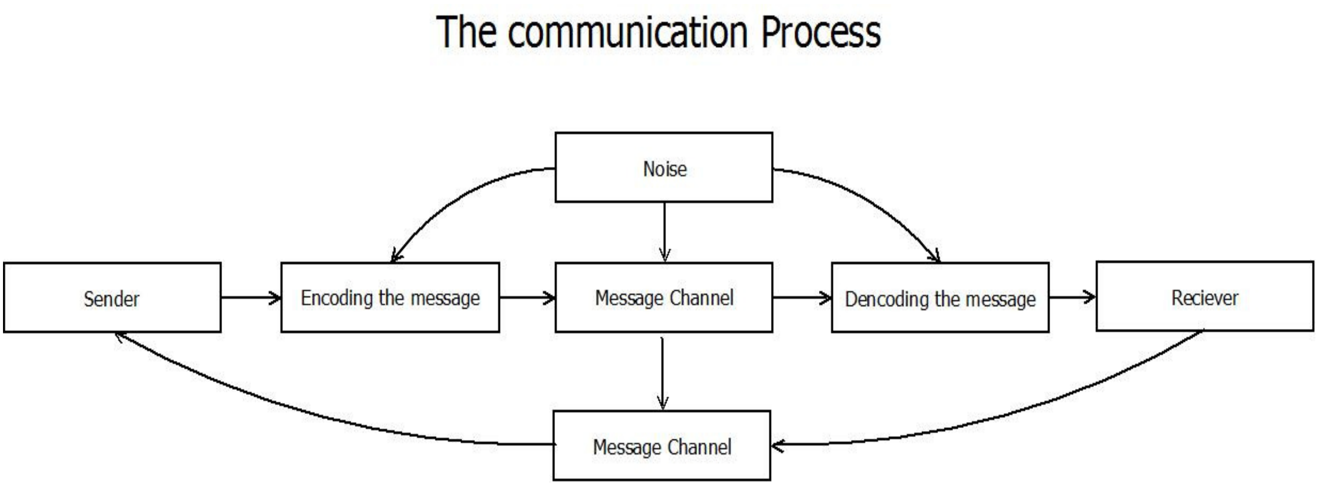

Figure 1: Basic schematic of a communication process

The most mentioned impact of BIM on communication is that it allows for a better understanding of the design trough 3D or 4D visualization (Goa & Fischer (2008); Kymmell (2008); McGraw Hill Construction (2009); Eastman et al. (2011); Wu & Hsieh (2012)). Because actors no longer have to translate and interpret 2D drawings into a 3D design, but can view the design in a 3D state, it leaves less room for interpretation errors. Also, the chance of communication failure due to a faulty encoding or decoding process becomes less as the 3D model represents the reality better (Eastman et al. (2011)). A 3D visualisation of a BIM model is able to represent far more information and details than can be contained in the visualization in the mind of individuals (Kymmell, 2008). In the same line of thought, BIM is able to improve communication by allowing time to be added to the visualization. A 4D simulation of a process has the same affect of 3D visualization of a project. Kymmell states "BIM simulations are by far the most effective way to communicate ideas, forms, concepts, and general approaches in design and construction-related issues."(Kymmell, 2008, p. 49). To summarise, the first impact of BIM on communication is that it improves (+) the medium by which a message is send, which would allow for a better (+) interpretation by the receiver, which would reduce (-) communication failure and therefore improves communication (see Figure 2)

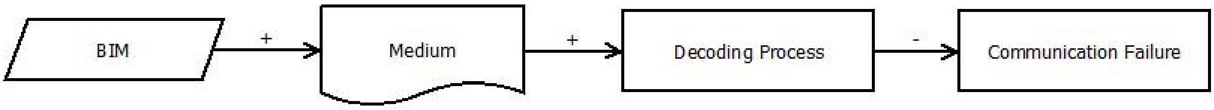

Figure 2: First perceived impact of BIM on communication

BIM can also impact communication as 3D visualisations are understood better by people who cannot read 2D visualisations (drawings) (Goa & Fischer (2008); Kymmell (2008); Eastman et al. (2011)). Non professionals, for example citizens, currently require other media like telephone or face-to-face presentations to explain the 2D drawings and Gantt charts. With the use of BIM, project teams no longer have to make different drawings or presentations to inform non professional stakeholders, but can show the 3D visualisations to professional and non professional stakeholders. The actual term for “receivers” in this case should be “stakeholders” as the real value is in reaching more stakeholders than quantitatively reaching more individuals. The reason for this second impact is based on a similar argumentation as presented in the previous section. BIM improves (+) the medium into a format which is better understood by receivers with no construction industry knowledge, which would allow those receivers to interpret a message better (+) than before, which would improve communication by reaching more (+) receivers with the same medium (see Figure 3).

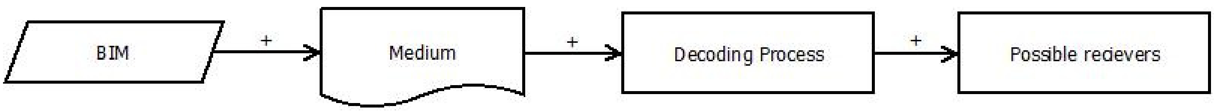

Figure 3: Second perceived impact of BIM on communication

Another important impact of BIM on communication is best explained by Kymmell (2008). He states that by embedding information into the model, actors can obtain the needed information better, and the actuality of the information is better assured. Having the most up-to-date information and having all the information more easily available will increase the knowledge of the receiver. As this knowledge is important for the interpretation of a message, the decoding process will improve. In other words, BIM improves (+) the availability and actuality of information, which would improve the knowledge of the receiver, which would improve (+) the interpretation process, which would reduce (-) communication failure and therefore improve communication (see Figure 4).

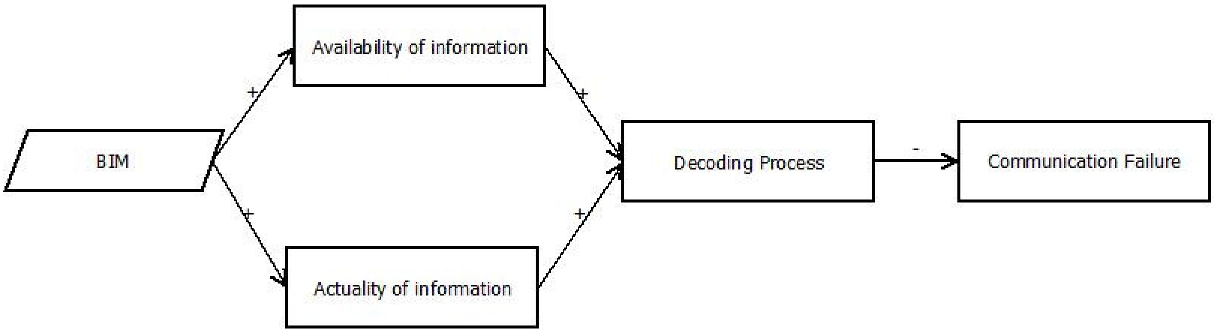

Figure 4: Third perceived impact of BIM on communication

To summarise, BIM is perceived to impact communication in three ways.

- First, understanding of the message is increased by improving the medium by which the message is send, which would reduce miscommunication
- Second, the same medium is able to reach more receivers which increases the effectiveness of the medium.
- Third, the medium allows for improved availability and actuality of information that is transmitted to a receiver, which would reduce miscommunication

2.1.2 Benchmark instrument input

First impact

The literature study showed that it is not feasible to measure whether communication media created from a BIM model are improved in comparison with traditional media or whether understanding is increased, due to the difficulty of substantiating the concept of "understanding" or an improvement of a media. Both of the clearer and often used metrics of communication failure, request for information's and note of information, are excluded from this research based on the scope of the study. The most logical method to present a meaningful measurement of the first impact is by questioning project members about their perception on the level of communication failure. This research in addition makes the claim that correctness of information can be used as a measurement of communication failure and would be improved by the use of BIM.

Second Impact

The impact of BIM media on the amount of receivers hasn't been measured in current literature, while it does present a clear metric. This measurement is excluded however, as the current amount of BIM projects at Grontmij is too low to make a valid measurement.

Third Impact

The third and final perceived impact of BIM on communication is that it allows for improved availability and actuality of information that is transmitted to a receiver. However, when measuring communication concepts, actors tend to relay on their instinct rather than actual measurements (Ellis, Barker, Potter, & Pridgeon, 1993). To resolve this issue, communication audits have been developed. The goal of a communication audit is to provide the means of assessing the state of communication in an organization against a set of criteria, and its potential has been recognized by business and research communities (Ellis, Barker, Potter, & Pridgeon, 1993). One of the mostly used and validated audit is the International Communication Association (ICA) Audit by Goldhaber & Rogers in 1979 (Tourish & Hargie (2004); Antonis (2005); Maki, Shimotsu & Avtgis (2009)).

The audit itself consists of several tools which are explained in appendix B, but when the questionnaire is examined it shows that respondents are asked to provide their experience with, among others: accessibility to information (availability), adequacy of information (correctness), relevance of communication (actuality), communication satisfaction and importance, communication content, communication relationships, and communication outcomes (miscommunication). These topics imply that the ICA questionnaire is capable of measuring the first and third impact which BIM can have on the communication process. Although the basis of the ICA questionnaire can be used, it should still be tailored to the company under analysis (Tourish & Hargie, 2004).

2.2 Impact on Motivation

2.2.1 Theoretical Foundation

There has been no actual research on the impact of BIM on employee motivation or employee morale. However, there are indications that such impacts exists (see Birx (2005) and Miller (2012)). The literature study further shows that only indirect evidence can be found in peer-reviewed articles (see Formoso, Santos & Powel (2002) with Sacks, Radosavljevic & Barak (2010); Keuhmeier (2008); Björk-Löf & Kojadionovic (2012)). In order to determine why BIM is perceived to impact motivation, basic motivational theory was examined.

A motivation pioneer, Herzberg (1959), believed that motivation heavily depends on whether a job is intrinsically challenging and provides opportunities. This believe of Herzberg is supported by Porter & Lawler (1986) as they report “The best performing managers do not report receiving much greater rewards in pay or security but they do report significantly more rewards in areas concerned with opportunities to express autonomy and to obtain self realization in the job.”(Porter & Lawler, 1986, pp. 121-122). Furthermore, if Ashcraft (2011) is correct in his statement that “Work satisfaction is perhaps the most significant motivating factor” (Ashcraft, 2011, p. 24), than intrinsic rewards, which increase work satisfaction, will in term increase the motivation of employees.

BIM is credited to increase the transparency (Formoso, Santos, & Powell, 2002) of the construction process, and increase employee satisfaction in a job (McGraw Hill Construction, 2009) which leads to the claim of this study that BIM will increase the intrinsic rewards in a job. When the instrument is capable of measuring these intrinsic rewards, a benchmark can be made from which the motivational impact of BIM can be assessed.

Nevertheless, motivation is an individual concept, and only expressed as a perceived outcome of more tangible factors, like certain needs in Maslow’s and Aldefer’s motivational theories, or the job aspects by Herzberg. It should therefore be mentioned that individual motivation itself will not be measured in this research, but only factors that influence motivation, which in term can be influenced by BIM.

2.2.2 Benchmark instrument Input

The benchmark instrument should be capable of measuring the motivational aspects of a job. To measure the motivational potential of a job design, Hackman & Oldham developed the Job Diagnostic Survey (JDS) (Hackman & Oldham, 1974) based on their own Job Characteristics Model (JCM) (revised version found in (Hackman & Oldham, 1976)) see Figure 5) and the work of Herzberg (1959). The JDS is a tested and validated instrument that has been used by both research and business communities for many years (Faturochman (1997); Van Saane, Sluiter, Verbeek & Frings-Dresen (2003); Boddy (2008)). With the JDS, the motivating potential score (MPS) of a job can be calculated using Equation 1. The MPS is frequently used to guide a job enrichment process (Boddy, 2008).

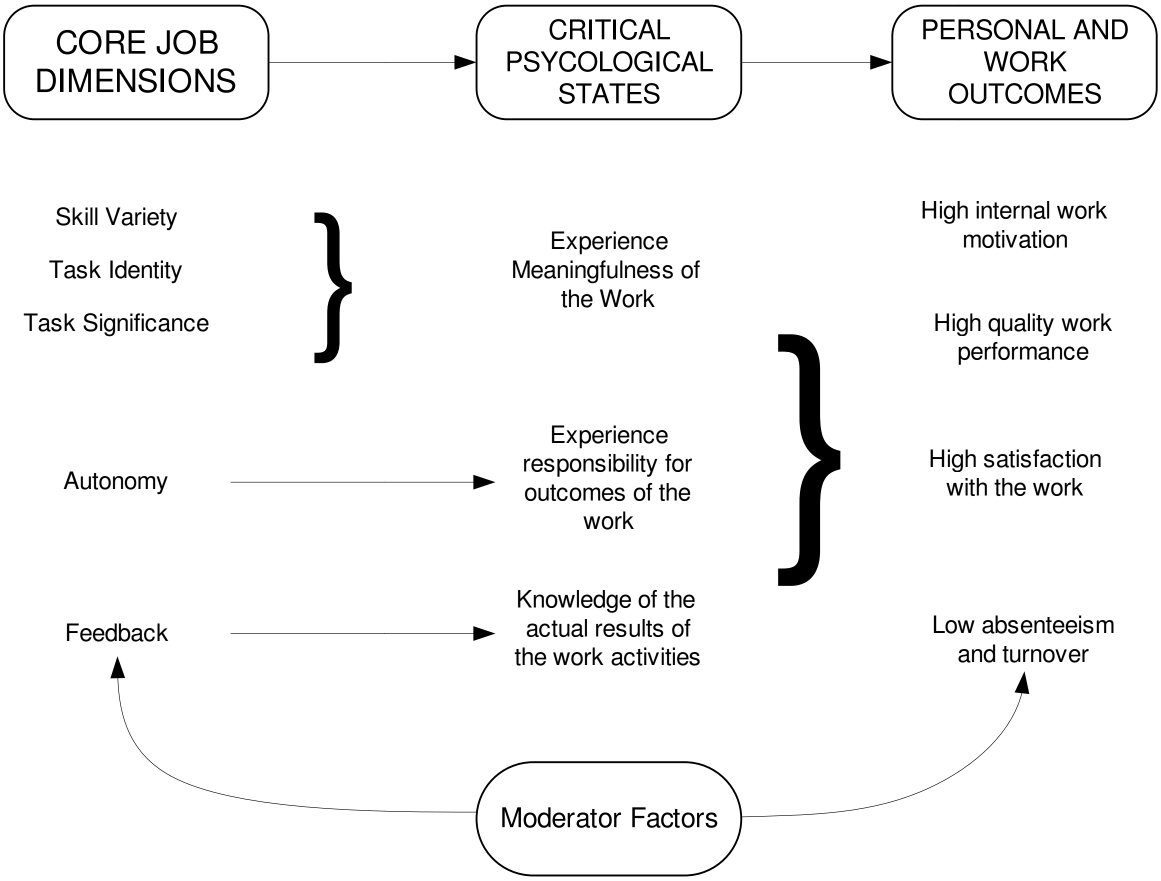

Figure 5: The Job Characteristics Model (source: (Hackman & Oldham, 1974))

$$\text{MPS} = \left[\frac{\text{Skill Variety} + \text{Task Identity} + \text{Task Significance}}{3}\right] \times [\text{Autonomy}] \times [\text{Feedback}]$$

Equation 1: Motivating potential score equation (source: (Hackman & Oldham, 1974))

The JCM claims the existence of three psychological states, which need to be experienced in a job by individuals in order for desirable outcomes like: high internal motivation, high quality of work performance, high satisfaction with the work and low absenteeism and turnover, to emerge. These states are:

- Experience meaningfulness in the work,
- Experience responsibility for the outcomes of the work
- Knowledge of the actual results of work activities,

All these states point to the interstice rewards that a job could give which should increase satisfaction, so if any of these states are not present, the desirable outcomes are weakened (Faturochman, 1997). These three psychological states can be measured by five distinct job characteristics. The first state can be measured by skill variety, task identity, and task significance. The second state is measured by the job characteristic of autonomy. The last state is measured by the characteristic of feedback. By measuring these characteristics via the JDS, the MPS of a job can be calculated, and with that the possibility within a job to achieve the desirable outcomes. A more detailed explanation of the JDS and it underlying constructs can be found in appendix B.

2.3 Validation and reliability

2.3.1 Validation

An important part in developing the benchmark instrument is to assure that the measured data are reliable and provides valid results. There are three types of validity, which can be divided in several subtypes. These three types are: internal validity, construct validity, and external validity (Trochim & Donnelly, 2006). The following table provides the overview the different validation types and the methods which can demonstrate the validity type. An explanation on these types can be found in appendix B.

Validity Type	Sub Type	Method of demonstration
Internal Validity	Conclusion validity	Correlation analysis
	Casual validity	Regression analysis
Construct validity	Face validity	Expert judgment
	Content validity	Expert judgment
	Predictive validity	Correlation analysis
	Concurrent validity	Comparative analysis
	Convergent validity	Correlation analysis
	Discriminate validity	Correlation analysis
External validity		For example: Sample selection

Table 1: Validity types and methods of demonstration

For the expert judgment and comparative analysis, the level of validity is dichotomous (valid or invalid). These can therefore be tested with hypotheses. With correlation analysis, however, the level of validity is related on the resulting test coefficient which does not have a single pass or fail criteria but a range which describes the level of validity. These are therefore assessed as conditions. Taylor (1990) explicitly states that blindly focussing on cut-off points for correlation coefficients to determine the level of validity is not advisable. Therefore, general accepted range points for the coefficients will be used as guidelines, but the interpretation of the coefficients will be leading in determining the level of validity. The general accepted points are: coefficients of ≤0.35 are considered low or weak relationships, 0.36 to 0.67 are considered moderate relationships and 0.68 to 1 are considered high or strong relationships (Taylor, 1990)

Validity tests of the benchmark instrument

- Internal validity:

With internal validity the question is posed if the instrument measures the relations that our found in the literature. Six conclusive relationships and no causal relationships are identified in the literature:

Hypothesis IV1: There is a negative relationship between the perception of communication failure and the height of rating correctness of information by project participants.

Hypothesis IV2: There is a negative relationship between the perception of communication failure and the height of rating availability of information by project participants.

Hypothesis IV3: There is a negative relationship between the perception of communication failure and the height of rating actuality of information by project participants.

Hypothesis IV4: There is a positive relationship between the perception of Skill variety, Task identity, Task Significance and the experience of meaningfulness of the work.

Hypothesis IV5: There is a positive relationship between the perception of feedback from the job itself and the experience of knowledge of the actual results of the work activities.

Hypothesis IV6: There is a positive relationship between the perception of autonomy and the experience of responsibility for the outcomes of the work.

Note that hypothesis IV4 claims a relation between one concept and a combination of three other concepts. Such a relationship cannot be examined by a standard bivariate correlation, but is tested with a multiple regression. Internal validity follows from a confirmed and statistical significant relationship.

- Construct validity:

Face validity refers to how valid the instrument looks “on the face of it”, and content validity is determined by how well the instrument follows the content domain from which it is derived. Both of these types are supported through the use of the two validated and well established source tools. These tools have withstand multiple experts judgment, where many facets of the tools have been evaluated. The benchmark instrument developed in this study will be evaluated as well to further support this claim.

The concurrent validity subtype refers to the ability of the instrument to make a distinction between groups which it should theoretically be able to make a distinction between. The motivational theory shows that a job with a higher level of autonomy and responsibility would have a higher MPS. It can be assumed that project leaders have a higher level of autonomy and responsibility than engineers, and engineers would score higher on those aspects than draftsmen. This makes the distinction between groups possible via the following hypothesis. The communication part of the benchmark instrument does not make a distinction between groups and so no concurrent validity hypothesis are required.

Hypothesis CV1: Project leaders will score a higher MPS than engineers.

Hypothesis CV2: Project leaders will score a higher MPS than draftsmen.

Hypothesis CV3: Engineers will score a higher MPS than draftsmen.

Convergent validity examines the degree to which question items which converge to a similar concept are related to each other. The larger the relationship, the more valid the results. Discriminate validity examines the opposite, by looking at the degree to which question items which measure non similar concepts are related. The JDS by Hackman & Oldham (1974) consists of several question items which converge on the different core job characteristics and psychological states. This aspect results in the following convergent validity conditions.

Condition CV4: There are relationships between the questions leading to the aggregated skill variety variable.

Condition CV5: There are relationships between the questions leading to the aggregated task identity variable.

Condition CV6: There are relationships between the questions leading to the aggregated task significance variable.

Condition CV7: There are relationships between the questions leading to the aggregated feedback variable.

Condition CV8: There are relationships between the questions leading to the aggregated autonomy variable.

Condition CV9: There are relationships between the questions leading to the aggregated experience meaningfulness variable.

Condition CV10: There are relationships between the questions leading to the aggregated knowledge of the results variable.

Condition CV11: There are relationships between the questions leading to the aggregated experience of responsibility variable.

ICA audit does not have such a clear set up of question items which converge on a single concept. It cannot be said that the level of experience of a concept via a direct channel, like a face-to-face meeting, will have a high relationship with the level of experience of a concept via an indirect channel, like e-mail. However, it can be argued that similar channels should have a high correlation. By doing so, the following construct validity conditions can be made.

Condition CV12: There are relationships between the questions concerning direct channels leading to the miscommunication variable.

Condition CV13: There are relationships between the questions concerning direct channels leading to the correctness of information variable.

Condition CV14: There are relationships between the questions concerning direct channels leading to the actuality of information variable.

Condition CV15: There are relationships between the questions concerning direct channels leading to the availability of information variable.

Condition CV16: There are relationships between the questions concerning indirect channels leading to the miscommunication variable.

Condition CV17: There are relationships between the questions concerning indirect channels leading to the correctness of information variable.

Condition CV18: There are relationships between the questions concerning indirect channels leading to the actuality of information variable.

Condition CV19: There are relationships between the questions concerning indirect channels leading to the availability of information variable.

Summary Table of validation hypotheses and conditions

No	claim
IV1	*- relationship; perception of communication failure <-> rating correctness of information*
IV2	*- relationship; perception of communication failure <-> rating availability of information*
IV3	*- relationship; perception of communication failure <-> rating actuality of information*
IV4	*+ relationship; perception of Skill variety, Task identity, Task Significance <-> the experience of meaningfulness of the work.*

IV5	*+ relationship; perception of feedback from the job itself <-> the experience of knowledge of the actual results of the work activities*
IV6	*+ relationship; perception of autonomy <-> the experience of responsibility for the outcomes of the work*
CV1	*Project leaders will score a higher MPS than engineers*
CV2	*Project leaders will score a higher MPS than draftsmen.*
CV3	*Engineers will score a higher MPS than draftsmen*
CV4	*There are relationships between the questions leading to the aggregated skill variety variable.*
CV5	*There are relationships between the questions leading to the aggregated task identity variable.*
CV6	*There are relationships between the questions leading to the aggregated task significance variable.*
CV7	*There are relationships between the questions leading to the aggregated feedback variable.*
CV8	*There are relationships between the questions leading to the aggregated autonomy variable.*
CV9	*There are relationships between the questions leading to the aggregated experience meaningfulness variable.*
CV10	*There are relationships between the questions leading to the aggregated knowledge of the actual results variable.*
CV11	*There are relationships between the questions leading to the aggregated responsibility for the outcomes of the work variable.*
CV12	*There are relationships between the questions concerning direct channels leading to the miscommunication variable.*
CV13	*There are relationships between the questions concerning direct channels leading to the correctness of information variable.*
CV14	*There are relationships between the questions concerning direct channels leading to the actuality of information variable.*
CV15	*There are relationships between the questions concerning direct channels leading to the availability of information variable*
CV16	*There are relationships between the questions concerning indirect channels leading to the miscommunication variable*
CV17	*There are relationships between the questions concerning indirect channels leading to the correctness of information variable.*
CV18	*There are relationships between the questions concerning indirect channels leading to the actuality of information variable.*
CV19	*There are relationships between the questions concerning indirect channels leading to the availability of information variable.*

Table 2: Summary table of validation hypotheses and conditions

Reliability

Where validity is concerned on how well the conclusions or propositions from an instrument represent the theory and intended goal, is reliability explained as how well the instrument is able to measure "true" scores. The problem with this explanation is that "true" scores are never known and so only an estimation of the real reliability can be made. Therefore reliability is also rephrased as the consistency of an instrument to measure certain concepts. There are four types of reliability estimates which are: inter-rater reliability, test-retest reliability, parallel forms reliability, and internal consistency reliability

(Trochim & Donnelly, 2006). The following table provides the overview the different reliability types and the methods to test the reliability (also see appendix B).

Reliability Type	Method of demonstration
Inter-rater or inter-observer reliability	Correlation analysis
Test-retest reliability	Correlation analysis
Parallel forms reliability	Correlation analysis
Internal consistency reliability	Cronbach's α

Table 3: Types of reliability and their methods of demonstration

The study consisted of one test, measured at one moment in time and so the most suitable method to tests the reliability is Cronbach's α. Cronbach's is determined by examining how much variance is shared between items and relating that to the total average covariance within the scale (Field, 2009) and can have a value between 0 and 1 like a correlation coefficient.

There have been some discussion to the extent to which size of Cronbach's α constitutes to a "reliable" instrument, which is elaborated in appendix B. For this report the more liberal point of view of George & Mallory (2003) is used. The authors provide the following rules of thumb:

- $\alpha > .9$ = Excellent reliability
- $.9 > \alpha > .8$ = Good reliability
- $.8 > \alpha > .7$ = Acceptable reliability
- $.7 > \alpha > .6$ = Questionable reliability
- $.6 > \alpha > .5$ = Poor reliability
- $\alpha < .5$ = Unacceptable reliability (George & Mallery, 2003, p. 231)

Another point of attention is the item-total correlation, which assesses the correlation between a single item and the entire scale without the item. Ferketich (1991) recommended in her article that these coefficients should be between 0.3 and 0.7 as higher item-total correlations could indicate that the single item measures most of the entire scale, and leaves the rest of the items redundant.

A final point of attention is the alpha score when a certain question is removed from the scale. If Cronbach's α becomes higher by removing a question, than that suggests that the question is unreliable and should be removed or adjusted. Similarly to the validation assessment, should these values be used as guidelines instead of clear cut off points. For example, an item-total correlation can be higher than 0.7 when Cronbach's α is higher.

2.4 Analysis methods

The previous paragraphs indicated that the validation tests and reliability tests of the instrument require several statistical analysis methods; namely, correlation analysis, comparative analysis and multiple regression analysis. These analysis methods have several different test statistics, and the choice to which test statistic best suits the hypotheses tests, depends on certain assumptions and conditions. A full analysis about the assumptions and how they are tested is provided in appendix B. Table 3 provides the results of this analysis. IV4 requires a multiple regression analysis method. This method should abide to more assumptions than the standard tests and have been added to the table as well.

Assumption	**Tested by**
Assumption of Normality	For this report the used method is the method of Field (2009), calculating the significant skewness and kurtosis, besides the graphical approach to determine normality of the data. The significant value in the z-test is p=0.05, which is common in scientific literature.
Assumption of Equal Variance	To test the assumption of equal variances in this study, the standard Levene's test is used when the data has passed the normality assumption. When it violates that assumption the non parametric version of the Levene's test is used. Similar like the normality assumption test, a significance level of p=0,05 is used.
Condition of sample size ration	The sample sizes are evaluated in paragraph 4.1.1
Assumption of linear relationship between variables (IV4 only)	This assumption can be tested by visually inspecting the standardized residuals plot (Osborne & Waters, 2002). When the standardized residuals show a curved pattern around the predictive values, linearity cannot be assumed
Assumption of independence of errors between observations. (IV4 only)	This assumption can be tested with the Durbin-Watson test, where test statistics lower than 1 or higher than 3 would indicate a violation of the assumption.

Table 4: General statistical assumption test

Figure 6 shows the decision tree for the comparative hypotheses, based on the analysis in appendix B. When analysing the data, the tree will be used to determine which tests statistic best suited the hypothesis.

Calculating effect size

It is becoming more common to report the effect size of significant statistical tests, and some professional journals are even insisting on it (Howell, 2010, p. 104). The most common effect size statistics are Pearsons *r* and Cohen's d but none has appeared to be universally superior to the other (Rosnow et al. (2000); McGarth & Meyer (2006)). Nevertheless, it appears that Cohen's d is more robust against unequal sample size, so Cohen's d will be used in this study to report the effect size when the data followes the parametric assumptions.

As Cohen's d is vulnerable to violation of the parametric assumptions, non-parametric statistics should be used when a data set violates the assumptions. Probability of superiority (PS), which is calculated using the well known Mann-Whitney U statistic, is robust against unequal sample sizes. Literature further provides a clear translation table between PS values and Cohen's d, which improves comparability in this study (Erceg-Hurn & Mirosevich, 2008). Therefore PS will be used in this research when the data violates the parametric assumptions.

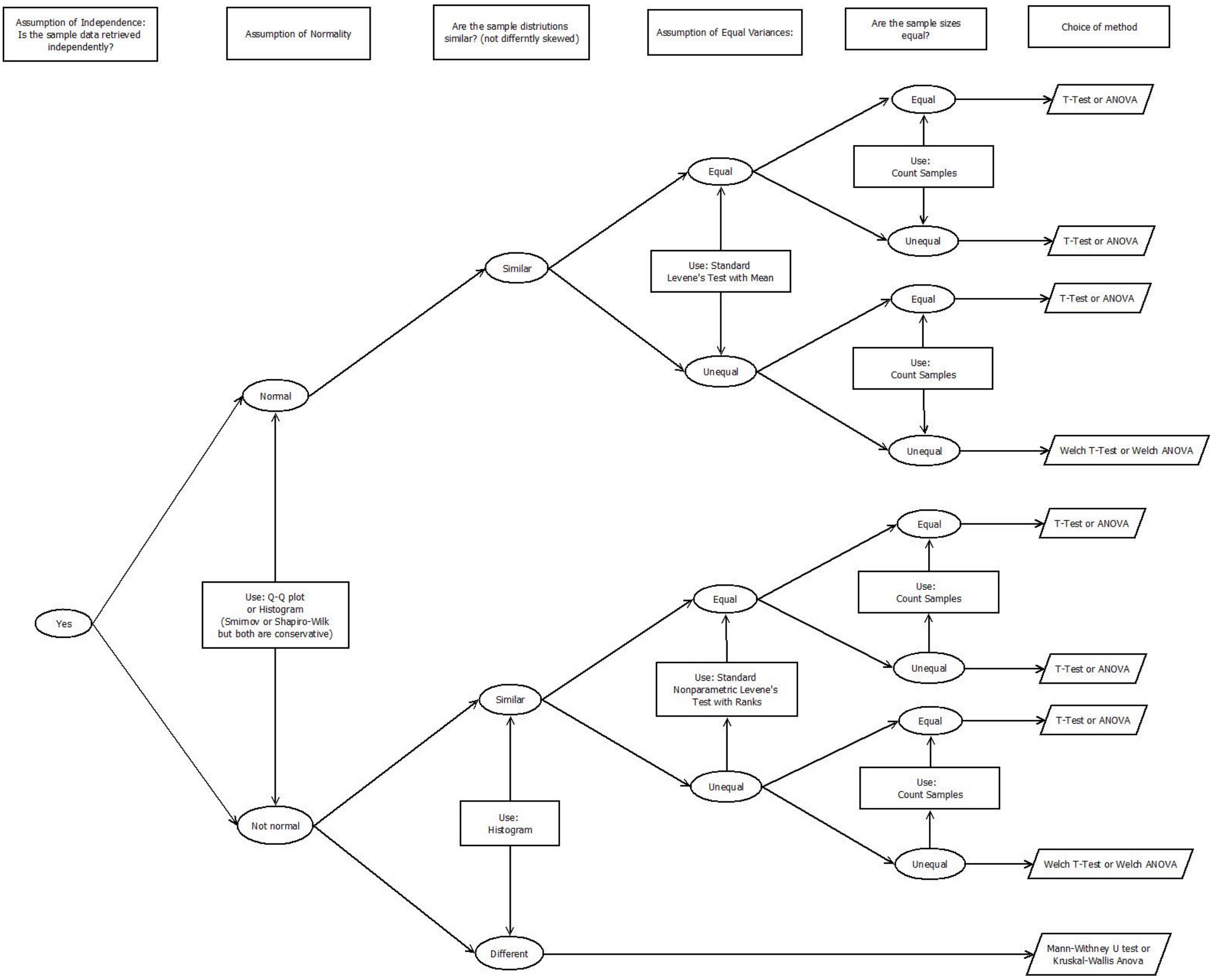

Figure 6: Decision tree concerning comparison tests

3

Chapter 3: Research methodology

In chapter 2, a summary of the literature review in appendix B is presented on the concepts which the instrument should measure. In the investigation, the reasons why BIM impacts certain communication and motivational concepts in a construction project process are shown. Furthermore, the methods of measuring these concepts are investigated.

The source tools developed by Hackman & Oldham (1974) and Goldhaber, Porter & Yates (1977) are well established, validated and accepted self-administered questionnaires. In order to retain as much of those features as possible, logic dictates that this research will use a similar survey methodology. However, it might be more appropriate to use a different method of data collection. The tools will also require an adaptation to fit the research goals and sample characteristics better.

In this chapter the outcome of an analysis for the most optimal research method, based on Fowler's (2008) eight points of attention, is presented. Next, the population and sample for this instrument are identified. Following that, the benchmark instrument itself is developed based on the two original tools. Finally, the initial instrument is tested and evaluated, and the final version constructed.

3.1 Research method

Every survey research is based on a set of questions. The method which is used to ask these questions can still differ. A questionnaire can be executed by an interviewer in a personal interview, focus group interviews or trough the telephone, but it can also be based on a questionnaire through the use of mail or internet. Which method best suits this research is determined in this paragraph.

Fowler presents eight issues or concepts which should be taken into account when choosing the proper survey strategy (Fowler, 2008). These issues are:

- Sampling
- Type of population
- Question form

- Question content
- Response rate
- Costs
- Available facilities
- Length of data collection

Appendix B shows a detailed analysis on these points in reference to this study. In the analysis it is identified whether a point results in a limitation to a method of data collection or if it results in a preference to a method data collection. The following table presents the results from that analysis.

Issue of Concept	Limitation	Preferences
Sampling	None	None
Type of population	None	None, but motivational risk
Question form	None	Self-administered
Question content	None	Self-administered
Response rate	None	None, but attention to possible nonresponse bias
Cost	None	Most efficient
Available Facilities	None	Computer aided method
Length of data collection	None	None

Table 5: Result of data collection method analysis based the eight points of Fowler (2008)

This table shows, after considering the eight issues towards the choice of data collection defined by Fowler (2008), that the most preferred data collection method in this research is a computer aided, self-administered data collection method. This method suits the notion of an efficient approach to financial and time cost, and is able to reach everybody in the sample population. It is also similar to the original tools which will help in the compatibility of this study with the theories and concepts on which those tools are based.

3.2 Population and sample

The research is executed at Grontmij, which is a Dutch consultancy engineering firm. It allows for the initial sampling to be done via the convenient sampling method. The downside of this method is that it introduces bias in the relationship between a sample and the population. This bias makes it more difficult to generalize the findings. Nevertheless, Grontmij is one of the major consultancy engineering firms in the Netherlands, so it is believed that the investigation will present valuable results.

Another refinement of the population can be made to the type of employees, after all there are many different employees working on design and engineering projects. The expectation is that BIM will mostly affect the work of the core team members in design and engineering projects. These are project leader, engineer, and draftsman. Therefore, the sample is further selected on the basis of the purposive sampling method.

With the use of these sampling techniques, the final instrument sample will consist of core team employees of design and engineering projects in the departments Stedelijk Gebied Randstad and Bouw & Vastgoed of Grontmij.

3.3 The instrument design

In this paragraph, the reasons and consequences for adaptations to the JDS and ICA audit questionnaire are explained. First the most major adaptation, translation of the tools into Dutch, is elaborated on and then the adaptations to the JDS are presented. Finally, the adaptations to the ICA audit questionnaire are explained.

3.3.1 Translation of the original tools

The respondents in this research are native Dutch speakers while both of the original tools are English. When the tools are not translated it is almost impossible to assume that respondents answered the questions the same way, as it cannot be strongly argued that they translated the questions similar.

In appendix B an in-depth analysis of translation methods is given. The analysis showed that the direct translation method should be used to translate the original tools from English to Dutch. The direct translation method is the “simplest” and cheapest translation procedure used. It is basically a single bilingual person who, to the best of his or her abilities, produces a translation of the source questionnaire. The benefits of such an approach are clear, but the drawbacks consist of, among others: relying on a single person’s perception and skills and data quality risks ((Harkness & Schoua-Glusberg, 1998),(Pan & De La Puente, 2005)).

3.3.2 The Job Diagnostic Survey

In the previous chapter, the JDS by Hackman and Oldham (1974) is introduced as a validated and accepted tool to measure the motivational potential of jobs. In this study, a version of this tool is used to measure the five different core job characteristics of several core jobs in civil engineering projects. These five characteristics explain the level of experiencing three psychological states in a job. These states again are examples of intrinsic job rewards, which are identified by Herzberg (1959) as being job motivators. There are examples of intrinsic rewards, like personal growth or the recognition within a group which also affect motivation, but this benchmark instrument will not asses personal motivation.

The total tool consists of 87 questions divided over eight sections. To calculate the MPS however, only the five job characteristics are required. The affective response to the job and the moderator factors are therefore excluded from this study. The psychological states still have value in view of the internal validity, and are not excluded.

The adaptation has decreased the amount of questions to 29. The variables that are measured are:

- Skill variety
- Task identity
- Task significance
- Feedback from the job itself
- Autonomy
- The experience of meaningfulness of the work
- The experience of responsibility for the outcomes of the work
- The knowledge of the actual results of work activities.

If the instrument is used with both BIM and non BIM respondents, than the MPS could be used to identify whether there is a difference in motivation potential between the two groups. If a difference is observed than this could provide evidence that BIM has affected the motivation potential of the jobs. Even though it is not the goal of this study, which is the initial development of the benchmark instrument, the confirmation of the following hypothesis could provide such evidence.

Hypothesis M1: Project participants in BIM projects will score a higher MPS than project participants in non BIM projects.

3.3.3 The ICA questionnaire

From the literature it followed that the ICA audit questionnaire should be used to measure the perception of employees on the level of communication failure, correctness of information, the availability of information, and the actuality of information in projects. All of concepts will be measured by asking respondents about their experience with the concepts. Looking at Figure 1 again, one can identify that the communication channel is at the heart of the communication process. Even though the encoding and decoding capability of receivers and senders will affect the quality of a message and with that the chance of miscommunication, it will only become “miscommunication” when the message is transferred via a communication channel. Also, the correctness, actuality and availability of information can only be assessed when the information is received or retrieved via different communication channels. Without a communication channel, there is no communication.

The instrument uses this aspect by questioning the respondents about their experience with communication aspects via different communication channels. By combining the experience from different channels, an valid aggregated score for a concept can be made. The channels can be divided in two groups: direct communication channels and indirect communication channels. The direct classification refers to the capability of a channel to allow for direct feedback on a message. Examples of direct channel are: face-to-face communication and telephone communication, where indirect channels are: e-mail and written reports.

The original questionnaire was adapted to better fit the company and the goals of this study. The original ICA questionnaire consisted of 118 questions, divided in eight sections (Goldhaber et al. (1977); Franklin (2004)). These sections are:

A. Receiving information about the work and your performance from others
B. Sending information about the work and your performance to others
C. The sources of information
D. The amount of follow-up or action taken on information you send to others
E. The quality of information
F. The channels of information used
G. The organizational communication relationships
H. Satisfaction with organizational outcomes

Every section measures different aspects of communication within an organization. Not all of these aspects are interesting in view of the goal of this research. Three major adaptations were made, together with several smaller ones. The full explanation and theory behind these adaptations can be found in appendix B.

The first major adaptation consisted of two steps, excluding the questions concerning section A, B, D, G and H as these are irrelevant for this study, and updating the question in section C by adding modern types of communication channels. After this first major adaptation, the questionnaire consisted of 86 questions divided over two sections.

The second major adaptation to the tool followed from what the tool should actually measure in this research. The original questionnaire is used to assess the current and desired states of communication according to the respondents. The goal of the instrument is to determine the current state of communication only. Therefore, all desired state questions were excluded from the questionnaire which resulted in a questionnaire consisting of 60 questions.

The third and final major adaptation concerned the response format and answer possibilities used in the questionnaire. The original ICA questionnaire used a five point Likert type response format and the JDS consists of seven point Likert type response formats. There are also a different types of questions where some ask respondents to provide their opinion on a frequency of occurrence or a statement, but others who ask respondents to provide a score on different aspects. A more complete summery of different arguments on the most optimal amount of answering points per question in a questionnaire is found in appendix B, but the conclusion is that for opinion on a frequency of occurrence or a statement questions a seven point category scale is used, where for the scoring questions a ten point numerical score is used.

The three major adaptations done to the ICA audit questionnaire resulted in a visually substantially different instrument. The amount of questions was decreased from 118 to 60, and the response formats were increased from a five-point scale to a seven-point scale. Three of the four goal concepts are measured on a numerical ten-point scale. Besides the visual difference, the contents is still similar to the original ICA audit questionnaire.

Construct validity of this part of the survey will be tested by analysing the relationships between the questions focussing on indirect channels of communication and the relationships between the questions which focus on direct channels of communication, as mentioned in the previous chapter. The following list shows the different channels and how they are classified in this respect.

- Direct communication channels
    - Face-to-face between two persons
    - Face-two-Face within a group
    - Telephone
- Indirect communication channels
    - E-mail
    - Written documents
    - Paper based drawings
    - Digital drawings

By measuring the experience in both BIM and non BIM groups, the benchmark instrument could provide evidence of the impact of BIM. Although providing this evidence is not the main goal of the study, the following hypotheses should provide the evidence of the impact of BIM when the impact has in fact occurred:

Hypothesis C1: Project participants in BIM projects will report a lower frequency of communication failure through various channels than project participants in non BIM projects.

Hypothesis C2: Project participants in BIM projects will rate correctness of information through various channels higher than project participants in non BIM projects.

Hypothesis C3: Project participants in BIM projects will rate availability of information through various channels higher than project participants in non BIM projects.

Hypothesis C4: Project participants in BIM projects will rate actuality of information through various channels higher than project participants in non BIM projects.

3.3.4 Interpretation of the data

All of the response formats of the questions, except the demographic questions, are Likert type response formats. In the past sixty years there has been a heated debate between two camps about what type of measurement scale a Likert scale is, ordinal or interval, and what type of data it actually generates. This discussion is important as the justification of using parametric statistical analysis or not is base on the type of measurement scale. A full review of the discussion is presented in appendix B. In this research data from single questions are interpreted as ordinal data, and data from a combination of items questioning a similar attitude are interpreted as interval data. Note that this also implies that hypotheses CV4 to CV19 now by definition require non-parametric test statistics as these consider relationships between individual questions.

Now that both of the tools are adapted and combined in a single instrument, the instrument will be evaluated and distributed. The evaluation is done in the following paragraph.

3.4 Instrument evaluation and Characteristics

3.4.1 Evaluation rounds

The final step before the benchmark instrument can be distributed among the sample population is to create the actual questionnaire and evaluate it. Evaluation of the benchmark instrument can support the face and content validity claim and was done in two rounds and considered the following aspects.

- The software used,
- The ease of filling out the form,
- The understanding of the questions and concepts,
- General comments

In the first evaluation round, team leaders of the department Stedelijk gebied were asked to review the questionnaire based on the before mentioned aspects. The choice of using the team leaders as a review committee was based on the assumption that they would be able to represent the skill, knowledge and wishes of their team members. An overview of the comments and solutions to these comments is presented in appendix C. Main comments concerned:

- The description of certain concepts, especially task identity appeared difficult to grasp,
- A lack of explanation for personal questions about work aspects,
- Anonymity in the instrument

The second round was mainly used to test the direct link between the questionnaire and the database. Two test subjects who operated in the same office as the researcher received the questionnaire and direct feedback was used to test and resolve issues that occurred.

After these two evaluation rounds the questionnaire was final. The evaluation rounds also strengthen the claim of face validity. Content validity was not supported as the evaluators are not experts in the respective fields of communication and motivation. However, the content validity remains supported by the use of the two source questionnaires.

It was recorded when a team leader sent the link to his team and after two weeks following that date, a follow-up e-mail was sent by the researcher. The full data collection process took a little over one month, and finally 152 of the 326 respondents filled in the form, resulting in a 47% response rate.

3.4.2 Demographics

The following table shows the demographic data retrieved from the instrument.

		BIM	**Non BIM**	**Total**
Respondents		37 (24%)	115 (76%)	152 (100%)
Department	Stedelijk Gebied (Civil)	15 (41%)	43 (37%)	58 (38%)
	Bouw en Vastgoed (AEC)	22 (59%)	72 (63%)	94 (62%)
Functions	Draftsman	8 (22%)	11 (10%)	19 (13%)
	Engineer	13 (35%)	23 (20%)	36 (24%)
	Project leader	13 (35%)	67 (58%)	80 (53%)
	Team leader	3 (8%)	5 (4%)	8 (5%)
	Supervisor	0 (0%)	9 (8%)	9 (6%)
Years working in industry	Less than 5	6 (16%)	6 (5%)	12 (8%)
	Between 5 and 15	18 (49%)	30 (26%)	48 (32%)
	Between 15 en 30	10 (27%)	45 (39%)	55 (36%)
	More than 30	3 (8%)	34 (30%)	37 (24%)

Table 6: Demographics of the instrument

Looking at the demographic results in the table above, the following observations are made.

- Both departments are represented rather well in the BIM respondents group. The AEC group is slightly bigger, but this was expected and the main reason for incorporating them in the survey. The difference becomes larger when looking at the total sample. The difference, however, is perfectly explained by ratio found in the entire sample of 326 respondents, which held 40% civil, and 60% AEC respondents.

- Looking at the functions, one can notice that there are an equal number of engineer and project leaders in the BIM group. This can be caused by certain distinct teams of people who are working on a BIM project. Draftsmen are rather underrepresented in both the BIM group as the total group. An explanation could be that there is less need for a draftsman in BIM projects (Khemlani, 2006), but the difference is probably due to the lower percentage of draftsman in the entire sample. The data further shows that there 1/2/4 ratio between project leaders/engineers/draftsman.
- The non BIM group and the total group show a rather equal distribution for years working in the industry, except for the least years experience category. Note that the range within each category, for example 5 years in the first, increases. This distribution represent an average company where the distribution of experience within the company is rather equal. The distribution of the BIM group however is slightly skewed to the low end of the scale. With the assumption that the years working in the industry is a general assumption to the age of a respondents, than it is interesting to see that the BIM group is slightly skewed to a younger generation.

3.4.3 Data characteristics

In chapter 2, it was identified that the statistical methods should be validated by testing certain assumptions. The assumption tests and accompanying graphs are found in appendix E. Table 6 shows the outcome of the tests for the individual hypotheses. The final choice of test statistic is based on the decision tree presented in chapter 2. Again, hypotheses CV4 to CV19 are not considered as they focus on relationships between single question items. Single questions are analysed as being ordinal data and therefore require non-parametric test statistics.

Hypothesis	**Assumptions**					**Method of Choice**
	Normality	Shape	Equal Variances	linear relationship	Independence of Errors	
IV1	Fail	n/a	n/a	n/a	n/a	Spearman's ρ
IV2	Fail	n/a	n/a	n/a	n/a	Spearman's ρ
IV3	Fail	n/a	n/a	n/a	n/a	Spearman's ρ
IV4	Pass		Pass	Pass	Pass, *d*=1.900	Pearson's r
IV5	Pass		n/a	n/a	n/a	Pearson's r
IV6	Fail	n/a	n/a	n/a	n/a	Spearman's ρ
CV1	Fail	similar	Pass ($F(1,113)=.827$, $p>0.05$)	n/a	n/a	Independent T-test

CV2	Fail	similar	Pass (F(1,93)=2.733, p>0.05)	n/a	n/a	Independent T-test
CV3	Fail	similar	Pass (F(1,50)=.759, p>0.05)	n/a	n/a	Independent T-test

Table 7: Results of assumption tests per hypotheses

4

Chapter 4: Validation of the benchmark instrument

In chapter 1, it was identified that the main contribution of this study will be a validated and reliable instrument which is capable of measuring concepts of communication and motivation in civil engineering projects. In this chapter the results of the instrument and the accompanying conclusions is presented. First, the validity tests are done, followed by the reliability tests. The chapter is concluded by a summary and exploration of the data for unanticipated findings. The comparative hypotheses between BIM and non BIM groups will not be shown as these were not part of the main goal of the study, but can be found in appendix F. The tables below show a summary of the validation and reliability test.

Summary table of Communicational validation hypotheses and conditions		
No	**Claim**	**Result**
IV1	*communication failure <-> rating correctness of information*	*Confirmed (moderate relationship)*
IV2	*communication failure <-> rating availability of information*	*Confirmed (weak relationship)*
IV3	*communication failure <-> rating actuality of information*	*Confirmed (moderate relationship)*
CV12	*relationships between direct channels leading to the miscommunication variable.*	*Confirmed (moderate to strong relationship)*
CV13	*relationships between direct channels leading to the correctness of information variable.*	*Confirmed (moderate to strong relationship)*
CV14	*relationships between direct channels leading to the actuality of information variable.*	*Confirmed (strong relationship)*
CV15	*relationships between direct channels leading to the availability of information variable*	*Confirmed (strong relationship)*
CV16	*relationships between indirect channels leading to the miscommunication variable*	*Confirmed (moderate to strong relationship)*
CV17	*relationships between indirect channels leading to the correctness of information variable.*	*Confirmed (moderate to strong relationship)*
CV18	*relationships between indirect channels leading to the actuality of information variable.*	*Confirmed (moderate to strong relationship)*

CV19	*relationships between indirect channels leading to the availability of information variable.*	*Confirmed (moderate to strong relationship)*

Table 8: Summary table of communicational validation hypotheses and conditions

Summary table of Motivational validation hypotheses and conditions		
No	**Claim**	**Result**
IV4	*+ relationship; perception of Skill variety, Task identity, Task Significance <-> the experience of meaningfulness of the work.*	*Rejected*
IV5	*+ relationship; perception of feedback from the job itself <-> the experience of knowledge of the actual results of the work activities*	*Confirmed (moderate relationship)*
IV6	*+ relationship; perception of autonomy <-> the experience of responsibility for the outcomes of the work*	*Confirmed (moderate relationship)*
CV1	*Project leaders will score a higher MPS than engineers*	*Confirmed*
CV2	*Project leaders will score a higher MPS than draftsmen.*	*Confirmed*
CV3	*Engineers will score a higher MPS than draftsmen*	*Confirmed*
CV4	*There are relationships between the questions leading to the aggregated skill variety variable.*	*Confirmed (moderate relationship)*
CV5	*There are relationships between the questions leading to the aggregated task identity variable.*	*Rejected*
CV6	*There are relationships between the questions leading to the aggregated task significance variable.*	*Confirmed (moderate relationship)*
CV7	*There are relationships between the questions leading to the aggregated feedback variable.*	*Confirmed (weak to moderate relationship)*
CV8	*There are relationships between the questions leading to the aggregated autonomy variable.*	*Confirmed (moderate relationship)*
CV9	*There are relationships between the questions leading to the aggregated experience meaningfulness variable.*	*Confirmed (weak to moderate relationship)*
CV10	*There are relationships between the questions leading to the aggregated knowledge of the actual results variable.*	*Confirmed (weak relationship)*
CV11	*There are relationships between the questions leading to the aggregated responsibility for the outcomes of the work variable.*	*Rejected*

Table 9: Summary table of motivational validation hypotheses and conditions

Summary table of Communicational reliability	
Concept	**Result**
Miscommunication	*Good Reliability*
Correctness of information	*Good Reliability*

Actuality of information	*Good Reliability*
Availability of information	*Good Reliability*

Table 10: Summary table of communicational reliability

Summary table of Motivational reliability	
Concept	**Result**
Skill variety	*Questionable Reliability*
Task Identity	*Unacceptable Reliability*
Task Significance	*Poor Reliability*
Feedback	*Poor Reliability*
Autonomy	*Questionable Reliability*
Experiencing Meaningfulness	*Poor Reliability*
Knowledge of the results	*Unacceptable Reliability*
Experiencing responsibility	*Questionable Reliability*

Table 11: Summary table of motivational reliability

4.1 Internal validity

The internal validity hypotheses test whether relationship found in the theory also exist in the data gathered by the instrument. The matrices are found in appendix H and resulted in the following test statistics. Note that a significant test statistic demonstrates the validity claim and that $p \leq 0.05$ is considered statistically significant.

Hypothesis IV1: There is a negative relationship between miscommunication and correctness of information.

- Test statistic: $\rho = .384$, p(one-tailed)<.01, $\rho^2 = 0.147$
- Correlation coefficient of .384 indicates a moderate positive relationship.
- High value for miscommunication meant lower experience miscommunication so the **hypothesis is confirmed.**

Hypothesis IV2: There is a negative relationship between miscommunication and availability of information.

- Test statistic: $\rho = .325$, p(one-tailed)<.01, $\rho^2 = 0.106$
- Correlation coefficient of .325 indicates a weak positive relationship
- High value for miscommunication meant lower experience miscommunication so the **hypothesis is confirmed.**

Hypothesis IV3: There is a negative relationship between miscommunication and actuality of information.

- Test statistic: ρ=.391, p(one-tailed)<.01, ρ^2=0.153
- Correlation coefficient of .391 indicates a moderate positive relationship.
- High value for miscommunication meant lower experience miscommunication so the **hypothesis is confirmed.**

Hypothesis IV4: There is a positive relationship between skill variety, task identity and task significance, and experiencing meaningfulness.

- Test statistics:
  - Skill variety: $t(141)$= 2.163, p<0.05
  - Task identity: $t(141)$= 1.615, p>0.05
  - Task significance: $t(141)$= 1.683, p>0.05
- Both task identity and task significance do not significantly contribute to a combined model. The data does not reveal that the three concepts together have a relationship with experiencing meaningfulness.
- **Hypothesis is rejected**

A backwards multiple regression, where the least significant variable is dropped and the model recalculated, shows that when task identity is dropped both skill variety (β=.191, $t(142)$= 2.089, p<0.05) and task significance (β=.205, $t(142)$= 2.241, p<0.05) have a significant contribution to the combined model This indicates that the reason why hypothesis IV4 is rejected is the concept task identity.

Hypothesis IV5: There is a positive relationship between feedback and knowledge of the results.

- Test statistic: r=.402, p(one-tailed)<.01, r^2=0.161
- Correlation coefficient of .402 indicates a moderate positive relationship
- **Hypothesis is confirmed**

Hypothesis IV6: There is a positive relationship between autonomy and experiencing responsibility for the work.

- Test statistic: ρ=.407, p(one-tailed)<.01, ρ^2=0.166
- Correlation coefficient of .407 indicates a moderate positive relationship
- **Hypothesis is confirmed**

The data shows that five out of six hypotheses are confirmed. These hypothesis all showed mainly moderate relationships. Therefore it is concluded that the instrument demonstrates to be internally valid to a moderate extend.

4.2 Construct validity

In chapter 3, face and content validity where already confirmed. In this paragraph the other construct validity hypotheses will be tested. In appendix H the full correlation matrices are shown, and

4.2.1 Concurrent validity

Concurrent validity referred to the ability of the instrument to distinguish between groups. Note that a significant test statistic supports the validity claim and that that $p \leq 0.05$ is considered statistically significant.

Hypothesis CV1: Project leaders will score a higher MPS than engineers.

- Test statistic:
  - Project leaders MPS $\bar{x}$=145.59
  - Engineers MPS $\bar{x}$=116.10
  - $t(113)=2.983, p<0.1$, PS= 0.67
- Project leaders score on average a higher MPS than engineers. This difference is tested significantly large. The PS indicates a medium effect size
- **Hypothesis is confirmed**

Hypothesis CV2: Project leaders will score a higher MPS than draftsmen.

- Test statistic:
  - Project leaders MPS $\bar{x}$=145.59
  - Draftsmen MPS $\bar{x}$=91.17
  - $t(93)=4.033, p<0.1$, PS= 0.82
- Project leaders score on average a higher MPS than draftsmen. This difference is tested significantly large. The PS indicates a large effect size.
- **Hypothesis is confirmed**

Hypothesis CV3: Engineers will score a higher MPS than draftsmen.

- Test statistic:
  - Engineers MPS $\bar{x}$=116.10
  - Draftsmen MPS $\bar{x}$=91.17
  - $t(50)=2.026, p<0.5$, PS= 0.70
- Engineers score on average a higher MPS than draftsmen. This difference is tested significantly large. The PS indicates a large effect size.
- **Hypothesis is confirmed**

All of the hypothesis are confirmed which indicates that there is concurrent validity in the instrument. Also, the effect sizes are medium to large which means that besides being statistically significant, the difference between MPS of different functions can be classified as a medium to large difference.

4.2.2 Convergent Validity

Convergent validity referred to how well questions converging on a similar concept are related to each other. First the validity of the motivational part is assessed, followed by the communicational part. The question number correspond with the questions of the instrument shown in appendix D.

Condition CV4: Questions leading to skill variety are related to each other.

- Question 4.3, 4.14 and 4.17(inverted)
- Test statistics:
  - 4.14 vs 4.17: $\rho=.362, p<.01, \rho^2=0.131$
  - 4.3 vs 4.14: $\rho=.442, p<.01, \rho^2=0.195$
  - 4.3 vs 4.17: $\rho=.569, p<.01, \rho^2=0.324$
- Correlation coefficients show moderate relationships

Condition CV5: Questions leading to task identity are related to each other.

- Question 4.2 , 4.15 and 4.20
- Test statistics:
  - 4.2 vs 4.20: $\rho=.082, p>.05$
  - 4.15 vs 4.20: $\rho=.110, p>.05$
  - 4.2 vs 4.15: $\rho=.174, p<.05, \rho^2=0.030$
- Two of the three correlations are not statistically significant. The third indicates a rather weak relationships. Note that this supports the claim that task identity is measured incorrectly.

Condition CV6: Questions leading to task significance are related to each other.

- Question 4.4, 4.18 and 4.23(inverted)
- Test statistics:
  - 4.4 vs 4.18: ρ=.386, p<.01, ρ^2=0.149
  - 4.4 vs 4.23: ρ=.386, p<.01, ρ^2=0.149
  - 4.18 vs 4.23: ρ=.411, p<.01, ρ^2=0.169
- Correlation coefficients show moderate relationships

Condition CV7: Questions leading to feedback are related to each other.

- Question 4.5, 4.16 and 4.21(inverted)
- Test statistics:
  - 4.16 vs 4.21: ρ=.244, p<.01, ρ^2=0.060
  - 4.5 vs 4.21: ρ=.346, p<.01, ρ^2=0.120
  - 4.5 vs 4.16: ρ=.501, p<.01, ρ^2=0.251
- Correlation coefficients show weak to moderate relationships. Note that the inverted question 4.21 is involved in the low coefficients.

Condition CV8: Questions leading to autonomy are related to each other.

- Question 4.1, 4.19(inverted) and 4.22
- Test statistics:
  - 4.19 vs 4.22: ρ=.428, p<.01, ρ^2=0.183
  - 4.1 vs 4.19: ρ=.435, p<.01, ρ^2=0.189
  - 4.1 vs 4.22: ρ=.567, p<.01, ρ^2=0.321
- Correlation coefficients show moderate relationships

Condition CV9: Questions leading to experiencing meaningfulness are related to each other.

- Question 4.7 (inverted), 4.9, 4.24(inverted) and 4.27
- Test statistics:
  - 4.7 vs 4.27: ρ=.160, p<.05, ρ^2=0.026
  - 4.7 vs 4.24: ρ=.260, p<.01, ρ^2=0.068
  - 4.24 vs 4.9: ρ=.288, p<.01, ρ^2=0.083
  - 4.9 vs 4.27: ρ=.310, p<.01, ρ^2=0.096
  - 4.7 vs 4.9: ρ=.455, p<.01, ρ^2=0.207
  - 4.24 vs 4.27: ρ=.552, p<.01, ρ^2=0.305
- Correlation coefficients show weak to moderate relationships. Note that inverted question 4.7 is involved in two lowest coefficients.

Condition CV10: Questions leading to knowledge of the results are related to each other.

- Question 4.8, 4.11(inverted), 4.26 and 4.29(inverted)
- Test statistics:
  - 4.11 vs 4.26: ρ=.203, p<.01, ρ^2=0.026
  - 4.8 vs 4.29: ρ=.219, p<.01, ρ^2=0.068
  - 4.8 vs 4.26: ρ=.256, p<.01, ρ^2=0.083
  - 4.26 vs 4.29: ρ=.290, p<.01, ρ^2=0.096
  - 4.8 vs 4.11: ρ=.341, p<.01, ρ^2=0.207
  - 4.11 vs 4.29: ρ=.375, p<.01, ρ^2=0.305
- Correlation coefficients show weak relationships.

Condition CV11: Questions leading to experiencing responsibility are related to each other.

- Question 4.6(inverted), 4.10, 4.12, 4.13, 4.25 and 4.28
- Test statistics:
  - 4.6 vs 4.13: $\rho=.129$, $p>.05$,
  - 4.10 vs 4.25: $\rho=.129$, $p>.05$,
  - 4.12 vs 4.25: $\rho=.171$, $p<.05$, $\rho^2=0.029$
  - 4.6 vs 4.28: $\rho=.173$, $p<.05$, $\rho^2=0.030$
  - 4.6 vs 4.12: $\rho=.182$, $p<.05$, $\rho^2=0.033$
  - 4.13 vs 4.25: $\rho=.189$, $p<.05$, $\rho^2=0.036$
  - 4.6 vs 4.25: $\rho=.203$, $p<.05$, $\rho^2=0.041$
  - 4.10 vs 4.28: $\rho=.239$, $p<.01$, $\rho^2=0.057$
  - 4.12 vs 4.28: $\rho=.272$, $p<.01$, $\rho^2=0.074$
  - 4.6 vs 4.10: $\rho=.286$, $p<.01$, $\rho^2=0.082$
  - 4.13 vs 4.28: $\rho=.293$, $p<.01$, $\rho^2=0.086$
  - 4.10 vs 4.13: $\rho=.506$, $p<.01$, $\rho^2=0.256$
  - 4.12 vs 4.13: $\rho=.609$, $p<.01$, $\rho^2=0.371$
  - 4.10 vs 4.12: $\rho=.672$, $p<.01$, $\rho^2=0.452$
  - 4.25 vs 4.28: $\rho=.715$, $p<.01$, $\rho^2=0.511$
- Two of the fifteen correlations are not significant and nine of the remaining thirteen have low to very low relationships. Note that question 4.6 has low relationships with the other question set (4.25 and 4.28), but also with its own question set (4.6 to 4.13). Also note that the questions which are asked in the same set have a high relationship.

The data shows that six out of eight conditions concerning the motivational part are within the evaluation boundaries. Condition CV5 is not and follows a similar pattern as hypothesis IV4 which further supports the claim that task identity is measured incorrectly in the instrument.

The failure of condition CV11 was not expected based on previous hypotheses or on the evaluation. It is interesting to see that the failure is probably caused by the different answers in the different question sets. The first set (4.6 to 4.13) asked respondents about their own experienced job characteristics, where the second (4.25 and 4.28) takes a perspective format and asks respondents to answer the same questions but now for other people who hold the same job as the respondents. Apparently, respondents in this survey rate their own experienced responsibility in a job differently than that of other people in the same job.

Furthermore, one condition showed weak relationships, two showed weak to moderate relationships, and none of the relationships could be considered high. This leads to the conclusion that the motivational part of the instrument has a low convergent validity and should be revised before it can be used in view of the philosophy of development. The communication part is assessed in the following part.

Condition CV12: Direct channels leading to miscommunication are related

- Question 2.8, 2.9 and 2.10
- Test statistics:
  - 2.9 vs 2.10: $\rho=.537$, $p<.01$, $\rho^2=0.288$
  - 2.8 vs 2.10: $\rho=.573$, $p<.01$, $\rho^2=0.328$
  - 2.8 vs 2.9: $\rho=.706$, $p<.01$, $\rho^2=0.498$
- Correlation coefficients show moderate to strong relationships

Condition CV13: Direct channels leading to correctness of information are related.

- Question 2.28, 2.29 and 2.30
- Test statistics:
  - 2.28 vs 2.30: $\rho=.494$, $p<.01$, $\rho^2=0.244$
  - 2.29 vs 2.30: $\rho=.556$, $p<.01$, $\rho^2=0.309$
  - 2.28 vs 2.29: $\rho=.775$, $p<.01$, $\rho^2=0.601$
- Correlation coefficients show moderate to strong relationships

Condition CV14: Direct channels leading to actuality of information are related

- Question 2.35, 2.36 and 2.37
- Test statistics:
  - 2.36 vs 2.37: $\rho=.674$, $p<.01$, $\rho^2=0.454$
  - 2.35 vs 2.37: $\rho=.699$, $p<.01$, $\rho^2=0.489$
  - 2.35 vs 2.36: $\rho=.821$, $p<.01$, $\rho^2=0.674$
- Correlation coefficients show strong relationships

Condition CV15: Direct channels leading to availability of information are related

- Question 2.42, 2.43 and 2.44
- Test statistics:
  - 2.42 vs 2.44: $\rho=.688$, $p<.01$, $\rho^2=0.473$
  - 2.43 vs 2.44: $\rho=.707$, $p<.01$, $\rho^2=0.500$
  - 2.42 vs 2.43: $\rho=.862$, $p<.01$, $\rho^2=0.743$
- Correlation coefficients show strong relationships

Condition CV16: Indirect channels leading to miscommunication are related

- Question 2.11, 2.12, 2.13 and 2.14
- Test statistics:
  - 2.11 vs 2.13: $\rho=.373$, $p<.01$, $\rho^2=0.139$
  - 2.11 vs 2.14: $\rho=.453$, $p<.01$, $\rho^2=0.205$
  - 2.12 vs 2.14: $\rho=.521$, $p<.01$, $\rho^2=0.271$
  - 2.11 vs 2.12: $\rho=.581$, $p<.01$, $\rho^2=0.338$
  - 2.12 vs 2.13: $\rho=.593$, $p<.01$, $\rho^2=0.352$
  - 2.13 vs 2.14: $\rho=.724$, $p<.01$, $\rho^2=0.524$
- Correlation coefficients show moderate to strong relationships

Condition CV17: Indirect channels leading to correctness of information are related.

- Question 2.31, 2.32, 2.33 and 2.34
- Test statistics:
  - 2.31 vs 2.33: $\rho=.431$, $p<.01$, $\rho^2=0.186$
  - 2.31 vs 2.34: $\rho=.525$, $p<.01$, $\rho^2=0.276$
  - 2.31 vs 2.32: $\rho=.584$, $p<.01$, $\rho^2=0.341$
  - 2.32 vs 2.34: $\rho=.592$, $p<.01$, $\rho^2=0.350$
  - 2.32 vs 2.33: $\rho=.698$, $p<.01$, $\rho^2=0.487$
  - 2.33 vs 2.34: $\rho=.788$, $p<.01$, $\rho^2=0.621$
- Correlation coefficients show moderate to strong relationships

Condition CV18: Indirect channels leading to actuality of information are related

- Question 2.38, 2.39, 2.40 and 2.41
- Test statistics:
  - 2.38 vs 2.40: ρ=.407, p<.01, ρ^2=0.167
  - 2.38 vs 2.41: ρ=.529, p<.01, ρ^2=0.280
  - 2.38 vs 2.39: ρ=.603, p<.01, ρ^2=0.364
  - 2.39 vs 2.41: ρ=.633, p<.01, ρ^2=0.401
  - 2.39 vs 2.40: ρ=.773, p<.01, ρ^2=0.598
  - 2.40 vs 2.41: ρ=.791, p<.01, ρ^2=0.626
- Correlation coefficients show moderate to strong relationships

Condition CV19: Indirect channels leading to availability of information are related.

- Question 2.45, 2.46, 2.47 and 2.48
- Test statistics:
  - 2.45 vs 2.47: ρ=.511, p<.01, ρ^2=0.261
  - 2.46 vs 2.48: ρ=.615, p<.01, ρ^2=0.378
  - 2.45 vs 2.48: ρ=.653, p<.01, ρ^2=0.426
  - 2.45 vs 2.46: ρ=.697, p<.01, ρ^2=0.486
  - 2.46 vs 2.47: ρ=.730, p<.01, ρ^2=0.533
  - 2.47 vs 2.48: ρ=.736, p<.01, ρ^2=0.542
- Correlation coefficients show moderate to strong relationships

The data shows that all of the conditions concerning the communication part are within acceptable ranges, moderate to strong. This leads to the conclusion that the communication part demonstrates a high convergent validity.

4.2.3 Conclusion

The instrument displays internal and external validity. Also face, content and concurrent validity are demonstrated and the instrument displays convergent validity for the communication part. However, the motivational part displays a low convergent validity which means that construct validity is not fully satisfied. Especially the measurement of task identity appears not to be valid. This leads to the conclusion that the instrument needs revision on certain questions before it can reveal fully valid evidence of an impact of BIM on communication and motivation. Questions which are expected to need revision based on the validity tests are: 4.2, 4.6, 4.7, 4.15, 4.20, 4.21 and 4.25. Nevertheless, the instrument will provide valid benchmark scores for future assessment, and these benchmarks can also be used to provide an indication of evidence of an impact of BIM.

4.3 Instrument reliability

The internal reliability tests whether questions are answered consistently and if the different concepts are rated consistently. Note that the guidelines are as follows: Cronbach's α should be at least higher than 0.5, Item-Total correlations between 0.3 and 0.7, and no higher value of Cronbach's α should be estimated when a question is removed from the scale.

Internal reliability assessment of miscommunication concept

- Cronbach's α=0.817
- Item-Total correlations are between .485 and .620
- No higher alpha when a question is removed
- **Measurement of miscommunication concept has a good reliability:** *all values follow guidelines*

Internal reliability assessment of correctness of information concept

- Cronbach's α=0.845
- Item-Total correlations are between .503 and .678
- No higher alpha when a questions is removed
- **Measurement of correctness of information concept has a good reliability:** *all values follow guidelines*

Internal reliability assessment of actuality of information concept

- Cronbach's α=0.882
- Item-Total correlations are between .566 and .789.
- No higher alpha when a questions is removed
- **Measurement of actuality of information concept has a good reliability:** *The upper item-total correlation is higher than 0.7 but is accepted in respect to the level of alpha and the height of the other item-total correlations.*

Internal reliability assessment of availability of information concept

- Cronbach's α=0.878
- Item-Total correlations are between .574 and .718.
- No higher alpha when a questions is removed
- **Measurement of availability of information concept has a good reliability** *The upper item-total correlation is higher than 0.7 but is accepted in respect to the level of alpha and the height of the other item-total correlations.*

Internal reliability assessment of skill variety concept

- Cronbach's α=0.681
- Item-Total correlations are between .409 and .558.
- When question 4.17(inverted) is removed, Cronbach's α becomes .717
- **Measurement of skill variety has a questionable reliability:** *Alpha is low, but item-total correlations are acceptable. Question 4.17 needs revision to increase the reliability to an acceptable level.*

Internal reliability assessment of task identity concept

- Cronbach's α=0.282
- Item-Total correlations are between .112 and .211.
- When question 4.20 is removed, Cronbach's α becomes .331
- **Measurement of task identity has an unacceptable reliability:** *Alpha is very low and item-total correlations are not acceptable. Revision of all questions needed to increase reliability.*

Internal reliability assessment of task significance concept

- Cronbach's α=0.575
- Item-Total correlations are between .357 and .444.
- No higher alpha when a questions is removed
- **Measurement of task significance has a poor reliability:** *Alpha is low, but item-total correlations are acceptable. Revision of all questions needed to increase reliability.*

Internal reliability assessment of feedback concept

- Cronbach's α=0.583
- Item-Total correlations are between .318 and .496.
- When question 4.21(inverted) is removed, Cronbach's α becomes .643
- **Measurement of feedback has a poor reliability:** *Alpha is low, but item-total correlations are acceptable. Revision of Question 4.21 needs revision to increase the reliability to a more acceptable level.*

Internal reliability assessment of autonomy concept

- Cronbach's α=0.667
- Item-Total correlations are between .379 and .563.
- When question 4.19(inverted) is removed, Cronbach's α becomes .732
- **Measurement of autonomy has a questionable reliability:** *Alpha is low, but item-total correlations are acceptable. Question 4.19 needs revision to increase the reliability to an accepted level.*

Internal reliability assessment of experiencing meaningfulness concept

- Cronbach's α=0.524
- Item-Total correlations are between .242 and .352.
- No higher alpha when a questions is removed
- **Measurement of experiencing meaningfulness has a poor reliability:** *Alpha is low and item-total correlations are not fully acceptable. Item-total correlation of Question 4.7 is below the threshold. Revision of all questions needed to increase reliability.*

Internal reliability assessment of knowledge of the results concept

- Cronbach's α=0.498
- Item-Total correlations are between .204 and .381
- No higher alpha when a questions is removed
- **Measurement of knowledge of the results has a unacceptable reliability:** *Alpha is low, item-total correlations are not fully acceptable. All questions need revision to increase reliability*

Internal reliability assessment of experiencing responsibility for the job concept

- Cronbach's α=0.686
- Item-Total correlations are between .015 and .614.
- When question 4.6(inverted) is removed, Cronbach's α becomes .739
- **Measurement of experiencing responsibility for the job has a questionable reliability:** *Alpha is low, item-total correlations are not fully acceptable. Item-total correlation of Question 4.6 and 4.25 are below the threshold. Both questions need revision to increase the reliability to an accepted level.*

The data shows that the communication part of the instrument results in consistent answers and the concepts all have a good estimated reliability. The motivational part, however, differs between questionable and poor estimated reliability. The failure of the instrument to measure task identity is again shown as the estimated reliability of the concept is unacceptable. The estimate reliability of knowledge of the results is also unacceptable, which was not anticipated based on previous tests. The reason of the concept failing the reliability test, could be similar to the reason why condition CV11 failed, namely the difference between personal and perspective points of view. Also in this case, the lower correlation coefficients are between questions of different point of views. Nevertheless, the low estimated values of alpha for the motivational concepts will also be caused by the low number of items. All communication concepts rely on seven items, but the motivational concept mostly rely on three or four items. This leads to the conclusion that the instrument in this state displays sufficient reliability in the communication part, but not in the motivational part, to be used in face of the philosophy for which it is developed. The instrument needs revision of the following questions: 4.2, 4.6, 4.7, 4.8, 4,11, 4.15, 4.17, 4.19, 4.20, 4.21, 4.25, 4.26 and 4.29. Nevertheless, the instrument can still be used to create benchmark scores from which future progress can be assessed.

4.4 Summary

The communication part of the instrument displays both valid and reliable results in measuring the concepts of miscommunication, availability, actuality and correctness of information. This part could readily be used to provide valid evidence of the impact of BIM in the future when an impact is found. The concepts in the motivational part however, displays a rather weak construct validity. They also demonstrates a lower reliability than preferred.

The concept of task identity provides invalid results for both internal and construct validity and has an unacceptable reliability. Measurement of that concept is therefore not possible with the current instrument. It is expected that the impact of this failure on the MPS calculation is low, as the concept is only $1/9^{th}$ of the total MPS score (see Equation 1). The concept of experiencing responsibility has a weak construct validity as its convergent validity failed, but the reliability is, although questionable, sufficient. The concepts of task significance, feedback, experiencing meaningfulness in the job and knowledge of the results al provide poor reliable results. These concepts therefore need revision before the instrument can be used to provide valid evidence of the impact of BIM in the future. The following questions are found to be in need of revision.

Question	**Validity revision**	**Reliability revision**
4.2	x	x
4.6	x	x
4.7	x	x
4.8		x
4.11		x
4.15	x	x
4.17		x
4.19		x
4.20	x	x
4.21	x	x
4.25	x	x
4.26		x
4.29		x

Table 12: Identified questions which require revision

Ideas on how these questions can be revised can be found at the end of this report. Even though the instrument cannot be readily used to examine whether BIM has impacted the motivation potential in engineering firms, it can be used to assess the impact on communication and provides valid current benchmark scores on the current communication and motivation potential in engineering firms.

4.5 Unanticipated Findings

Following the testing of the validity and reliability for this study, the data has been explored further to identify possible unanticipated relationships which were not identified in the literature. For the exploration two correlation matrices were created in SPSS, using the entire sample and correlating every construct measured by the instrument. The first matrix calculated the Pearson coefficient and the second the Spearman coefficient, as the relationship between these two can provide an indication to the data characteristics. The exploration mainly focused on relationships between the two theoretical foundations, Motivational theory and Communication theory, as most of the relationships within a theoretical foundation are already described and tested in the previous paragraph. The matrices are shown in appendix I.

From the computed correlation matrices, a selection was made based on three criteria: 1) the relationship has to be between constructs of different theoretical foundations, 2) the relationship should have a significant coefficient of $p<0.01$ in order to strengthen the relational claim, and 3) relationships with task identity and knowledge of the results are excluded as previous analysis indicates that the construct are invalid and/or unreliable. All the constructs of the communication theory have failed the normality assumption tests in the previous paragraph and therefore only the spearman correlation coefficient is used when testing the significant value. This resulted in four interesting correlations which are:

- R1: The level of miscommunication has a negative relationship with experiencing meaningfulness in the job ($\rho=.237$, $p<0.01$, $\rho^2=0.06$)
- R2: The actuality of information has a positive relationship with the task significance of a job ($\rho=.221$, $p<0.01$, $\rho^2=0.05$)
- R3:The actuality of information has a positive relationship with experiencing meaningfulness in the job ($\rho=.232$, $p<0.01$, $\rho^2=0.05$

All of these relationships are small sized relationships according to rules of thumb ((Field, 2009), (Grissom & Kim, 2005)). When looking at the effect size by squaring the ρ values, it shows that only between 5% and 8% of the variation in ranks, can be explained by the other variable. Interestingly, miscommunication does correlate statistical significantly with experience meaningfulness and knowledge of the results but not with the underlying constructs.

When the data is explored further, and the sample is split into a BIM and non BIM group, it is revealed that R1, R2, and R3, are mainly due to the answers given by the non BIM group ($R1_{NB}$ $\rho=.252$, $p<0.01$, $R2_{NB}$ $\rho=.303$, $p<0.01$ & $R4_{NB}$ $\rho=.205$, $p<0.05$), and are no longer statistically significant in the BIM group. This is interesting as it indicates that R1, R2 and R3 are stronger in the non BIM group. It does not indicate that these relationships do not exist in the other groups, as the total sample does indicate that these relationships exist.

These relationships are not directly explained in the literature study, but plausible causes for these relationships can be reasoned. Whether or not the reasoning is correct requires additional research. The need for extra research on the subject is added trough the constrain that experiencing meaningfulness displayed a weak validity and poor reliability estimate, which undermines the finding of actual relationships.

R1: The level of miscommunication has a negative relationship with experiencing meaningfulness in the job.

Experiencing meaningfulness in the job is explained in this research as a manifestation of the intrinsic rewards of a job. There are far more intrinsic rewards in a job than only the three job characteristics of the JDS. Also, the relationship between project actors, and the form of collaboration between project actors are examples of factors that could influence the experience of meaningfulness in a job. It can be argued, that the level of miscommunication, experienced by a respondent, would influence such relationships and collaborations as well. If there is, for example, a high level of miscommunication between project actors than this could frustrate the process and the actors themselves. This in term could influence the amount of pleasure and meaningfulness that an actor experiences in projects. Another correlation matrix (see appendix I) between four measured basic collaboration and interaction variables (two within a department, and two between departments), identified a significant positive correlation between the experience of meaningfulness and the collaboration between actors of the same department (ρ=.188, $p<0.05$). However, the same matrix shows that there is no statistically significant relationship between miscommunication and the collaboration and interaction variables. The significant correlation does provide evidence for the before mentioned hypotheses, even though the other variables do not significantly correlated with experience meaningfulness.

R2: The actuality of information has a positive relationship with the task significance of a job.

Task significance can be defined as a level of impact a job has on its surroundings and other people. A higher level of actuality of information would allow a respondent to act more appropriately and directly to a changed situation in its surroundings. When the definition is followed, than a higher level of actuality of information could allow a respondent to have a higher and more direct impact on its surroundings as it understands its surroundings better. It is not strange that this relationship would appear stronger in the BIM group as the ability of a BIM to react to changes is one of the benefits of BIM found in the literature study.

R3: The actuality of information has a positive relationship with experiencing meaningfulness in the job.

The previous relationships explained the possibility of the relation between actuality and an underlying construct of experiencing meaningfulness. Relationship 1 also explained that there are more underlying constructs which affect experiencing meaningfulness than only the three job characteristics.

This relationship could mean that actuality of information might also be an underlying construct of experiencing meaningfulness, although causality is not implied by the correlation. Nevertheless, one could assume that actuality of information would also influence the interaction and collaboration between project actors, and in fact the correlation matrix in appendix I shows such a relationship. The matrix shows that collaboration ($\rho=.329$, $p<0.01$) and interaction ($\rho=.207$, $p<0.05$) between colleagues of the same department is positively correlated with the actuality of information. Therefore, a plausible cause for this relation is similar to relationship R1, meaning actuality of information has a positive relationship with the collaboration and interaction between colleagues, which would lead to a higher experienced meaningfulness of the job.

5

Chapter 5: Discussion, Conclusions and Recommendations

In the previous chapter, the results of the instrument and unanticipated findings were presented. In this chapter the impacts of the statistical tests and the exploration of the data is shown. Also limitations to the study will be present. Finally, the conclusion of this master thesis and the recommendation for future research is provided.

5.1 Discussion

5.1.1 Impact of the results

- Initial exploration of the data reveals that respondents are rather positive about their communication skills, information handling skills, and the quality of information within projects. “Miscommunication” happens occasionally, “correctness” and “actuality of information” score between 7 and 8 out of 10, and the “availability of information” scores around 7 out of 10. This is a positive result which indicates that these constructs are performing well within Grontmij.
- Initial exploration of the five job characteristics (task identity, skill variety, task significance, feedback and autonomy) shows that respondents rate every individual construct above the average value of 4, which indicates that the respondent are rather positive about their jobs. The MPS of the different functions (Project leader = 146, Engineer = 116 and Draftsmen = 91) are low in comparison to the normative score provided by Hackman, Oldham & Stepina (1979), which state an MPS of 154 for professional jobs. However, the jobs which lead to the normative score are not directly comparable with the current jobs at Grontmij and over 34 years old, which leads to the conclusion that a valuable comparison cannot be made. Unfortunately, no more recent scores of comparative jobs have been found in the literature. This finding emphasizes the contribution of the development of the instrument with providing such new scores.
- The communication part shows internal validity, construct validity and sufficient internal reliability estimates. The weakest internal validity relationship is between “miscommunication” and “availability of information”. A reason for this weaker relationship can be the difference in tangibility of the two constructs. “Availability of information” is more tangible than “miscommunication”, which makes it easier for respondents to define the construct. This clearer definition would than lead to a more distinct and different opinions, which could explain the lower relationship. Looking at the

variance of “availability”, “actuality” and “correctness of information”, this explanation is supported as it shows that “availability” has the highest variance. With the validity and reliability tests it is proven that the instrument is capable of generating valuable benchmark scores. These scores can also be used in the assessment of the impact of BIM on communication.

- Currently BIM respondents do not statistically experiences lower levels of miscommunication. Also, BIM respondents do not statistically rate the information handling skills or the quality of information within projects higher than non BIM respondents (see appendix F for tests). It is expected that these results are mainly due to the early stage of implementation of BIM in the work processes at Grontmij.
- Validity and reliability tests for the motivational part have revealed that the responses on “task identity” construct are internal and construct invalid and provide unreliable results in the instrument. This failure is mainly caused by the difficulty for respondents of defining the construct based on the questions. This difficulty was already noticed at the translation and evaluation stage of the development, where the phrasing and translation of the questions was difficult and not completely understood in the concept stage by the evaluation team. Looking at the scatter plots of the questions it is also observed that the distribution of responses become more linear instead of s-shaped towards the end of the questionnaire, which could indicate that respondents become more capable of defining the questions and provide a more distinct answer. Nevertheless, the construct “task identity” only represents $1/9^{th}$ of the total MPS calculation (see Equation 1) over 1/3th for feedback and autonomy. This indicates that variations of “task identity” will not have a large effect on the MPS, and that the calculation via the instrument can be used as benchmark score, but need revision to provide evidence for the impact of BIM.
- The “experiencing of responsibility” construct appears to have no construct validity and the “knowledge of the results” construct provides unreliable measurements. The constructs are not used in the calculation of the MPS score and therefore of less concern towards the value of the benchmark scores, but it does mean that the instrument needs revision before it can be used to provide evidence of the impact of BIM. Nevertheless, Both failures appear to be caused by the difference in point of view (POV) of two question sets which are combined to generate the construct. The first set takes the personal POV where respondents are asked to grade themselves, and the second set takes the perspective POV where respondents are asked to grade somebody else in a similar job. There is a high relationship between questions of the same POV, but low to none relationship between questions of different POV’s. These relations effect both the validity as the reliability tests and result in the failure.
- The unanticipated findings indicate that there are synergy effects between constructs of communication and motivation that can be impacted by BIM. The data indicated triangular relationships between “miscommunication”, “collaboration & interaction between colleagues”, and “experiencing meaningfulness”, and between “actuality of information”, “collaboration & interaction between colleagues”, and “experiencing meaningfulness”. These synergy effects provide evidence for the broadly reported positive impact of BIM and indicate the added value of implementing BIM.

5.1.2 Limitations of the study

Although the correlation hypotheses validate the instrument, there are still some aspects that provide a limitation to the study.

- The study is performed at a single company, and respondents were selected based on convenience. This leads to a limitation to the external validity of the results of the study. However, this limitation is assumed to be minimal as the instrument itself can be easily used in other companies as well, and the basic work process in projects can be assumed similar for other civil engineering and consultancy companies.
- The translation of the measurement tools was done via a simple translation, which causes limitations to the reliability and validity of the results. The validation and reliability tests show that the translation did not lead to issues in the validity and reliability of the communication part, but is expected to have caused the failure of the "task identity" construct and lower correlation coefficients. Nevertheless, the impact is expected to be minimal when using the instrument as benchmark instrument as the impact of the troubled construct on the total scores is low.

5.2 Conclusion

The problem and goal of this study were provided in a clear statement in chapter 1. This statement was as follows:

> *This study focuses on developing a benchmark instrument, which is capable of measuring communication and motivation potential in a civil engineering firm. The philosophy behind the development is that the data from the instrument should be able to provide quantitative evidence that BIM impacts these concepts when data sets from a BIM and non BIM group are compared.*

This report has provided such a benchmark instrument, which has been implemented at Grontmij to identify its validity and reliability. The data provides sufficient validity for the instrument to be used as a benchmark instrument. The data also revealed that there is a relationship between the constructs from the two theoretical foundations. This provides evidence for synergy effects within the different concepts which can be strengthened with the use of BIM.

Practical contribution

The practical contribution of this thesis can be found in the benchmark instrument, and benchmark scores provided by this study. The instrument has been made available to Grontmij, combined with a report which explains how to use the instrument, and an excel file which allows for an easy analysis of the results. Furthermore, the literature study on other impacts found in the appendix has provided possibilities for Grontmij to add other measurement to the instrument, which would increase the use of the instrument. The data can further be used to identify the current state of communication and motivation potential in jobs, which can be used to determine possible areas where improvement is wanted.

Theoretical contributions

This study provides an overview of the current literature on the five perceived impacts of BIM and provides ideas on how these impacts are measured. It also provides the basis for an instrument of a new benchmark instrument for the impacts of BIM, and gives new benchmark scores for the MPS of jobs in Dutch engineer and consultancy firms which could be used in combination with others to assess the MPS at other companies. It also provides evidence for synergy effects which could add convincing arguments for the implementation of BIM.

5.3 Recommendations

As final part of this thesis, recommendations for future research are made.

- This study is performed at only one company. By increasing the amount of companies, more current benchmark scores can be made, and the impacts of BIM can be identified more quantitatively.
- The study is also performed within a restricted time frame. By executing a longitude study the instrument could be further developed iteratively and simultaneously provide the host company with an idea on how BIM evolves within the company.
- The tests have shown that the questions of Table 12 should be revised in order to improve the validity and reliability of the instrument. I would advise to review the translation from the two source tools to the instrument. A direct translation method by a professional translator or a committee translation method could improve the validity of the translation and with that the validity of the instrument. I would also advise to review the content validity using experts of the different source tools. By using those expert judgments the validity of the translation can be further increased. Finally, I would advice to use an item analysis in order to analyse the individual question items on their current quality and guide the revision process. See Allen, Lehman & Mehrens (1967) on the value of item analysis and how it is conducted.
- The test also indicates that respondents answer questions differently when asked to review their job from different point of views (personal or perspective). It can be argued that this is caused by the independents from the subject of respondent when a perspective point of view is taken. Such independence from the subject could result in either a more harsh or more lenient evaluation, depending on, for example, the personal relationship with colleagues. However, the observed difference has not been found or mentioned as a threat to the source tool in the literature. An investigation into the cause of the difference and how it affects the instrument could improve the quality of the instrument.
- The results have shown a relation between the theoretical foundations of this research. Two of the three found relations consist of the psychological state of experiencing meaningfulness in the job. Even though the instrument does not yet provide conclusive evidence for the relationships, it is interesting to note that it seems that communication has a relationship with the motivation potential of a job and vice versa. A more in-depth investigation into the synergy effects between the two concepts, but also with other concepts, has not been found in the literature yet. Such an

investigation would greatly improve the knowledge into the possible benefits of BIM and how process can be attuned to provide the maximum benefit to a company.

- The current instrument only incorporates the impacts on motivation and communication, but the literature study also elaborates on other impacts like the impact on design deliverables, cost estimation and project duration. It would be beneficial to the instrument, as well as the companies who would use it, to incorporate these impacts as well.

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Appendix A. Host company profile

The study was executed at a host company to support the practical input, and ensure that data generation was done in a real environment, which increases the value of the study. The choice of the host company, Grontmij NL, was largely driven by the wish of the company to investigate the implementation of BIM in their work process. During the study Grontmij NL allocated the required resources and personal from which the data was retrieved.

Grontmij Group is an international design and consultancy company for the civil and AEC industry. Its headquarters is based in The Bilt, Netherlands. It operates in the markets of water, energy, transportation and sustainable planning and design. It nearly has 300 offices across northwest Europe and 50 office over the rest of the world and employs nearly 9,000 professionals(Grontmij 1, 2012). Grontmij NL is the Dutch venture of Grontmij Group and has its headquarters in The Bilt as well. Their goal is to be a leading European design, engineer and management firm for the build and natural environment. The company has a hierarchical post-bureaucratic divisional structure. As of yet it still consists of three business units (Grontmij 2, 2012) with multiple subdivisions (see Figure 1), although a the Planning and Design business unit is currently being split in two business units, one concerning the AEC industry and one concerning the urban area management.

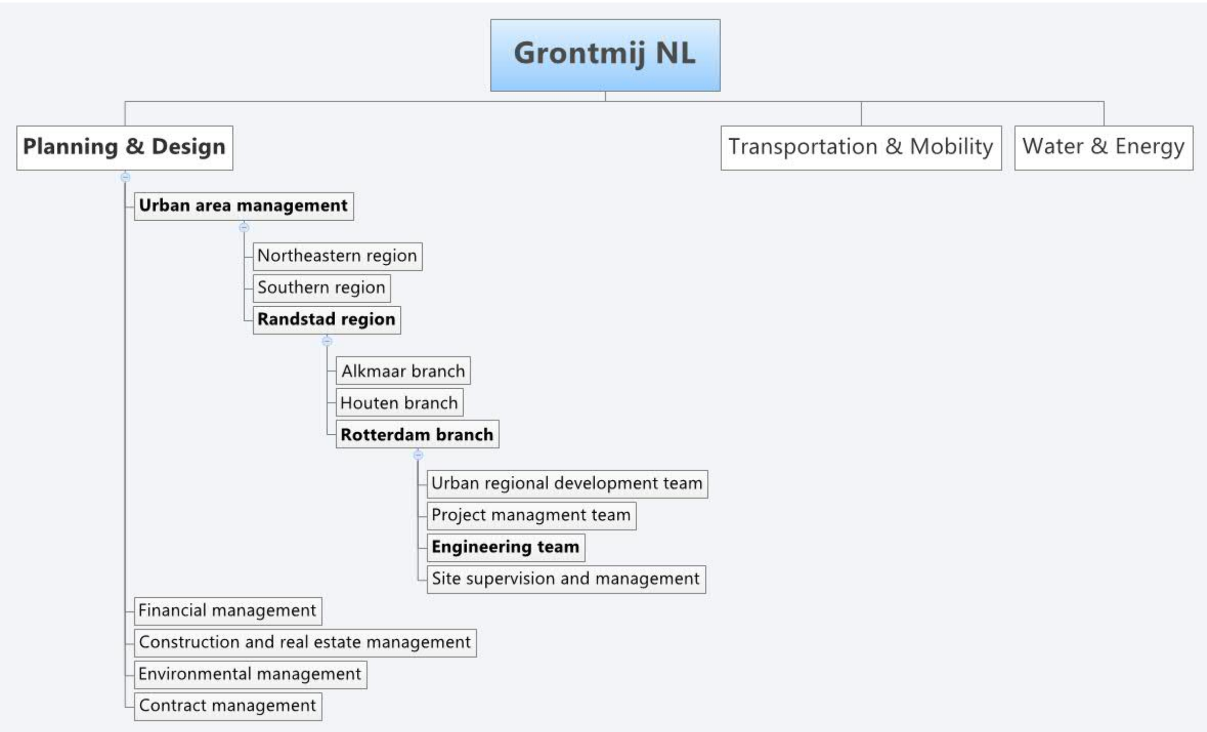

Figure 1: Business structure host company Grontmij

The main part of the study was executed at the engineering team of the Rotterdam branch and the survey sample consisted of the Randstad region personal (urban regional development teams excluded) and the construction and real estate management personal.

Appendix B. Literature Study and Analysis

B.1 Literature study into the impacts of BIM

B.1.1 Introduction

Section A of the research model showed the use of key project actors and basic BIM concepts to determine the expected impacts of BIM. The review provided the following Table 1 of impacts.

BIM Impacts found in literature	Source
Schedule benefits	(Barlish & Sullivan, 2012), (Eastman et al. (2011)), (McGraw Hill Construction, 2009), (Birx, 2005), (Becerik-Gerber & Rice, 2010)
Better sequencing coordination	(Barlish & Sullivan, 2012), (Eastman et al. (2011))
Improved productivity	(Barlish & Sullivan, 2012), (McGraw Hill Construction, 2009), (Birx, 2005)
Earlier collaboration of multiple design disciplines	(Eastman et al. (2011))
Improved Communication	(Barlish & Sullivan, 2012), (Eastman et al. (2011)), (McGraw Hill Construction, 2009)
Improved quality	(Barlish & Sullivan, 2012), (Eastman et al. (2011)), (McGraw Hill Construction, 2009), (Birx, 2005)
Value engineering during design phase	(Eastman et al. (2011))
Improved project cost calculation	(Eastman et al. (2011))
Improved Staff moral	(Birx, 2005)
Opens up new markets to new Clients	(McGraw Hill Construction, 2009), (Birx, 2005)
Educational for young architects	(Birx, 2005), (Peterson et al. (2009))

Table 1: Perceived BIM impacts based on recent AEC literature

Grontmij had made a concept implementation plan for BIM for civil projects before the start of this research (Van Oosterhout, 2012). Among the contents of the report is a list of goals for BIM for infrastructure. A translation of the goals that are listed in the report is shown below.

- Time savings along the entire design process,
- Rapid detection of design errors and no surprises in later stages of the project,
- Unambiguous and transparent communication,
- Reduction in the number and size of design errors, and therefore a reduction of failure costs,
- Better and faster visualizations,

- Consistency in products,
- Better and faster cost estimates,
- Motivation of the employees,
- Savings on construction costs,
- Savings on maintenance costs,
- Responding to market demands,
- Profiling of Grontmij.

The list of company goals and the list of perceived impacts of BIM from recent AEC literature show clear similarities. The company goals are based on their current knowledge of BIM impacts, and the knowledge of the AEC industry is far more advanced than the civil industry which would explain the similarities. These two lists were used to determine the impacts that would be investigated. A selection of impacts is made based on scope criteria and commonality between impacts.

B.1.2 Short list of expected impacts of BIM

The lists mention time savings, faster processes, and schedule benefits. Impacts like better sequencing coordination, improved productivity, early collaboration, and faster detection of errors, also assume an increase in process efficiency and with that a reduction of project time. These impacts all result in a similar effect, and it will make the study more feasible when investigated under “Impact on project duration”. Next, both lists mention an improvement of communication. The impact on communication might also result in less project duration, but it will affect other aspects of the project as well, like the amount of stakeholders one can reach. Therefore these impacts are investigated under “Impact on communication”. Following, the AEC list shows an impact on quality, and the company list shows a reduction of design errors and consistency in products. These are investigated under “Impact on design deliverables” together with the possibility of value engineering. Subsequently, both lists mention an impact on cost estimations which are investigated in this research under “Impact on cost estimations”. Also, an impact of employee motivation and moral is mentioned in both list and is investigated under “Impact on motivation”.

Not all impacts can be used due to scope criteria. The scope of this research is focused on direct impact in the design and engineering phases of civil projects, as stated in chapter 1 of this report. Impacts on construction and maintenance costs are therefore excluded from this research. Also, impacts on the profile and market opportunities of the company will not be assessed as they are only indirectly influenced by BIM itself. The educational impact of BIM for young architects or engineers is also excluded, but not based on scope criteria. A BIM requires designers to understand more about the different facets of their design. The higher understanding would teach young architects or engineers more about the limitations and possibilities of a design. However, in the current stage of implementation it is expected that the novelty of BIM in the work process will overshadow any educational impact. This selection leaves five impacts under investigation for the measurement tool to be developed. These impacts are as follows:

- Impact on Project Duration,
- Impact on Communication,
- Impact on Design Deliverables,
- Impact on Cost Estimation,
- Impact on Motivation.

In the next section of the research model, section B, the impacts are investigated using performance measurement theory and BIM implementation theory. The theories were analysed via a literature study.

The main method used in the literature research was the snowball method, where new sources where identified from reference lists of initial sources. As a starting basis, the literature from the research proposal was used in which impacts of BIM where identified. The snowball method can bias a particular "view" or "school", so additional sources where identified via hub.sciverse.com and Google Scholar, using different keywords based on the initial literature. The use Google Scholar might be questionable as it does not solemnly provide peer reviewed articles, but is believed to be useful as it theoretically encompasses all digital material available. A review by Falagas, Pitsouni, Malietzis & Pappas (2008) identified the only real weakness to be inadequate citation information. Nevertheless, sources found via Google Scholar where carefully scrutinized to determine their scientific value, based on the following criteria: the name of the author(s), the availability of reference, the value of those references, an explanation of the research methods and the medium by which they were published. The search for new sources was stopped when the available sources provided sufficient support for a certain tool or theory to be used in view of the goals of this research. A limitation of such an approach instead of a more systematically approach is that there might be other tools and theories available which could also be useful to this research. The limitation was minimized by focusing on well established tools and theories, which also further increased the usefulness and validity of the tools and theories proposed.

In the next chapter the selected impacts are analysed. The analysis follows a clear schematic. First the theoretical foundation for the impact is described. Next methods of measurement for the impact, found in the literature are elaborated on. Finally the application for this research is presented.

B.1.3 Impact on Project Duration

B.1.3.1 Theoretical foundation

An impact of the use of BIM on the project duration has been mentioned in many sources. A literature study of 21 sources (Barlish & Sullivan, 2012) shows that schedule impacts are the top mentioned impact of BIM implementation. In another literature study of 13 sources, the beneficial impact of BIM on project duration is the only impact that is identified in all sources(Qian, 2012). The before mentioned literature studies do not provide any suggestion to the main cause of the reduction mentioned in the sources. Surveys among AEC industry professionals also frequently mention the reduction of project duration. A survey among 424 respondents working in the AEC industry (Becerik-

Gerber & Rice, 2010), which asked about the impacts of BIM, showed that 58% of the responds mentioned a decrease in project duration between 0% and 50%. This means, despite the large range, that more than half of the respondents experienced a project duration reduction when working with BIM. Again no causes of the reduction are mentioned in the survey. An analysis of the authors does show that schematic and conceptual design phases take slightly longer with the use of BIM, but the detailed design phase duration is reduced. An explanation for this phenomenon is not presented by the authors, but it suggests that the reduction is caused by an increase in activities in the earlier phases. An earlier survey (McGraw Hill Construction, 2009) among 2,228 AEC professionals supports the findings and analysis of the before mentioned survey. The respondents of this survey were more likely to say that BIM increased project time in the schematic and conceptual design phases, and 42% of the respondents experienced a decrease in time of the detailed design phase. The majority of the respondents (63%) experienced a reduction of total project duration at the end, but again no cause is mentioned. However the survey report also presents a case study of two towers where were schedule optimizations where believed to be achieved by reduction of rework, early coordination and 4D simulations.

The causes mentioned in the case study support the suggestion made earlier, and reveals one of the main causes for project duration reduction with the use of BIM, namely the integration and early coordination of work processes. This integration and early coordination is also a main cause for time reduction effect in work methodologies like: concurrent engineering, early supplier involvement and collaborative engineering. Another case study which supports this idea is presented in Eastman et al (2011). Via the use of BIM to support early collaboration, constructability analysis and prefabrication, the design of the project was improved which in term caused an improved field productivity, reduced field effort, and significant reductions in the overall construction schedule.

The surveys show that in practice, the time reduction benefits of integration manifest themselves more strongly as the project progresses, and require additional efforts in the early phases. In the current market of civil engineering projects it is still uncommon to use a BIM in the schematic and conceptual design phases, which would mean that the additional efforts will have to be made in the detailed design phase. The scope of this research is focused on the core business of Grontmij, which is in the detailed design and engineering phases of a project. This means that benefits which manifest in later stages would not direct impact Grontmij. However, even in the design and engineering phases multiple disciplines are working together to create the final design. An internal integration and early coordination of work process, supported by BIM could therefore still result in a reduction of project duration.

Another cause for project duration reduction with the use of BIM, presented in the case studies, is optimization of work processes themselves. For example: construction schedule can be optimized with the use of 4D simulations ((Becerik-Gerber & Rice, 2010)(Eastman, Teicholz, Sacks, & Liston, 2011), (McGraw Hill Construction, 2009)), quantity take-off can be automated which reduces the laborious task of manually extraction of these quantities from 2D drawings ((Eastman, Teicholz, Sacks, & Liston, 2011)(Hartmann, Van Meerveld, Vossebeld, & Adriaanse, 2012)) and automated clash detection reduces the time searching for clashes between different disciplines(Eastman, Teicholz, Sacks, & Liston, 2011).

B.1.3.2 Measurement tool input

From the literature study it becomes apparent that measurements of the impacts of BIM are mostly based on personal experiences. Data is retrieved from individual sources via qualitative interviews, surveys among industry professionals or the personal experience of the author himself. These methods allow the researcher to identify if an impact of BIM on project duration can be assumed without having to go into detailed project and process specifics. The validity of the results then comes from the fact that the individual reports all give similar conclusions. The approach however is prone to a form of bias or subjectivities, because the result depends heavily on the type and formulation of questions, the recollection of events by the subjects and the sampling of subjects. Also, the method does not present empirical data on the extent to which BIM impacts project duration. Gilligan & Kunz (2007) suggest that the perception of great value by BIM users in qualitative methods, in the face of a general lack of quantitative data, is a by-product of the complex nature of the construction process (Gilligan & Kunz, 2007, p. 13). However, the lack of empirical data, and the subjectivity of personal experience results in a form of uncertainty, which causes dilemmas for users on the decision to utilize BIM or not (Barlish & Sullivan, 2012).

It is interesting that there have been few attempts to consistently measure the impact of BIM on project duration in order to present empirical and clear data. Quantifiable results might not be exactly replicable on every project, but this should not discourage researchers or companies to make those attempts. Brix (2005) presents in his article the impact of BIM on the amount of man-hours for projects in his architectural firm, but his data is no more than an example of his experience and therefore of little scientific value. Giel, Issa & Olbina (2010) analyzed the return of investment of BIM in two comparative case studies of two sets of projects, and used “BIM preventable time overrun” in their calculations. However, the scope of the research was not to identify the impact of BIM on the project durations, and so a careful evaluation of the causes for the time overrun within the projects is not included. Azhar, Hein & Sketo(2008) use a case study where the participants estimated the schedule impacts based on the amount of conflicts resolved during 3D coordination meetings. Unfortunately, no framework on which the estimations where based is mentioned. Barlish & Sullivan (2012) also discover a lack of consistency in empirical data concerning BIM impacts, and developed a framework to measure the most quantifiable impacts. Among these was the impact of BIM on schedule change. The authors used to framework on multiple similar case studies, some implementing BIM and some executed via the traditional method. As measurement method the authors used the actual vs. the standard duration of the projects. They report the values in percentage change, in order to promote a valid comparison with further research. Gilligan and Kunz (2007) provide a case study where a similar approach was used to assess the reduction in project duration. Although this method does result in empirical data some points of attention should be noted.

The first difficulty with the method is that projects are never identical; standard project duration is thus non-existed. Nevertheless design, engineering and construction projects are heavily depended on the expected duration, as the duration is a factor in the estimated costs and the proposed payment schedule. Currently, the expected duration of projects are based on estimates, which in term are based on the accumulated knowledge of different disciplines and the company. When a proposal is received, and the decision is made to tender for the proposal, a project leader is assigned. The project leader will collect the estimates of the work to be done from different discipline within the company and forms the final estimation and offer (lavèn & Costermans, 2012). The resulting estimate is interpreted as the best prediction of the actual project duration, and could therefore be seen as the standard project duration for that particular project when executed by the estimating company. With this interpretation the method of Barlish & Sullivan(2012) should be changed to actual duration vs. estimated duration, where the estimated duration is the project duration based on company and project team experience without the use influence of BIM. This also complies with the method used in Gilligan & Kunz (2007) case study. However, the terminology or interpretation does not change the fact that estimation is not perfect, and can still be flawed.

A second difficulty is that there are more factors that impact the actual project duration besides the implementation of BIM. Gilligan & Kunz (2007) state “There are simply too many variables to be able to attribute success on a single project to one specific part of that project”(Gilligan & Kunz, 2007, p. 13). Factors could include social and environmental changes, but also strategic decisions or financial decisions. The impact of these factors are difficult to quantify, and therefore difficult to account for in the analysis.

Both of these difficulties can be mitigated however within a statistical analysis when sufficient empirical data is collected. Trough valid assumptions and careful evaluation, the likelihood of an impact of BIM on the individual project duration can be increased until there is enough data for a statistical determination.

B.1.3.3 Application in this study

In the previous paragraph I analysed approaches on how to measure the impact of BIM on project duration. From this analyses I proposed to compare the estimated project duration made by the company with the actual project duration. This comparison would result in a graph which would show the variations of actual project duration around the estimation. This comparison would than be executed for both BIM and non-BIM projects and the two resulting graphs would be analysed on difference to see how BIM impacts the variations of project duration vs the estimation.

The data for the non-BIM projects is available and therefore the baseline graph could easily be made. However, in order to create the BIM graph, also sufficient BIM projects should have been executed. If a rule of thumb for the central limit theorem is taken, this would mean a minimum of thirty BIM projects. It is impossible at the current stage of implementation of BIM at Grontmij Stedelijk Gebied, Randstad, to retrieve information about thirty completed BIM projects. This means that it is not possible to create a meaningful BIM graph and therefore it is not possible to achieve meaningful results with this approach in this research. It leads me to conclude that this approach will not be used further in this study.

B.1.4 Impact on Communication

B.1.4.1 Theoretical foundation

The impact of BIM on communication is another frequently mentioned impact. A survey among 70 AEC professionals working with BIM in Singapore showed that 60% experienced improved communication, and 46% experienced enhanced ability to refer back to data in projects(Qian, 2012). In the same survey, 58% experienced a better information management at company level. The use of BIM would improve communication in all phases of the project ((Eastman, Teicholz, Sacks, & Liston, 2011)(Barlish & Sullivan, 2012)) as it allows information to be easily shared (Azhar, Hein, & Sketo, 2008). It can improve communication during project meetings as it allows for more dynamic views (Wu & Hsieh, 2012). Sacks et al. (2010) and Eastman et al. (2011) state that effectively communicating design intent to professionals and non professionals is one of BIM's key functionalities, and Kymmell (2008) mentions that in theory a BIM could include all the needed information, and makes 2D drawings obsolete.

To understand how BIM can impact communication, first the concept of communication has to be more clearly defined. The Oxford dictionary defines communication as "The imparting or exchanging of information by speaking, writing, or using some other medium". It is a simplistic and clear description, but it does not reveal that there is a whole field of study related to communication theory. Over the years three main communication models have been developed: starting with the linear model by Shannon & Weaver in 1994, the interactive model, and the transactional model of Barlund in 2008. The Linear model represents the basic imparting of information from a sender to a receiver, for example a news paper. Both the interactive as transactional model are based on the linear model. The interactive model represents the indirect exchange of information, and adds a feedback phase where the receiver also becomes sender and sends his feedback on the initial message back to the sender, for example within a chat room. The transactional model represents direct interaction where a sender is receiving direct feedback from his message, for example in a face-to-face conversation. All models add the concept of noise which can be defined as anything that confuses, diminishes or interferes with communication(Boddy, 2008).

All of these models of communication can be found during a construction project, and follow a similar basic pattern(see Figure 2): First a sender has a message, which he then encodes using symbols, words or expressions. Next, he transmits the coded message via a medium. The receiver decodes the message from the medium, and the message is "communicated" from sender to receiver. When this process is related to the communication of a design than the following example can be given. The designer (sender) has a 3D design idea (message) in his mind he then encodes the massage using a set of lines, rectangles, triangles and circles. Next he transmits the coded message via a 2D drawing (medium). The receiver (client or constructor) than decodes this message to a 3D design in his mind or on the job site. Understanding than comes from how well the receiver is able to decode the message he receives via the medium, and interpret it. The reason why the designer encodes his message via lines rectangles etc. is because he assumes that the receiver (client or constructor) is able to decode the message, and interpret it as his 3D design idea. Understanding between sender and receiver in construction projects is critical, for example between designer and client in relation to project requirements (Kymmell, 2008).

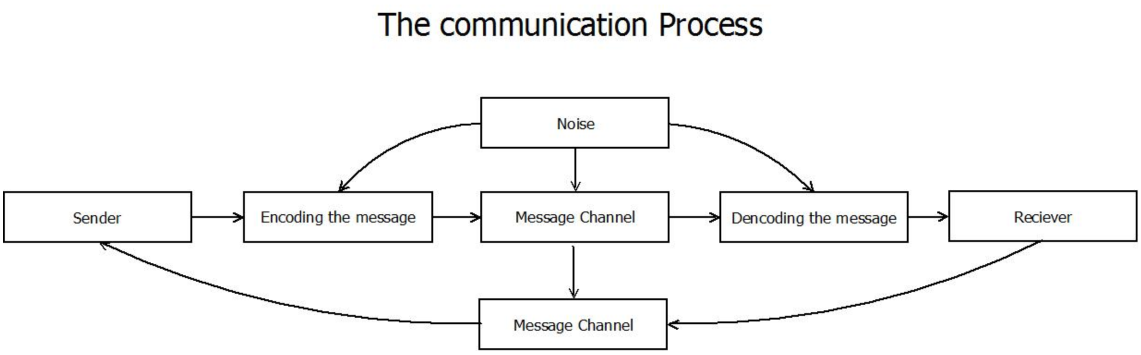

Figure 2: Basic schematic of a communication process

The assumption made by the designer is one of the reasons for communication failure, as the sender and receiver have different knowledge, experience, and interests and so they might encode and decode information different or interpret messages different (Boddy, 2008). Encoding and decoding is done in someone’s mind, so it is not always known that communication failed. The result is that errors are noticed to late in the process to be resolved, for example during realization (Kymmell, 2008). Kymmell (2008) states that “The largest problem in the planning and construction of building projects is the incorrect visualization of the project information (“the devil is in the details”)” (Kymmell, 2008, p. 11). The minimization of such a communication failure is the main reason why construction projects use 2D drawings, as visualization is proven to be clearly better for comprehension and conceptualization tasks than text (Nosek & Roth, 1990) and at the root of communication for coordination and collaboration (Kymmell, 2008). Furthermore, Dennis & Valacich (1999) state that successful communication requires the receiver to understand the message the sender intended to send. A 2D drawing leaves less room for interpretation than text, but it still requires the receivers to be able to translate and interpret the information from 2D drawing to a 3D design or even a 4D process when time is added. This is the first area where BIM could have an impact.

The most mentioned impact of BIM on communication is that it allows for a better understanding of the design trough 3D or 4D visualization ((McGraw Hill Construction, 2009)(Eastman, Teicholz, Sacks, & Liston, 2011)(Kymmell, 2008)(Wu & Hsieh, 2012), (Gao & Fischer, 2008)). Because actors no longer have to translate and interpret 2D drawings into a 3D design, but can view the design in a 3D state, it leaves less room for interpretation errors. Also, the change of communication failure due to a faulty encoding or decoding becomes less as the 3D model represents the reality better(Eastman, Teicholz, Sacks, & Liston, 2011). A 3D model is able to represent far more information and details than can be contained in the visualization in the mind of individuals(Kymmell, 2008). In the same line of thought is

BIM able to improve communication by adding time to the visualization. A 4D simulation of a process has the same affect of 3D visualization of a project. According to Kymmell are "BIM simulations by far the most effective way to communicate ideas, forms, concepts, and general approaches in design and construction-related issues."(Kymmell, 2008, p. 49). To summarise, the first impact of BIM on communication is that it improves (+) the medium by which a message is send, which would allow for a better (+) interpretation by the receiver, which would reduce (-) communication failure and therefore improves communication.

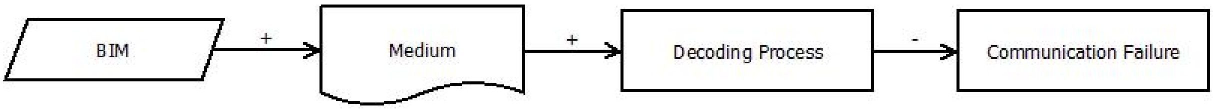

Figure 3: First perceived impact of BIM on communication

BIM can also impact communication as 3D models are understood better by people who cannot read 2D drawings ((Kymmell, 2008), (Eastman et al. (2011)), (Gao & Fischer, 2008)). Non professionals, for example citizens, currently require other media like telephone or face-to-face presentations to explain the 2D drawings and Gantt charts. With the use of BIM, project teams no longer have to make different drawings or presentations to inform non professional stakeholders, but can show their model to professional and non professional stakeholders. The actual term for "receivers" in this case should be "stakeholders" as the real value is in reaching more stakeholders than quantitatively reaching more individuals. The reason for this second impact is based on a similar argumentation as presented in the previous section. BIM improves (+) the medium into a format which is better understood by receivers with no construction industry knowledge, which would allow those receivers to interpret a message better (+) than before, which would improve communication by reaching more (+) receivers with the same medium.

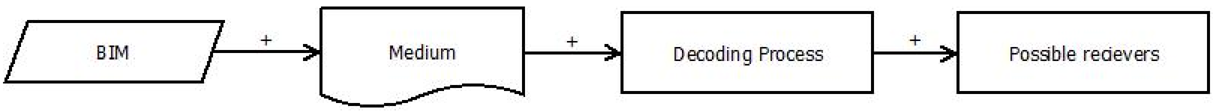

Figure 4: Second perceived impact of BIM on communication

Another important impact of BIM on communication is best explained by citing Kymmell(2008). He states "Important aspects of communication are the free access to and flow of information. The BIM is characterized by the availability and connectedness of all information that has become part of the project, such as its dimensionality and any other type of information. In a centralized model all information can be connected to the model and accessed with embedded links. Information should exist only once, rather than be duplicated unnecessarily for convenience of individual access. There is a significant risk in the duplication of information for convenience sake, because it creates difficulty for the user to discern whether that specific information is in fact the latest available."(Kymmell, 2008, p. 49). He states that by embedding information into the model, actors can obtain the needed information better, and the actuality of the information is better assured. As this knowledge is important for the interpretation of a message, the decoding process will improve. In other words, BIM improves (+) the availability and actuality of information, which would improve the knowledge of the receiver, which would improve (+) the interpretation process, which would reduce (-) communication failure and therefore improve communication.

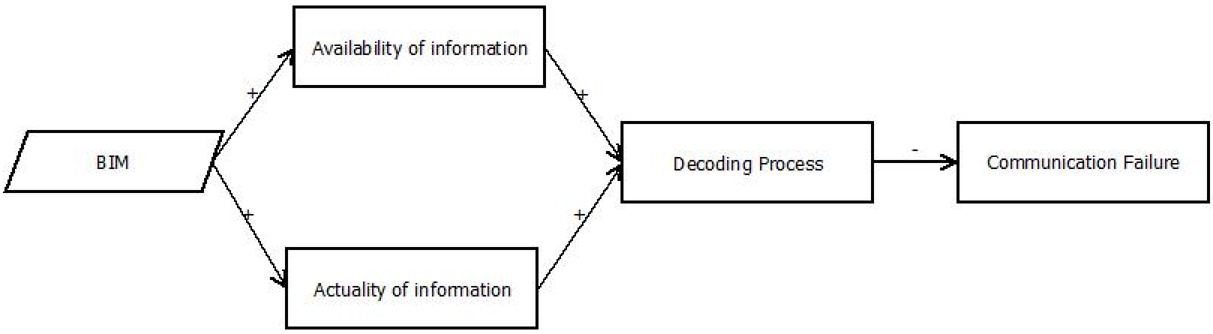

Figure 5: Third perceived impact of BIM on communication

B.1.4.2 Measurement tool input

To summarize the previous paragraph, BIM is perceived to impact communication in three ways. First understanding of the message is increased by improving the medium by which the message is send. Second, more receivers can be reached with the same medium which increases the effectiveness of the medium. Third, the medium allows for improved availability and actuality of information that is transmitted to a receiver. The first perceived impact uses the following reasoning: BIM improves the information richness of the medium, a richer medium improves understanding of the message, improved understanding of the message leads to less communication failure between sender and receiver, less communication failure between sender and receiver means improved communication.

Measuring the first assumption would mean measuring if BIM media indeed have higher information richness than current media. Boddy (2008) defines information richness as “The amount of information that a communication channel can carry and the extent to which it enables sender and receiver to achieve common understanding”(Boddy, 2008, p. 531). It refers to the Media Richness Theory proposed by Lengel & Daft (1988). A literature study performed by Yu (1997) shows that media richness, i.e. information richness, is rarely explicitly measured. There are authors who do measure information richness by ranking the different media on a scale where face-to-face conversation has the highest media richness ((Lengel & Daft, 1984)(Adams, 1996)), but Dennis & Valacich (1999) claim that no medium can be labelled as “richest” on Lengel & Daft’s terms. According to the authors different media posses different capabilities which can be more or less important in any given situation, and so face-to-face communication cannot be labelled as “richest” medium. Measuring or determining information richness on a scale is therefore not feasible, and could also be view as off little value due to the validity of the assumption that 3D and 4D visualization carry more information due to the extra sets of dimensional information in comparison with 2D drawings or Gantt-charts.

The second assumption, that a richer medium improves the understanding of a message, is supported by the before mentioned Media Richness Theory of Lengel & Daft (1988) and the research of Nosak & Itzhak(1990). The Media Richness Theory uses the idea of information richness of a medium to compare the capacity of channels to promote understanding between senders and receivers. The authors suggest that knowledge of the media richness will aid in the selection of the proper medium, which will increase understanding and with that increase communication effectiveness (Lengel & Daft, 1988). The impact on understanding is a valid assumption, but it is difficult to make the term understanding tangible. The operational definition of understanding is that “somebody who reacts appropriately to x understands x”, and is supported by Kymmell(2008) who states that the degree of success in communication is determined by the action taken by the receiver. However, this view is contradicted by John Searl (1980) in his thought experiment known as “the Chinese room”. In the though experiment Searl shows the difficulty of placing “appropriate reaction” as the sole measurement of understanding, by imagining a computer who appropriately reacts in a Chinese conversation. The question Searl asks is “does the computer really understand Chinese?” These two views show the difficulty of measuring understanding and why it is not feasible for this study.

The third and final assumption, an improved understanding leads to less communication failure, should be more feasible to measure. Communication failure commonly leads to some form of extra work, and is therefore usually documented. For example, if a misinterpretation leads to errors or questions during the construction phase it is reported as a Request For Information (RFI). As the name suggest is a RFI a request for extra information to clarify misinterpretations. Measuring a decrease in the amount of RFI could therefore be the result of less communication failure, and consequently an improvement of communication (Kymmell, 2008). However the scope of this research is primarily focused on the core business of engineering firms which is in the design and engineering phases of a project. RFI’s are not used in these phases, and are therefore excluded from this research as a valid metric. Nevertheless, a formal request for information is also part of a more traditional approach.

In traditional public projects, where the design and engineering phases are separate from the construction phase, Dutch law presents the contractor with the opportunity to ask queries about unclear aspects of the project, before the tender is closed. The engineer than answers these questions in a note of information, which is send to all interested parties. Internal informal questioning in the host company reveals that the queries usually concern aspects in the products of the design and engineering phases. If the assumption is correct that BIM media improves understanding and leaves less room for interpretations, than it should reduce the amount of questions that are asked by contractors. However, the initial products of BIM produced for tendering will still be 2D drawings and work instructions. Until a 3D BIM model is accepted as final product by clients and presented in public tenders, will the impact on the amount of questions in the note of information assumed to be minimal, and therefore excluded as metric in this research.

As both of these clear metrics of communication failure are excluded from this research, other possibilities have been investigate. The most logical option is to question project members about their perception about communication failure. This option will present results about the level of communication failure in projects and could therefore be used to identify if a BIM project would have less communication failure as non-BIM projects. However, the results would be based on the feelings and opinions of the project members, which could result in a subjective bias towards a preferred or “conventional wisdom” instead of providing objective proof. Another option can be augmented based on the previous sections. In a previous section the argument was made that an increase of knowledge would improve the interpretation process of a receiver and therefore lead to less communication failure. The knowledge of the sender would be based on accumulated sources information, which he himself received trough communication. If the sender and the receiver have received similar information, either through the same or different channels, but interpreted it differently based on their own experience and knowledge, than a assessment of the correctness of information by the receiver could point to a failure of interpretation by the original sender of source information. As BIM improves the medium by which information is send, and improves the availability and actuality of information, the knowledge of the sender would increase as well, which would improve the correctness of information, based on the assessment of the receiver.

To summarize, measuring if BIM media has a higher information richness is not feasible due to the inability to present information richness on a scale. Next measuring if BIM improves understanding is also not feasible as the concept of understanding is difficult to define and measure. Finally, both of the more clear metrics of communication failure, RFI’s and note of information, are exclude for this research based on reasoning. The most logical method to present a meaningful measurement of the first impact is by questioning project members about their perception on the amount of communication failure. This research also makes the claim that correctness of information can be used as measurement of the communication failure and would also be improved by the use of BIM.

The second perceived impact of BIM on communication is that the medium created by BIM is able to reach more receivers than traditional media, meaning 3D and 4D models can be understood by more receivers than 2D drawings and Gantt charts. The impact of BIM media on the amount of receivers hasn’t been measured in current literature, while it does present a clear metric. The importance of communication with non-professionals differs per project. Stakeholder mapping techniques, like the power-interest grid of Eden & Ackermann, could aid in identifying the stakeholders and their importance to the project. When the analysis shows that non-professionals are involved and of importance, the use of BIM could aid in the communication to those stakeholders. Trough experience, professionals will then be able to determine how many extra stakeholders can be reached with the use of BIM.

The third and final perceived impact of BIM on communication is that it allows for improved availability and actuality of information that is transmitted to a receiver. The use of a central database where relevant information concerning the project is stored, and linking that information to the relevant objects within a model, represents the I in BIM. Access to the model is only limited by hardware, software and preferences of the client, and can be by both internal as external actors. The goal of BIM for the host company in its current stage of implementation is focused on improvement for internal actors. Therefore this research will focus on the impact of BIM on the internal communication. Communication within an organization is called intraorganizational communication. Barker and Du Plessis (2002) in Antonis(2005) define intraorganizational communication as “the internal, work-related messages that are shared amongst members of an organization, whether intrapersonal, interpersonal or in small groups.” The importance of effective internal communication is stressed by Tourish and Hargie (2004) as a vital pre-requisite for the functioning of all organizations. However, when measuring the effectiveness of internal communication, managers tend to relay on their instinct rather than actual measurements(Ellis, Barker, Potter, & Pridgeon, 1993). In order to resolve this issue, communication audits have been developed.

The goal of a communication audit is to provide the means of assessing the state of communication in an organization against a set of criteria, and its potential has been recognized by business and research communities (Ellis, Barker, Potter, & Pridgeon, 1993). One of the mostly used and validated audit is the International Communication Association (ICA) Audit by Goldhaber & Rogers in 1979 ((Tourish & Hargie, 2004)(Maki, Shimotsu, & Avtgis, 2009)(Antonis, 2005)). The ICA audit was designed as limitations of prior measurement tools, for example single instrument and spans of time, diminished generalizability and predictability(Maki, Shimotsu, & Avtgis, 2009). The audit uses five different measurement tools to obtain information about the current and desired state of intraorganizational communication. These are: a Critical Incident Analysis (CIA), a Network Analysis (NA), a Communication Diary (CD), Interviews and a Survey (Antonis, 2005). However, the full audit will be too time consuming for this research and so choices concerning which part of the audit is executed are made.

The purpose of the audit in this research would be to determine the current availability, actuality and correctness of information within a project. This current state can than form a baseline to which future states can be measured ((Tourish & Hargie, 2004)(Ellis, Barker, Potter, & Pridgeon, 1993)). Even though the predictability of the ICA audit has been questioned this type of diagnostic power is confirmed (Maki, Shimotsu, & Avtgis, 2009). The following information is extracted from Antonis (2005). The CIA is a tool to identify communication problems, measure the communication climate, and personal skills by asking respondents to describe an effective and ineffective communication experience. Yet, in comparing a BIM state with a Non-BIM state are these incidents less interesting, and therefore the CIA will not be used in this research. The NA is used to map the interconnections between members within an organization. This does not concern the information or medium by which it is send, and as a result the NA is also excluded in this research. With the CD participants are asked to keep a record of all there communications. Among the measured aspects could be: the number of interactions, the duration of interactions, and the initiator. It would not be difficult to add aspects like: availability and actuality to the measurement, but it will put enormous strain on the participant to keep such a detailed record for all of their communications over a period of time. This makes the CD tool less feasible for this research. The interview is one of the most basic and central tools in internal communication audits. It allows for a more personal approach, and an in-depth view of the current practice and issues of communication. Another benefit of using interviews is that it allows for an improved elaboration of the findings in other tools of the audit. Nevertheless, interviews are timely and only represent the views of the persons that participated. A survey however, is less time consuming and can easily reach every effected person which increases reliability. Another benefit of using a survey over interviews is that it can easily be duplicated in other contexts, which is especially useful for the goal of comparing a BIM state and a Non-BIM state. When the ICA audit questionnaires are examined it shows that topics usually include: accessibility to information, adequacy of information, relevance of communication, communication satisfaction and importance, communication content, communication relationships and communication outcomes. These topics fit the purpose of this study well, and provide sufficient support for the choice of an ICA audit questionnaire in this research. Although the basis of the ICA audit questionnaire can be used it should still be tailored to the company under analysis (Tourish & Hargie, 2004).

To summarize this paragraph, BIM is perceived to impact communication in three ways. First understanding of the message is increased by improving the medium by which the message is send. This can only be measured by asking project members about their perception about communication failures and the correctness of information. Second, more receivers can be reached with the same medium which increases the effectiveness of the medium. This impact can be measured by analyzing the stakeholders of a project, and then determine trough experience how many extra stakeholders BIM can reach. Third, the medium allows for: improved availability and actuality of information that is transmitted to a receiver. By measuring the perception of employees on these aspects in non-BIM projects via an adapted ICA audit questionnaire, and using the same questionnaire to measure same aspects in BIM projects, it is believed to be possible to measure if BIM impacts the availability, actuality and correctness of information in projects and changes the amount of communication failure.

B.1.4.3 Application in this study

In the previous paragraph I analysed the possible methods to measure the impact of BIM on communication. From this analysis I propose to use a version of the ICA audit questionnaire to measure the perception of project members on miscommunication, and measure the state of availability, actuality, and correctness of information in non-BIM and BIM projects. By comparing the data sets of BIM and non-BIM respondents, meaningful results and conclusions about the impact of BIM on communication could be presented.

Also in the previous paragraph the stakeholder analysis was mentioned as a tool to determine the amount of stakeholders associated with a project in order to compare the amount of stakeholders which can be reached with the design products in non-BIM and BIM projects. This analysis will not be done in this research, as the current stage of BIM implementation at Grontmij Stedelijk Gebied Randstad results in too few BIM projects to provide a valid comparison.

B.1.5 Impact on design deliverables

B.1.5.1 Theoretical Foundation

The idea of an impact of BIM on the design is undisputed, but has been difficult to actually measure. For example, a mentioned impact of BIM on design is that designers and engineers are able to visualize their design earlier and more accurate (Eastman, Teicholz, Sacks, & Liston, 2011). As the designers and engineers produce 3D models, and no longer 2D views of their design, the ability to understand what is being represented is improved(Kymmell, 2008). This improved understanding allows other disciplines, owners, and the designers themselves, to spot errors earlier in the process, and increase the quality of the design product. The impact of BIM on understanding might be difficult to measure, especially because project actors are used to working with 2D, and so might not be aware of any improved understanding when working with BIM.

Another impact of BIM on the design is the ability of the software to automatically make low-level corrections when changes are made, due to the information embedded in the model ((Eastman, Teicholz, Sacks, & Liston, 2011)(USACE, 2006)). Changes made, in for example levels or road designs, will automatically adjust the entire model based on that new information. This reduces the effort of designers to ensure that changes are consistently managed within the design. Checking and updating all of the other views is an error prone process, and one of the major causes of poor design products (Azhar, Hein, & Sketo, 2008). By reducing the effort and need for such process, the quality of the design product should increase. This reduction of effort might however also be difficult to measure.

In paragraph B.1.3, it was found that integration and early coordination of work processes via BIM is one of the main causes for a reduction in project duration. The integration and early coordination of work processes via BIM also causes an impact on the design. Trough early coordination and the use of BIM software, different disciplines are able to identify spatial or design conflicts between each other more easily ((Eastman, Teicholz, Sacks, & Liston, 2011), (Gao & Fischer, 2008)(Kymmell, 2008)). Besides the reduction in conflicts, does the early coordination also allows the disciplines to make better decisions earlier in the project, which reduce the need for changes later on in the process (Gao & Fischer, 2008). Both the reduction of conflicts and the reduction of needed changes improve the quality of the design product. Although the amount of clashes can be measured it difficult to determine how many clashes would have been detected without BIM and the reduction of needed changes is even more intangible.

Two more impacts of BIM on design have been experienced in practice. The first is that the use of BIM makes early and easy analyses of the design possible, and with it increased value engineering. The model has more information richness than traditional documents and information can be more selectively accessed. It allows advisors to use the information in the model as it is designed, and make analyses, like safety analysis, environmental analysis, sewer requirements analysis, water management analysis, traffic flow analysis or sustainability analysis before the design is in its final stages. Initial analyses can even be automated by the software. The increased information in earlier stages of the design allows designers and engineers to make more well-thought decisions which could increase the value of the design ((Eastman, Teicholz, Sacks, & Liston, 2011)(Azhar, Hein, & Sketo, 2008), (Gao & Fischer, 2008)).

The second impact of BIM on the design is actually a result from previous impacts, but a valid impact in the current stage of transition between 2D and 3D design deliverables. Because of the automated corrections and the 3D design instead of 2D views on a 3D design, will 2D drawings and details generated from a model be more accurate and more consistent than the original 2D drawings ((Eastman, Teicholz, Sacks, & Liston, 2011) (Hartmann & Fischer, 2008) (Becerik-Gerber & Rice, 2010)).

B.1.5.2 Measurement tool input

The design deliverables together with the work instructions are important products when it comes to legal liability. Work which is not or wrongly described in the deliverables or work instructions will result in RFI's (request for information), and change orders in the construction phase. RFI's and change orders usually lead to higher costs, and increased project duration. With the assumption that BIM increases the quality of design deliverables, and that an increase of quality reduces the amount of work which is not or wrongly described, deductive reasoning shows that BIM reduces the amount of work which is not or wrongly described. If the reasoning is continued, BIM should impact the amount of RFI's and Change orders, and then in term impact project cost and duration. These assumptions show the expected value of the use of BIM as it impacts the design quality of deliverables.

To support this reasoning and measure the amount of RFI's and change orders, researchers have used both qualitative and quantitative methods. Researchers have counted the amount of RFI's in BIM and non BIM projects ((Barlish & Sullivan, 2012), (Gao & Fischer, 2008) (Kymmell, 2008), (McGraw Hill Construction, 2009)), and the amount of change orders or their value as percentage of the total project value ((Barlish & Sullivan, 2012), (Gao & Fischer, 2008) (Kymmell, 2008) (Suermann, 2009)). Others have asked respondents to see if they experience any change in the amount or value of change orders and the amount of RFI's ((Qian, 2012)(Gilligan & Kunz, 2007), (McGraw Hill Construction, 2009)). However the manifestation of these impacts is only in the construction stage (Gao & Fischer, 2008), and as the scope of this research does not include that phase these measurements are not useful.

Another method of measuring the impact of BIM on design is by tracking the number of conflicts caught using BIM ((Gilligan & Kunz, 2007)(Azhar, Hein, & Sketo, 2008)). This method is used during the design phase, and would therefore be more feasible for this research. A limitation to this method is that it is unknown how much of these conflicts would have been resolved if BIM was not used so it lacks comparative strength. It could mean that actors in Non-BIM projects could detect a similar amount of conflicts but only via a more cumbersome process. The amount of conflicts will also increase just because the possible level of detail of designs reviewed via the computer is much higher than designs reviewed via paper. It raises the question how many of those conflicts are small enough to have been resolved on-site without a change order or RFI. If this amount becomes to great one could even ask if the time and effort of setting up a coordination meeting to analyze every clash is worth the returns of increased design quality.

To summarize, many of the impacts of BIM on design are difficult to measure. Researchers have developed methods to substantiate the claims made in qualitative studies with quantitative data but these methods are either not applicable in the research scope or lack comparative strength. An investigation into the quality assurance methodology Quality In Projects (QIP) used by the host company, shows that every design product is subjected to a quality test by coordinators. In this quality test the coordinators check the 2D drawings for clear design errors and layout errors. The coordinators also place an attention if there is an unusual solution or aspect on the drawing. The attention might be an error, but could also be a client decision or have another reason. As these drawings are the final product of the entire design process any improvements done in that design process which impact the quality of design deliverables should reflect in these drawings. Otherwise said, if BIM impacts the design than these coordinators would at least identify less design errors and less layout errors. The reduction in needed changes would reflect itself more in the project duration than in the quality of the design product.

The classification of notification types, e.g. design errors, layout errors and attentions, used for this research is broad but will improve the comparative strength of the data as every project could have these types of error notifications.

B.1.5.3 Application in this study

In the previous paragraph I analysed several approaches to measure the impact of BIM on design deliverables. From this analysis it showed that the methods described where either not applicable in this research or lacked comparative strength. For this reason I proposed an approach which was more suited to the company and utilized the current quality assurance methodology in the company. However after four months of data gathering with this approach it showed that in practice not every project follows this methodology yet. The result is that the gathered data is not from a representative sample of projects of Grontmij and can therefore not be used as baseline measurement.

Another aspect of this approach is to have a comparable set of BIM data. In the approach this data set is retrieved from 2D drawings produced from a BIM project. Unfortunately is it not possible in this stage of the BIM implementation at Grontmij Stedelijk Gebied Randstad to retrieve the representative set of 2D drawings. As both the baseline and BIM data sets will not be representative for project within Grontmij Stedelijk Gebied Randstad, I have to conclude that it is not possible to achieve meaningful results via this approach in this research and therefore this approach will not be used

B.1.6 Impact on cost estimations

B.1.6.1 Theoretical foundation

Integration of 3D design and cost estimation process is another frequently mentioned impact of BIM. A survey shows that 41% of the frequent users of BIM (four or more projects) experience added value with the use of BIM for cost estimation (McGraw Hill Construction, 2009). With the integration of design and costs, the existing electronic information embedded in the design is utilized more efficient which improves the cost estimation process (Staub-French & Fischer, 2001). Cost estimations made using BIM are found to be more accurate ((Azhar, Hein, & Sketo, 2008)(Gilligan & Kunz, 2007), (Gao & Fischer, 2008) (Eastman, Teicholz, Sacks, & Liston, 2011) (Shen & Issa, 2010)) and done much quicker ((Azhar, Hein, & Sketo, 2008), (Gao & Fischer, 2008)(Staub-French & Fischer, 2001)) than with traditional methods. BIM is able to automate the estimation process to an extend in which estimators no longer have execute time consuming tasks like quantity counting, but can focus more on the core tasks like calculation of cost affects due to change (Peterson, Fischer, & Tutti, 2009). Besides these effects, BIM also allows for estimates to be more accurate earlier in the process, and can therefore be used in the design process as a tool to evaluate design decisions based on costs ((Eastman, Teicholz, Sacks, & Liston, 2011)(Staub-French & Fischer, 2001)).

The cost estimation is a specific process and product within construction projects, and can have far reaching consequences. An increase in estimation accuracy lowers the risk for overpaying or getting underpaid and helps in making better supported design decisions. Research is mostly focused on this aspect of the BIM impact. The estimation process in general consists of four steps(Staub-French & Fischer, 2001). First, 2D drawings and specifications are analyzed to determine the scope of work, and identify critical design properties that affect the cost. Second, cost assemblies are made corresponding to the to-be-estimated components. For example, the component “pavement” could have an assembly with materials, labour and equipment costs per square meter. Third, the quantity of the different components is calculated and estimated using the drawings and specifications. This is known as the quantity takeoff. The total project cost can then be estimated with the quantity takeoff and cost assemblies, and profit, overhead, risk etc. added. This process is similar to the estimation process of Grontmij, and shows the two major components of a cost estimation namely: the quantity takeoff, and the cost assemblies. In most traditional projects, the goal of the estimation made by Grontmij is to be a reference against estimations made by contractors. Contractors are able to make different cost assemblies based on their internal planning or agreements with sub-contractors and suppliers. The quantity takeoff directly represents the work to be made in such projects, and is therefore less affected by the contractor’s choices. So the major impact of BIM on the estimation process of Grontmij would be the automation of the quantity takeoff.

The survey mentioned earlier also found that 51% of the frequent users of BIM (four or more projects) see added value with the use of BIM for quantity takeoff, and that civil engineers are most likely to experience benefits of using BIM for the quantity takeoff (McGraw Hill Construction, 2009). Computer generated quantities are more precise and less prone to human error(Staub-French & Fischer, 2001). Another benefit is that the quantity takeoffs can be used in validation and verification processes more easily. Quantities are directly extracted from the model, and therefore represent all the elements described in the model which can be used as validation of design intent(Staub-French & Fischer, 2001)(Gilligan & Kunz, 2007).

B.1.6.2 Measurement tool input

From the theoretical foundation it is expected that BIM will impact the estimation process time and the estimation accuracy, with the quantity takeoff accuracy in particular. Measurement of the impact on estimation process time has been reported in several articles. These articles report a reduction of time up to 80% in comparison with the traditional process ((Azhar, Hein, & Sketo, 2008)(Staub-French & Fischer, 2001)). For this research, the impact on time will be explored together with other impacts on project duration. Also, case studies indicate a correlation between the project complexity, and the impact of BIM on the estimation process time ((Van Meerveld, Hartmann, Adriaanse, & Vermeij, 2009)(Shen & Issa, 2010)). As project complexity differs per project the impact on the estimation process time would differ, but this effect is expected to be less for accuracy measurements. The possibility to explore different design alternatives is also limited according to Staub-French & Fischer (2001) as only a change in quantities or cost assemblies can be measured.

Measurement of the impact of BIM on the accuracy of cost estimation has also been done in different articles. The measurement is usually done in relation to the actual project cost. Reports show an accuracy of the estimation between 3% and 0,6% of the actual costs(Gilligan & Kunz, 2007)(Azhar, Hein, & Sketo, 2008). Gao & Fischer (2008) propose to measure the accuracy of cost estimation by measuring the variation between cost items and the final cost within a 95% confidence interval. Shen & Issa (2010) also propose to measure the deviation from the correct value, but determine the percentage of the cost items that fall into a similar category, divided into 5% intervals. However, cost variations between the estimation and the real value can also be cause by events that could not have been predicted at the time of the estimation process. It is one of the reasons why contingency costs are added to a final estimation. It can be argued that it is more important to know how accurate the cost estimation represents the final design than how accurate it represents the final costs, especially for a consultancy engineering firm like Grontmij. The accuracy of such an estimation would highly depend on how well the quantity takeoff represents the final design. Staub-French & Fischer (2001) do mention that in their case study they did find “several quantity takeoff errors in comparison with the traditionally generated estimate” (Staub-French & Fischer, 2001, pp. 52-53). Other examples of measuring the accuracy of quantity takeoffs are not known.

Another benefit of acquiring accurate computer based quantities is that the takeoff becomes more transparent and easier reproduced. Reproducibility of the takeoff is both a goal of Grontmij as it will be valuable in conversations with other actors as they can reproduce the figures themselves.

B.1.6.3 Application in this study

The previous paragraph analyses the approaches to measure the impact of BIM on cost estimation. It proposes that the most appropriate way to measured this impact in a consulting engineering firm is by analysing if the quantity takeoff from a BIM model represents the final design better than through traditional methods. This analysis should be done trough a approach similar to Staub-French & Fischer (2001), which means comparing the quantity takeoff made from a BIM to the quantity takeoff made trough traditional methods.

A major limitation to this approach is that it will remain unknown what the “true” quantity takeoff from a design is. Both BIM and traditional methods of quantity takeoff require human work, and are therefore both susceptible to human error. A BIM takeoff is only as good as the model from which it’s made, which is made by humans, and a traditional method is only as good as the person doing the quantity takeoff. When a direct compression between a BIM takeoff and a Traditional takeoff is made, like Staub-French & Fischer (2001) did, it already assumes that the BIM takeoff is closer to the “true” takeoff than the traditional method. It will be difficult to make this assumption scientifically valid in this research.

As it is difficult to make this important assumption scientifically valid in this research, I have to conclude that this approach will not result in meaningful results at this stage and will therefore not be used in this study.

B.1.7 Impact on Motivation

B.1.7.1 Theoretical Foundation

There has been no actual research on the impact of BIM on employee motivation or employee morale. However there are indications that those impacts exists. For example Miller(2012) states, in his article about the implementation of BIM in his company, that the BIM tools reduced the repetitiveness and boringness of production of information, which improved team morale and motivation. Brix (2005) and a BIM-software vendor(Autodesk, 2010) also mention the impact of BIM on staff morale, although the latter only refers to the possibility of increasing future staff morale by analyzing aspects like lighting and ventilation during design. These sources are not peer-reviewed and therefore unreliable for scientific research, but they do present initial observations from practice.

Only indirect evidence can be found in peer-reviewed articles. For example, Formoso, Santos & Powell(2002) identified benefits of increased process transparency in construction work, among which an improved employee motivation. Sacks, Radosavljevic & Barak (2010) propose a lean production management system based on BIM which should reduce waste, and increase process transparency trough visualization. If BIM is able to make the construction process more transparent, and a more transparent process in construction leads to improved employee motivation, than it could be deducted that BIM improves employee motivation. A similar reasoning can be extracted from Keuhmeier (2008). The author states that as changes and discrepancies occur on the drawings, they are corrected trough a bureaucratic process which takes time and reduce the productivity on site. The loss in time and reduced production can than decrease the morale among the employees. Although there is no clear correlation between morale and motivation, one can argue that in this case motivation to the work would also decrease. In other words, the author indicates that there is a negative correlation between the amount of changes and discrepancies in drawings, and the morale of employees. If that is true than BIM would be able to improve moral as it is able to reduce changes and discrepancies in drawings as explained in chapter 4, and with that also improve motivation. Also Björk-Löf & Kajodionovic (2012) promote the use of BIM in the company of Skanska to improve motivation of employees. Unfortunately, both the findings of Formoso et al.(2002) and Keuhmeier (2008) are based on observations made on site during the construction phase and the employees mentioned are site workers. Also the proposition of Björk-Löf & Kajodionovic(2012) concerns the motivation of site workers. The question still remains if an increased process transparency or a decrease of changes and discrepancies would also improve the motivation of office employees, and if the same correlation effect is found during the design phase. Finally, Ellis, Barker, Potter & Pridgeon(1993) state that effective communication is recognized as a motivator of the workforce, so if BIM is able to improve the effectiveness of communication BIM is able to improve motivation. The impact of BIM on communication was more thoroughly examined in chapter 3.

The examples above show that there are indications for a connection between the use of BIM and employee motivation. To substantiate this indication and measure the possible impact, I will first take a closer look into motivational theories. Boddy(2008) presents a clear summary for this, and the following is extracted from his work.

There are several basic and well known theories on motivation, like Maslow's hierarchy of needs also known as “The Pyramid of Maslow”, Alderfers ERG Theory and McClellands Achievement Motivation Theory. These theories are focused on individuals, and the needs which drive them to act in a certain way. BIM will not fulfil these needs but it will change the work process so there is no need to go into detail about these theories. Nevertheless, these theories, especially Maslow, are at the basis of the work of Herzberg (1959), who was one of the first to relate motivation to the nature of the work. From interviews he developed his two-factor theory, which identified two types of factors that influenced work satisfaction. He proposes that job dissatisfaction is not the opposite of job satisfaction but two separate dimensions influenced by different factors, namely Hygiene or maintenance factors to reduce job dissatisfaction, and Motivator factors to increase job satisfaction. According to the theory, factor like salary and company policies do not contribute to job satisfaction but increase job dissatisfaction when absent or insufficient, and factors like the work itself and responsibilities do not contribute to job dissatisfaction when absent or insufficient but increase job satisfaction.

The two factors of Herzberg theory (1959), Hygiene and motivator factors, actually uncover the difference between extrinsic (Hygiene) and intrinsic (Motivator) rewards. Although both are valued by people, Herzberg believed that motivation heavily depends on whether a job is intrinsically challenging and provides opportunities. This believe of Herzberg is supported by Porter & Lawler (1986) as they report “The best performing managers do not report receiving much greater rewards in pay or security but they do report significantly more rewards in areas concerned with opportunities to express autonomy and to obtain self realization in the job.”(Porter & Lawler, 1986, pp. 121-122). Furthermore, if Ashcraft(2011) is correct in his statement that “Work satisfaction is perhaps the most significant motivating factor” (Ashcraft, 2011, p. 24), than intrinsic rewards, which increase work satisfaction, will in term increase the motivation of employees.

To summarize this paragraph: BIM should be able to increase the motivational potential of the work by increasing or enhancing intrinsic rewards trough new work processes or by increasing process transparency, and BIM should be able to increase employee satisfaction (McGraw Hill Construction, 2009). Both employee satisfaction and higher motivational potential of the work are motivational factors for employees, so it could be argued that BIM will impact the motivation of employees.

B.1.7.2 Measurement tool Input

In the previous paragraph it is argued that BIM will impact the motivation of employees. The arguments are mainly based on the work of Herzberg who investigated the influence of the nature of work on employee satisfaction and dissatisfaction. Herzberg linked his motivational ideas with job designs, and especially the motivational potential of job enrichment(Boddy, 2008). Nevertheless is motivation on a basic level an individual concept, and only expressed as a perceived outcome of more tangible factors, like certain needs in Maslow's or Aldefers work or the job aspects by Herzberg. It should therefore be mentioned that motivation itself will not be measured in this research, but the impact of BIM on factors that could influence motivation. As BIM changes the work process, the main focus for this research will be if a "BIM Job" has more motivation potential than a "Non-BIM Job".

To measure the motivational potential of a job design, Hackman & Oldham developed the Job Diagnostic Survey (JDS)(Hackman & Oldham, 1974) based on their own Job Characteristics Model (JCM)(Hackman & Oldham, 1976). The JDS is a tested and validated instrument that has been used by both research and business communities for many years ((Boddy, 2008)(Faturochman, 1997)(Van Saane, Sluiter, Verbeek, & Frings-Dresen, 2003)). With the JDS the motivating potential score (MPS) of a job can be calculated, and is usually used to guide the job enrichment process (Boddy, 2008). The MPS can also be used to compare different job and determine if a job has a relative high or low MPS in comparison with the other job(Hackman & Oldham, 1974). This aspect of the JDS suites the need of this research to determine if a "BIM Job" has more motivation potential than a "Non-BIM Job". Before the JDS can be used, a more detailed investigation into the JCM should be made.

The JCM attempts to describes the relationship between job characteristics, and individual response to work ((Hackman & Oldham, 1976)(Faturochman, 1997)). The model assumes the existence of three psychological states which need to be experienced in a job by individuals in order for desirable outcomes like: high internal motivation, high quality of work performance, high satisfaction with the work and low absenteeism and turnover, to emerge. The first state, experience meaningfulness of the work, is defined as the degree to which the individual experiences the job as one which is generally meaningful, valuable, and worthwhile (Hackman & Oldham, 1976, p. 256). The second state, experience responsibility for the outcomes of the work, is defined as the degree to which the individual feels personally accountable and responsible for the result of the work the individual does (Hackman & Oldham, 1976, p. 256). The last state, knowledge of the actual results of work activities, is defined as the degree to which the individual knows and understands on a continuous basis how effectively the individual is performing his job (Hackman & Oldham, 1976, p. 257). All these states point to the interstice rewards that a job could give which should increase satisfaction, and so if any of these states are not present, the desirable outcomes will be weakened(Faturochman, 1997).

These three psychological states can be measured by five distinct job characteristics. The choice of these characteristics have been subjected to debate as other researchers have opted frameworks for three, four and six characteristics instead of the original five, but a larger sample of studies tend to support the five factor framework proposed by the JCM (Faturochman, 1997). The first state can be measured by skill variety, task identity and task significance. Especially skill variety and task significance appear to have a strong relationship with the first state of experienced meaningfulness(Faturochman, 1997). The second state is measured by the job characteristic of autonomy, which is defined as the degree to which the job provides substantial freedom, independence, and discretion to the individual in scheduling the work and in determining the procedures to be used in carrying it out (Hackman & Oldham, 1976, p. 258). The last state is measured by the characteristic of feedback, and research has shown a strong correlation between the state and characteristic(Faturochman, 1997). By measuring these characteristics via the JDS, the MPS of a job can be calculated, and with that the possibility within a job to achieve the desirable outcomes.

As mentioned before is motivation an individual concept, and Hackman & Oldham (1976) also recognized that not every individual will automatically respond positive to a job with high motivational potential. Even though the relationship between characteristics and psychological outcomes like motivation is support by most studies, research disputes the effect of MPS on objective outcomes like absenteeism and productivity(Faturochman, 1997). In order to complete the model, Hackman and Oldham(1976) added three moderator personal moderators which impact the effect of MPS on desirable outcomes. These moderators are: Knowledge & Skill to perform the work, Work context such as salary and job security, and most importantly the individual growth-need strength. The last moderator is defined as the need of an individual for personal growth and development, and the basic prediction is that people with high growth-need strength are likely to respond more positively to jobs with high MPS.

These moderators will not be measured in this study as the main focus will be if a “BIM Job” has more motivation potential than a “Non-BIM Job”, and not if individuals are personally motivated or not. It does give insight to possible reasons why actors are not motivated to start using BIM, especially the moderator of Knowledge & skill to perform the work. It also shows the value of education of staff for the use of BIM and could be helpful in the choice of the first BIM pioneers within a company.

To summarize this paragraph, Job characteristics are able to influence psychological states which in term influence desirable outcomes like high motivation. Measuring the job characteristics via the JDS results in a MPS of a job design which can be compared to the MPS of other jobs. Via this process it is possible to measure if a “BIM Job” has more motivation potential than a “Non-BIM Job”, and with that if BIM could impact employee motivation.

B.1.7.3 Application in this study

In the previous chapter I analysed the origin of the possible impact of BIM on the motivational potential of jobs. I also introduced the JDS of Hackman and Oldham (1974) as a validated and accepted tool to measure the motivational potential of jobs. In this study I will use a version of this tool to measure the MPS of jobs in normal projects and the MPS of jobs in BIM projects. By comparing the MPS and underlying concepts I believe it is possible to create meaningful results and conclusions on the impact of BIM on motivation potential of jobs.

B.2 Validation and Reliability

B.2.1 Validation

An important part in developing the framework is to assure that the measured data is reliable and provides valid results. The framework itself cannot technically “have” validity, only the propositions, inference or conclusions made from data retrieved by the framework can have validity. Therefore, when the validity of the framework is mentioned, it actually refers to the validity of the propositions, inference or conclusions made the framework. There are three types of validity, which can be divided in several subtypes. These three types are: internal validity, construct validity, and external validity (Trochim & Donnelly, 2006).

With internal validity the question is posed if the framework measures the relations that our found in the literature. In other words, does a theoretical relation also exist in the measured data. These relations can either be cause-and-effect relations or general relations. Internal validity of a framework can be shown by using a correlation or regression analysis which shows whether a relation exists in the data. However, there are some sociological threats in this study that can weaken the claim of internal validity, like the Hawthorne effect, and the novelty effect (Boddy, 2008). Complete mitigation of these effects to strengthen the validity is difficult, but strategies like triangulation or double-blind experiment can improve the argument of internal validity.

Where internal validity focuses on theoretical relationship between concepts, construct validity focuses on validating the concepts themselves. In other words, it investigates how well the framework measures what is supposed to measure. There are two sides to the construct validity.

On one side refers to a valid translation from the theoretical realm to the contents of the framework and is tested by face and content validity. Face validity is the weakest way of demonstrating construct validity (Trochim & Donnelly, 2006). It tests the validity by looking if the framework layout and questions seem valid to measure the concepts. This can be done by the researcher, but a stronger argument can be made when the framework is evaluated by experts. Content validity refers to the level to which the framework represents all of the intended theoretical content of a concept. For example, when the concept miscommunication is measured one could intend to measure both interpersonal and intrapersonal miscommunication. If only interpersonal miscommunication is measured the framework will not represent all of the intended content, and therefore will not provide valid results for the intended concept. The more insubstantial a concept becomes the more difficult it is to demonstrate content validity. Again, expert judgment can help in this respect.

The other side tests the individual items of a framework based on certain criteria found in the theory. Predictive, concurrent, convergent and discriminate validation are the subtypes of this side. When a framework provides evidence of a theoretical prediction it demonstrates predictive validity. The concurrent validity subtype refers to the ability of the framework to make a distinction between groups which it should theoretically be able to make a distinction between. Convergent validity examines the degree to which question items which converge to a similar concept are related to each other. The larger the relationship, the more valid the results. Discriminate validity examines the opposite, by looking at the degree to which question items which measure non similar concepts are related. Besides similar sociological effects that threat the internal validity, are some threats that strictly affect the construct validity. Clear examples are the mono-operation bias, where only the framework is only tested in one sample in one point in time, or the mono-method bias, where only one method is used to measure a concept. Most of these threats, however, like the two examples are difficult to mitigate this study due to the small time frame.

Finally there is external validity, which refers to the extent to which the results of the study apply to situation beyond the study itself. This validity is important as without this type, the impact of the study is limited.

The following table provides the overview the different validation types and the methods which can demonstrate the validity type.

Validity Type	Sub Type	Method of demonstration
Internal Validity	Conclusion validity	Correlation analysis
	Casual validity	Regression analysis
Construct validity	Face validity	Expert judgment
	Content validity	Expert judgment
	Predictive validity	Correlation analysis
	Concurrent validity	Comparative analysis
	Convergent validity	Correlation analysis
	Discriminate validity	Correlation analysis
External validity		For example: Sample selection

Table 2: Validity types and methods of demonstration

For the expert judgment and comparative methods of demonstration, the level of validity is dichotomous (valid or invalid). In correlation analysis, however, the level of validity is based on the resulting test coefficient. Generally, values of ≤0.35 are considered low or weak relationships, 0.36 to 0.67 are considered moderate relationships and 0.68 to 1 are considered high or strong relationships (Taylor, 1990). Taylor (1990) explicitly states that blindly focussing on these cut-off points is not advisable. When for example several relationships to a single construct are tested high, but one is 0.5

it is rather conservative to claim a moderate validity. Therefore, these values will be used as guidelines, but the interpretation of the values will be leading in determining the level of validity.

B.2.2 Reliability

Where validity is concerned on how well the conclusions or propositions from a framework represent the theory and intended goal is reliability explained as how well the framework is able to measure "true" scores. The problem with this explanation is that "true" scores are never known and so only and estimation of the real reliability can be made. Therefore reliability is also rephrased as the consistency of a framework to measure certain concepts. There are four types of reliability estimates which are: inter-rater reliability, test-retest reliability, parallel forms reliability, and internal consistency reliability (Trochim & Donnelly, 2006).

Inter-rater or inter-observer reliability refers to the reliability of measurement between multiple raters or observers, and is tested using a correlation analysis between the raters. Test-retest reliability refers to the reliability between two similar tests taken at different points in time, and is tested using a correlation analysis as well but between the different data sets. A similar method is used to test the parallel forms reliability, which concerns the reliability between two test which measure a similar concept at the same point in time but with different questions. Finally, internal consistency reliability is used to test when a single framework is used in a single moment in time. It tests whether items which measure a similar concept within a single framework, provide consistent data across the different items. The most common method used in determining the internal consistency is by using Cronbach's α. The following table provides the overview the different reliability types and the methods to test the reliability.

Reliability Type	Method of demonstration
Inter-rater or inter-observer reliability	Correlation analysis
Test-retest reliability	Correlation analysis
Parallel forms reliability	Correlation analysis
Internal consistency reliability	Cronbach's α

Table 3: Types of reliability and their methods of demonstration

The study consisted of one test, measured at one moment in time and so the most suitable method to tests the reliability is Cronbach's α. Cronbach's is determined by examining how much variance is shared between items and relating that tot the total average covariance within the scale (Field, Discovering statistics using SPSS, 3th Ed., 2009) and can have a value between 0 and 1 like a correlation coefficient.

There have been some discussion to the extent to which size of Cronbach's α constitutes to a "reliable" framework. Generally an alpha of 0.7 is considered for internal reliability claims. However, Lance, Butts & Michels (2006) wrote a critical article which reviews the discussion and mention that an alpha of 0.7 could be used for developing frameworks, but that a much higher reliability score is needed when the results are used for very important decisions. Furthermore, Cortina (1993) claims no single cut-off point should be used, as Cronbach's α is depended on the amount of items used and the correlations between the items. He showed for example that the lower the number of items, the lower Cronbach's α becomes, and that the low item effect only subsides from 19 items or higher. As a result the more liberal point of view of George & Mallory (2003) is used in this study. The authors provide the following rules of thumb:

- α>.9 = Excellent reliability
- α>.8 = Good reliability
- α>.7 = Acceptable reliability
- α>.6 = Questionable reliability
- α>.5 = Poor reliability
- α<.5 = Unacceptable reliability (George & Mallery, 2003, p. 231)

Another interesting point of attention is the item-total correlation, which assesses the correlation between a single item and the entire scale without the item. Ferketich (1991) recommended in her article that these should be between 0.3 and 0.7 as higher item-total correlations could indicate that the single item measures most of the entire scale, and leaves the rest of the items redundant.

Similar to with the validation assessment, should these values be used as guidelines instead of clear cut off points. For example, an item-total correlation can be higher than 0.7 when Cronbach's alpha is higher. A final point of evaluation is the alpha score when a certain question is removed from the scale. If Cronbach's becomes higher by removing a question, than that suggests that the question is unreliable and should be removed or adjusted.

B.3 Literature study into the statistical assumption tests

The validation tests and reliability tests of the framework require several statistical analysis methods; namely, correlation analysis, comparative analysis and multiple regression analysis. These analysis methods have several different test statistics, and the decision to which method best suits the hypotheses tests, depends on certain assumptions and conditions. The assumptions are important as they will reduce the statistical error of the results of the methods, and with that increase the value of the analysis and conclusions. These conditions and assumptions are:

- Condition of independence
- Assumption of normality
- Assumption of equal variances
- Condition of sample size ratio

The first condition is one of the most basic conditions of probability theory. If the condition is met, one assumes that the events, or answers from a sample population are retrieved independently from one another. Independence indicates that there is no connection between the occurrence of the one event and that of the other. In this study the data is generated via individual self-administered questionnaires, and it is assumed that respondents did not have an impact on the answers of others. Therefore, this condition is met and will not be mentioned further.

B.3.1 Assumption of Normality

The first assumption concerns the distribution of the sample population. This assumption is most important in hypothesis testing as the significance value and its probability in parametric test are based on the underlying distribution. There are several ways in which the normality assumption can be tested. The most easy form is the graphical form, which means using histograms and Q-Q plots to visually inspect the data and determine the normality of it ((Field, Discovering statistics using SPSS, 3th Ed., 2009),(Howell, 2010)). Histograms are a type of bar-chart, but it displays continue data instead of the categorical data in a bar-chart. It displays the frequency of a certain value in the data. If the data is normally distributed, the histogram should have a similar bell shaped pattern. A further explanation will be given in chapter 6 based on the actual histograms. Q-Q plots is a graphical method which compare two distributions, by plotting their quantiles against each other. Quantiles are data points taken at a regular interval. A example of a quantile is the median, which is the middle value of the data. This plot can be used to examine the normality of the data by comparing the sample distribution to expected values from a normal distribution. The Q-Q plot and its interpretation will also be further explained in chapter 6 based on the actual Q-Q plots. Although this method is very useful and insightful it is also fully depended on the ability of the researcher to correctly identify whether a distribution is normal or not. The possible personal bias towards claiming normality in order to be able to use parametric statistics is therefore present. To overcome this bias a second approach can be used to confirm the findings.

Another simple approach is mentioned by Field (2009). He proposes to calculate the Z-scores of skewness and kurtosis. Skewness and kurtosis both describe the shape of a distribution, where skewness represents a tendency in the data to one side of the mean, and kurtosis represents the "peakedness" of a distribution. A normal distribution is not skewed and has no kurtosis. The Z-score is a score from a normal distribution with a mean of 0 and a standard deviation of 1. It can be calculated by subtracting the mean of the distribution (which is 0 for this case) from the found value, and then divide that value by the standard deviation (see Equation 1). The calculated score can be used to test the hypothesis whether the data set is significantly skewed /kurtosis or not. It is done by comparing the calculated score to significance scores from the z-distributions which are 1.96 for a two-tailed significance value of $p=0.05$ and 2.58 for a two-tailed significance value of $p=0.01$. When the calculated score is higher than the significance score, the null hypothesis that the data is *not* significantly skewed/kurtosis should be rejected and therefore it indicates that the data is *not* normally distributed. However, as Field (2009) mentions that this method can give some better insight into the normality of data, he also warns that the approach become less useful for large data sets.

There are also different statistical tests, like the Komogorov-Smirnov test and the Shapiro-Wilk test, which look at the extent to which a distribution deviates from a comparable normal distribution. However, also these tests can lead to wrong conclusions, and Howell (2010) even discourages the use of the tests. To conclude, there is no "best" method to determine normality of the data set, and the advice in determining the normality assumption from both Howell (2010) as Field (2009), is that one should use both the graphical and a second method to assess the normality.

$$Z_{skewness} = \frac{Skewness - 0}{SE_{skewness}} \quad Z_{kurtosis} = \frac{kurtosis - 0}{SE_{kurtosis}}$$

Equation 1: Z-score calculations of Skewness and Kurtosis

For this report I will use the method of Field (2009), calculating the significant skewness and kurtosis, besides the graphical approach to determine normality of the data. The significant value in the z-test will be p=0.05, which is common in scientific literature.

B.3.2 Assumption of Equal Variance

The second assumptions concerns, as the name suggest, that the variance in both samples are more or less equal to each other. The equality of variance in the sample is also called the homoscedasticity of a sample. This assumption is especially important when comparing two means. The variance of a sample can also be called the scale parameter of a distribution and determines what the distribution looks like. If the samples have different scale parameters, it is more difficult to determine whether they come from a similar single population or not. The most use method of assessing the equality of variances is the Levene's test ((Field, Discovering statistics using SPSS, 3th Ed., 2009),(Howell, 2010)). The Levene's test looks at the absolute difference between a observation and the group mean, and then uses those values in an ANOVA or T-test to compare two samples with the null hypothesis that the variances are equal. When the Levene statistic is significant, the null hypothesis should be rejected and so no homoscedasticity can be assumed. ((Field, Discovering statistics using SPSS, 3th Ed., 2009),(Howell, 2010)). The Levene's test is a parametric test however, and so assumes normality of the data. Recent research has shown that this test is not robust against skewed data and therefore not robust against a violation of the normality assumption (Nordstokke & Zumbo, 2010). In order to overcome this problem, a non-parametric version of the Levene's test has been developed (Nordstokke & Zumbo, 2010). This test uses the pooled rank scores of the observations and calculates the mean of those score. Than the difference between the mean and the rank score is used in an ANOVA or T-test to compare two samples. The use of pooled rank scores makes the test distribution free and therefore robust against the non-normality violation. For a extended explanation on the method see Nordstokke & Zumbo (2010). The simulation study by the authors confirmed that this method is robust and powerful enough when the normality assumption is violated.

To test the assumption of equal variances in this study, the Levenes test is used when the data is passed the normality assumption, but when it violates that assumption the non-parametric version of the Levene's test will be used. Similar like the normality assumption test, a significance level of p=o,05 will be.

B.3.3 Condition of sample size ration

The condition of sample size ratio is more a side condition which can limit the meaningfulness of statistical tests, as unequal sample size increase the impact of confounding variables. A confounding variable is a hidden or unidentified variable which correlates with the variables measured in both samples. As one sample is larger than the other, this variable could influence one sample more than the other and therefore produce erroneous results. This condition is also more important in comparing the groups than in the correlation studies.

B.3.4 Comparing Groups

The two methods which are mostly used when comparing the means of two or more samples are the Student-test or T-test, and the analysis of variance (ANOVA). The t-test is used compare the means of two groups and is limited to that number, where the ANOVA method is capable of comparing multiple means. The t-test however is capable of analysing depended measurement samples where the ANOVA cannot. All in all, one could say that the T-test method is a special form of the ANOVA method. Both methods are parametric methods and therefore require the data to conform with the above mentioned assumptions. Analysis from data sets which respect these assumptions are more powerful, meaning the method has less chance of failing to reject a false null hypothesis, when the alternative hypothesis is true.

Nevertheless, research has shown that both tests are highly robust against violation of the normality assumption, when the sample distributions have a similar shape ((Boneau, 1960),(Field, Discovering statistics using SPSS, 3th Ed., 2009),(Norman, 2010),(Howell, 2010)). When the sample distributions are skewed in opposite direction, non-parametric tests will provide more meaningful results. Research has also shown that both tests are robust against a violation of the equality of variance assumption, when the sample sizes are equal ((Boneau, 1960),(Field, Discovering statistics using SPSS, 3th Ed., 2009),(Norman, 2010),(Howell, 2010)). Different sample sizes are also no problem, when both assumptions are met ((Boneau, 1960),(Howell, 2010)), and even when both the normality and equality of variance assumption are violated, will the ANOVA method and T-test method provide meaningful results, as long as the distributions have a similar shape, and sample size is equal ((Boneau, 1960),(Howell, 2010)). However, when both the equal variance assumption is violated, and there are different sample sizes, an adaptation to the original tests by Welch should be used ((Boneau, 1960),(Howell, 2010)).

The previous section makes claims bases on research done on the robustness of the T-test and the ANOVA test, and the referenced articles and books are only a small portion of the scientific literature on this subject. It should also be mentioned that the robustness of these methods does not mean that the assumptions are invalid or should be neglected, as analysis based on data sets which do conform to the assumptions is still more powerful. An overview on the assumptions and the method of choice based on them is provided in Figure 6. Independently of which method is used, a significance value of $p=0.05$ or lower should be obtained before the null hypothesis will be rejected.

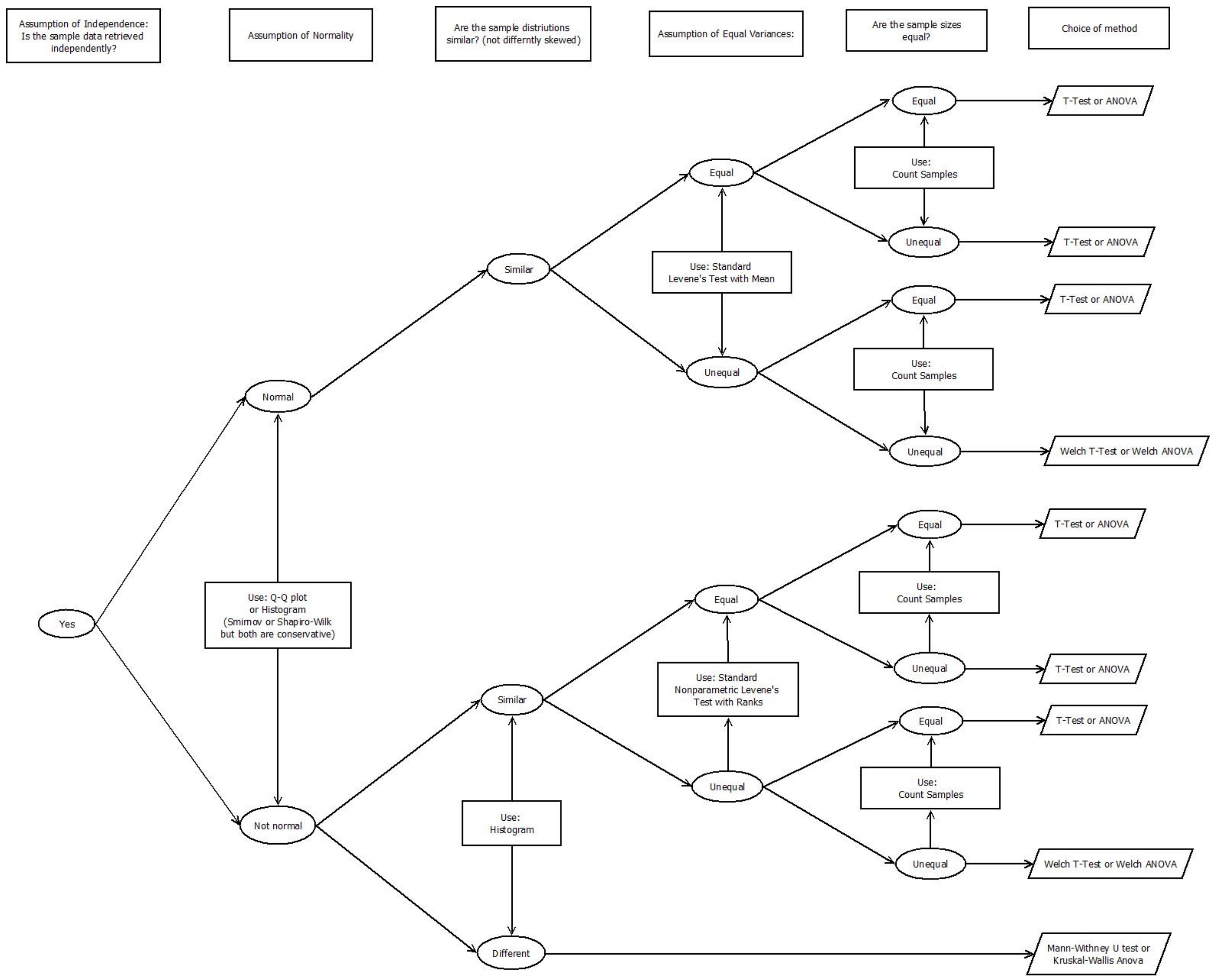

Figure 6: Decision tree concerning comparison tests

B.3.5 Correlation methods

This study will mostly examine the correlation between two variables, also known as a bivariate correlation. The most commonly used bivariate correlation method is the Pearson product-moment correlation coefficient or Pearson's *r*. Both Howell (2010) and Field (2009) mention that when using the Pearson coefficient to describe the data, or asses the degree to which variance in y is linearly attributable to variance in x, than no assumptions are needed. The only requirement is that the data is at least measured on a linear scale. A study by Havlicek and Peterson (1977) even state that the coefficient is insensitive to extreme violation of the normality assumption or the type of measurement scale. However, one can also estimate whether the found correlations is significant or due to chance. When testing the significance of the correlation, the assumption of normality becomes important, as the significance value is based on the normal distribution ((Field, Discovering statistics using SPSS, 3th Ed., 2009),(Howell, 2010)). If any of the two variables is non-normally distributed, than the non-parametric version of the Pearson coefficient should be used, known as Spearman's ρ.

Hypothesis M2 is actually a little different than the other relational hypothesis. Instead of only investigating the relationship between two variables, it assumes a relationship between four variables. The correlation between multiple variables can be investigated using a multiple regression method.

The only real restriction is that the depended variable should be a linear or ratio variable. There are in total nine different assumptions(Field, Discovering statistics using SPSS, 3th Ed., 2009) which a multiple regression should respect, but Osborne & Waters (2002) claim that there are only four assumptions are particularly vulnerable against violations. These assumptions are 1) the assumption of normality, 2) the assumption of equal variance, 3) the assumption of linear relationship between variables and 4) the independence of errors between observations. The first two have already been discussed, while the last two are new. Due note that for the predictors itself normality does not need to be assumed, and that normality only pertains to the significance tests. The assumption of linearity indicates the relationship between the two variables is linear in nature. This assumption can be tested by visually inspecting the standardized residuals plot(Osborne & Waters, 2002). Residuals are the difference between the predicted value of a model, and the observed value (Field, Discovering statistics using SPSS, 3th Ed., 2009). When the standardized residuals show a curved pattern around the predictive values, linearity cannot be assumed. The independence of errors also concerns these residuals. The residuals from different variables should not correlate as this could lead in a over-estimated correlation between variables. This assumption can be tested with the Durbin-Watson test, where a test statistic lower than 1 or higher than 3 would indicate a violation of the assumption. For violation of the first two assumptions there are clear solutions, like bootstrapping when normality assumption is violated (Field, Discovering statistics using SPSS, 3th Ed., 2009), weighted least square method when then assumption of equal variances is violated (NIST/SEMATECH, 2012). This is less so the case when the other two assumptions are violated, or when a combination of assumptions is violated. In that case the significance value of the multiple regression will be mentioned but with the notation of the failing assumptions.

B.3.6 Calculating effect size

Besides the use of p-values to determine whether a observed difference is significant or not, the effect size can be calculated. The effect size is an objective and standardized measure of the magnitude of the observed effect (Field, 2009, p. 56). It is becoming more common to report this size as well, and some professional journals are even insisting on it (Howell, 2010, p. 104). Pearson’s r is an example of such a measurement and can therefore be used to represent the effect size in correlation analysis. The r statistic can also be squared to identify which percentage of the variance of a variable is explained by the other variable. Spearman’s ρ shares these attributes (Field, Discovering statistics using SPSS, 3th Ed., 2009).

The answer to the question which method is most optimal when comparing to groups again depends on whether the data sets follow the two basic parametric assumptions above or not, the assumptions of normality and the assumption of equal variance. Especially the assumption of normality is important in this case. Meissel (2010) cites a research that claims that fewer than 10% of the researcher consider this assumption when reporting effect size measures. Nevertheless, parametric effect size statistics appear to provide inaccurate estimate when both or any of two assumptions are violated (Erceg-Hurn & Mirosevich, 2008). First the method of choice when de data sets follow the assumptions is explained. Next the non-parametric method of choice is elaborated on.

There are multiple measures of effect size and the most common are the Cohan's d and the Pearson's r, as mentioned above ((Howell, 2010)(Field, Discovering statistics using SPSS, 3th Ed., 2009) (Rosnow, Rosenthal, & Rubin, 2000)). Cohen's d is calculated by taking the difference between population means and dividing by the standard deviation of either population. In case of a sample, the population means are changed to the sample means and the standard deviation is changed to the pooled standard deviation of the samples. In general, when d=0.2 than the effect is considered small, when d=0.5 the effect is considered moderate and when d=>0.8 the effect is considered large ((McGarth & Meyer, 2006),(Howell, 2010)). The Pearson's r statistics measures to what extend the variation in one variable is accounted by the other variable. As a effect size calculation when r=0.1 the effect is considered small, when r=0.3 the effect is considered medium and when r= 0.5 the effect is considered large (Field, Discovering statistics using SPSS, 3th Ed., 2009). Neither of these statistics has appeared to be universally superior to the other ((McGarth & Meyer, 2006), (Rosnow, Rosenthal, & Rubin, 2000)), and so a careful decision has to be made. Howell (2010) prefers to use Cohen's d as he claims that Pearson's r is less informative. Field (2009) prefers to use Pearson's r as he claims that interpretation is more easy as the value is constrained to lie between 0 (no effect) and 1 (a perfect effect). Rosnow et al. (2000) mention that the statistics are identical in a two group setting, but that the r statistics is better suited when comparing multiple groups. The authors also claim that Cohen's d may be favoured when there are unequal sample sizes. A similar claim is made by McGarth & Meyer (2006), who also provide adapted benchmark scores for when the sample sizes are unequal.

In this study only two groups are compared, which indicates that all of the methods can be used. However, it appears that Cohen's d is more robust against unequal sample size, and with the adapted benchmark scores of McGarth & Meyer (2006). Cohen's d will be used in this study to report the effect size when the data followes the parametric assumptions. Rosnow et al. (2000) provide an equation wich can be used to calculate Cohen's d when using a t test and when there are unequal sample sizes.

As Cohen's d is vulnerable to violation of the parametric assumptions, non-parametric statistics should be used when a data set violates the assumptions. Again there are several non-parametric approaches which can be used to estimate the effect size, for example Cliff's delta and probability of superiority (PS). Altough Meissel (2010) provides a list of references which advocate the use of Cliff's delta, PS is more modern and also well advocated in the literature (Erceg-Hurn & Mirosevich, 2008). The PS is calculated using the well known Mann-Whitney U statistic and is robust against unequal sample sizes.The literature further provides a clear translation table between PS values and Cohen's d (see the table below), which improves comparability in this study(Erceg-Hurn & Mirosevich, 2008). Therefore PS will be used in this research when the data violates the parametric assumptions.

TABLE 5.1
Approximate Relationships Among Some Measures of Effect Size

Δ	r_{pop}	*PS*	U_3(%)
0	.000	.500	50.0
.1	.050	.528	54.0
.2	.100	.556	57.9
.3	.148	.584	61.8
.4	.196	.611	65.5
.5	.243	.638	69.1
.6	.287	.664	72.6
.7	.330	.690	75.8
.8	.371	.714	78.8
.9	.410	.738	81.6
1.0	.447	.760	84.1
1.5	.600	.856	93.3
2.0	.707	.921	97.7
2.5	.781	.962	99.4
3.0	.832	.983	99.9
3.4	.862	.992	>99.95

Table 4: Relation between PS and Cohens *d*(Δ) (source:(Grissom & Kim, 2005)).

Note that the Δ≤.20 is considered a small effect size, Δ=.50 is considered a medium effect size, Δ≥.8 is considered a large effect size.

B.4 Fowler's eight point analysis for data collection methods

Every survey research is based on a set of questions. The method trough which these questions are asked, can still differ. A questionnaire can be asked by an interviewer in a personal interview, focus group interviews or trough the telephone, but it can also be asked trough the use of mail or internet. Which method best suites this research will be determined in this paragraph.

Fowler presents eight issues or concepts which should taken into account when choosing the proper survey strategy(Fowler, 2008). These issues are:

- Sampling
- Type of population
- Question form
- Question content
- Response rate
- Costs
- Available facilities
- Length of data collection

A.1.1 Sampling

The sampling issue presented by Fowler (2008) focuses on the fact that different sampling techniques provide different levels of information availability. If the sample, for example, is chosen based on a simple random sampling method from a list, than the information on that list is important to the type of data collection. Does the list contain telephone information, address, e-mail of every individual in the sample of does it only list a more general location, for example a company address.

This study uses a combination of convenient en purposive sampling techniques. The resulting respondents in the sample all work for the host company and so there is no limitation to the type of contact information available. This leads to the conclusion that there is no limitation on or preference for the type of data collection method in this study, based on the sampling method.

A.1.2 Type of population

The issue concerning the type of population is focused around two aspects: 1) the reading and writing skills of the sample and 2) how motivated the sample could be in view of filling out the questionnaire. For an illiterate sample, interviewer-administered data collection would be preferred as the interviewer can ask the question and write down the response. Also, if a low motivation of respondents is expected it is more preferable to use an interviewer-administered data collection method. The use of an interviewer will assure that enough data is collected and that the full questionnaire is asked.

First the reading and reading and writing skills aspect is analyzed. The original tools are both written in English, which is not the native language of the respondents in this study. As it is not their native language, respondents will have to translate the original tools, or adaptations to the tools, when presented in English. The translation process can be difficult and demotivating for the respondents, and will make the answers less comparable as it is unknown how the respondents personally translated the questions. The questions will have to be translated into Dutch prior to the data collection by the researcher, in order to prevent such linguistic issues. This will be a difficult tasks as Fowler even states that “it is doubtful that adjectival rating scales are ever comparable across languages”(Fowler, 2008, p. 77). All respondents are skilled in reading and writing in Dutch, which leads to the conclusion that there is no limitation on or preference for the type of data collection method in this study, based on the reading and writing skills of respondents.

As the first aspect does not result in limitation or preferences, the second aspect is investigated. The impacts under investigation in this research might not directly be associated with BIM by some of the population. The lack of direct association could lead to some form of indifference or reluctance to answer the questions, in with that a lower motivation to participate. On the other hand, this lack of direct association could also cause a form of curiosity with the respondents. Also, the questions will be asked in a work environment where the management staff is motivated to know the answers to the questions. Their motivation can spill over to the sample itself, which could nullify the before mentioned indifference or reluctance. Another aspect which could affect the motivation is the type of questions.

The more difficulty in answering the questions, the lower the motivation can become in answering a self-administered questionnaire. To summarize, there is a motivational risk but it is difficult to estimate the level of risk in this stage in the research. Therefore, the motivational risk should be taken into account when designing the survey, but it does not limit any of the data collection methods or provide a preference in this stage of the research.

A.1.3 Question form

Open or closed questions, many or few answer possibilities and the required use of figures or numbers are all form choices that can affect the preferred type of data collection method. Open questions are less suitable in self-administered questionnaires as they are less likely to produce useful data. On the other hand, when a question has many, but distinct, answer possibilities the interviewer-administered methods are less valuable as respondents can forget the options from which they can choose. Although the actual questionnaire is not designed yet, the original tools do provide a clue on the type of questions to be used.

Both original tools consist only of closed questions with a 5 or 7 point Likert type response format. Such question forms are more difficult to answer in interviewer-administered methods as respondents tend to forget their options. The form of questions in the original tools makes a self-administered data collection method more preferable for the tool developed in this research.

A.1.4 Question content

The question content issue points to the amount of sensitivity of the subjects involved and difficulty of the reporting task. When looking at the original tools it shows that the ICA audit questionnaire mostly consists of recollection and perception of aspects about communication. Besides the questions about miscommunication, which requires the respondent to admit possible failure on his or her side, there are no highly sensitive subjects asked. The JDS however asks more about the actual feelings of the respondents about his work and activities within his work. It also asks about the respondents perception on the feeling of others about the work. Although this might not be sensitive subjects to some, it will be sensitive to others to talk about their feelings.

Many studies have tried to compare the difference in data collection methods when asking sensitive questions, and for each of the methods plausible arguments have been made why a particular method should create better results than the rest. There haven't been convincing evidence yet which clearly favours one of the methods but Fowler (2008) does present three generalization which are: 1)self-administered data collection will at least be as good as the other methods, 2)Telephone interviews are most likely to have a bias when asking sensitive questions, and 3)If highly sensitive subjects are involved, at least initial personal contact is preferred. Nevertheless, Fowler (2008) finishes by saying it will be more plausible that the data collection method will be chosen by other issues than by the interaction between the question content and the method of data collection.

The difficulty of the reporting task depends on if the questions require the respondents search for or discuss the answer with others. Interviewer-administered questionnaires are more of a quick question and answer process which provide little opportunities for such aspects. In such case the self-administered methods would be more preferable as they allow the respondents more time. If the original tools are taken as an example than the questions do not require the respondents to search for or discuss the answer. To conclude, from the view of difficulty of the reporting task, no data collection method is excluded or preferred. From a sensitive viewpoint, however, the self-administered methods would be more preferable as questions can be perceived as sensitive and these methods will collect such data at least as good as other methods.

A.1.5 Response rate

It is not difficult to acknowledge the fact that different data collection methods have different most likely response rates. For example a group interview will most likely provide a response rate near 100% and a mail survey will most likely have a much lower response rate. The amount of response has traditionally been a measurement for the quality of the survey as there was a expected link between non-response and survey bias. This claim has been disputed however in recent years, due to declining response rates in public surveys. A special edition of Public Opinion Quarterly was fully focused on this debate. In the introduction of the paper, a research by Keeter, Miller, Kohut & Groves from 2000 is mentioned where the authors found that a decrees in response rate from 60% to 30% only significantly affected only very few variables (Singer, 2006). Similar results were found in studies that compared survey estimates to benchmark data from the U.S. Census database or large governmental sample surveys ((Singer, 2006), (AAPOR, 2006)). Also a large methodological study and review of the then known literature by Groves (2006) points out that there is no simple relationship between non-response and non-response bias. Nevertheless the author also warns for the extreme misinterpretation of this finding and the before mentioned findings as “implying that there is rarely, if ever, a reason to worry about non-response bias [due to low response rates]” (Groves, 2006, p. 657). This lead to the conclusion that all of the data collection methods can be used despite their most likely response rates, but that attention have to be made to the possible non-response bias when low response rates are achieved.

A.1.6 Costs

On first sight it is logical to assume that mail and telephone surveys cost less than personal interviews. Not only in financial costs but also time is an important factor, especially when the geographic dispersion of the sample is large. However, the financial and time costs for follow-up procedures and initial execution of mail and telephone surveys should not be underestimated. In this particular research, financial and time costs are not of major importance, but nevertheless the most cost and time efficient approach is preferred.

A.1.7 Available Facilities

The available facilities can directly affect the choice of data collection method. If no telephone or trained interview personal are available, telephone or personal interviews are not preferred. In this particular research there is not trained interview personal available and there are valuable available computer facilities available which allows for a large distribution (Microsoft Access to create a database, Microsoft InfoPath to create the Questionnaire and Microsoft Outlook to send the questionnaire) computer aided methods are preferred.

A.1.8 Length of data collection

Also the time available for the data collection can be a issue which can make a method more preferable than the other. A telephone survey is mostly quicker executed than either a mail survey or a personal interview. The distinction between a mail and personal interview is difficult to make according to Fowler (2008) because the time needed for personal interviews is difficult to estimate. Some personal interview surveys will take longer than mail surveys and others will take shorter time to collect the data. The benefit of an internet survey over a traditional mail survey is that it will take less time to send the initial questionnaire and the follow-ups. As time is not directly an issue, this concept does not present a preferable method in this stage of the research.

A.1.9 Conclusion

The following table summarizes the conclusions from the previous paragraph:

Issue of Concept	Limitation	Preferences
Sampling	None	None
Type of population	None	None, but motivational risk
Question form	None	Self-administered
Question content	None	Self-administered
Response rate	None	None, but attention to possible nonresponse bias
Cost	None	Most efficient
Available Facilities	None	Computer aided method
Length of data collection	None	None

Table 5: Result of data collection method analyses based the eight points of Fowler(2008)

This table shows, after considering the eight issues towards the choice of data collection defined by Fowler (2008) , that the most preferred data collection method in this research is a computer aided, self-administered data collection method. This method also suits the notion of an efficient approach to financial and time cost, and is able to reach everybody in the sample population.

A self-administered data collection method does provide a bigger motivational risk than a interviewer-administered method, and so this risk should be taken into account when designing and evaluating the survey instrument, and when retrieving the data. Also the chance of a low response rate is higher with a self-administered data collection method, than with a interviewer-administered method. This is in some way's a result from the motivational risk within the population and so the same attention should be given to this aspect.

Finally, this method of data collection is very similar to original tools which will help in the compatibility of this study with the theories and concepts on which those tools are based.

B.5 Literature study into translation methods

Recent benchmark study across 54 countries showed that the Netherlands scores top three with their English Proficiency Index (2012) score, which places the Netherlands at the top of non-native English speaking countries. Nevertheless, common sense can still explain a preference to translating the tools. Although translation is seen as the only means to ensure item and scalar equivalence across languages, it will always be different from the original tool as languages are not isomorphic (Harkness & Schoua-Glusberg, 1998). The translation should therefore be as, reliable, complete, accurate and culturally appropriate as possible, taking in mind practical limitations and the non-isomorphic issue.

Bahling & Law(2000) present two critical questions before translating a questionnaires: 1) should we translate the questionnaire and 2) can we translate the questionnaire. The first question comes from a more philosophical and theoretical perspective, and mainly revolves around the difference between cultures on those concepts. For example, the western culture is different from the eastern culture in their thinking, feeling and behavioural patterns (Behling & Law, 2000). In this particular study, one could argue that there is a difference between the Netherlands and the USA on work motivation and satisfaction. However, the JDS has been used in the Netherlands before, (see for example (Boumans & Landeweerd, 1994) And (Jerkovic-Cosic, 2012)) and the affect of the possible differences is assumed to be negligible in view of the purpose of this study.

The simple answer to question one is yes, as a questionnaire can always be translated. The real question here is to what extend can a questionnaire be translated and still present meaningful results. Again Bahling & Law(2000) present three basic concepts which are behind this question which are: the lack of semantic equivalence across languages, the lack of across cultures and the lack of normative equivalence across societies. The semantic equivalence refers to the choice of words and sentences in the translation and the extent to which they have a similar meaning as in the source language. For example, the English word for "cry" can be translated two four different Dutch words which could mean "crying" but also "pleading". The conceptual equivalence actually refers back to a the issue of question one, namely to what extend to different cultures “know” or “recognize” similar concepts. As with the first question it is assumed that the Dutch and North-American culture a similar enough for this study to not cause a problem. The normative equivalence refers to the rules and values of a society, which could affect the impact of a questionnaire. For example, people from the republic of China will be less likely to answer questions about their sex life than people living in Europe. For this particular study it is assumed that the normative difference between the Netherlands and the USA, like the cultural difference, are negligible. To summarize, with the assumption that normative and cultural difference are minimal between the Netherlands and the USA, both critical questions can be answered positively and the appropriate method of translation can be chose. During the translation however, attention must be paid to the possibility of semantic issues.

There are several procedures of translation that can be identified, which can be divided in three categories. The most common are:

- Translations during the drafting stage of the source questionnaire
  - Decentring in translation (Harkness & Schoua-Glusberg, 1998)
  - Advance translation (Harkness & Schoua-Glusberg, 1998)
- Translations of a finished source questionnaire before data collection
  - “Direct”, “Simple Direct”, “One-for-One” translation ((Harkness & Schoua-Glusberg, 1998)(Pan & De La Puente, 2005))
  - Committee translation ((Harkness & Schoua-Glusberg, 1998)(Pan & De La Puente, 2005)(Cha, Kim, & Erlen, 2007))
- Translations of a finished source questionnaire during data collection
  - “On the fly” translation (Harkness & Schoua-Glusberg, 1998)

Other mentioned procedures are: the bilingual technique(Cha, Kim, & Erlen, 2007) and especially Back-translation ((Harkness & Schoua-Glusberg, 1998)(Pan & De La Puente, 2005)(Cha, Kim, & Erlen, 2007))). These procedures however, are more evaluative procedures than actual translation procedures and will therefore not be explained here but further on in the chapter.

Both of the source questionnaires in this particular study are long past there drafting stage and completely finished, which excludes the first two procedures. In the “on the fly” translation procedure, an interviewer will orally translate the source questionnaire into the target language. The procedure is most common when there is only a small sample of the respondents is expected to require translation. (Harkness & Schoua-Glusberg, 1998) The method is also excluded however as both of these aspects are not present or required in this study. This leaves the direct or simple direct translation method, the committee translation method, and their modified versions.

The direct translation method is the “simplest” and cheapest translation procedure used. It is basically a single bilingual person who, to the best of his or her abilities, produces a translation of the source questionnaire. The benefits of such an approach are clear, but the drawbacks consist of, among others: relying on a single persons perception and skills and data quality risks ((Harkness & Schoua-Glusberg, 1998)(Pan & De La Puente, 2005)). The procedure is actually at the base of the before mentioned back-translation procedure. In the back translation procedure there is a iterative process between two translators, both executing a direct translation method. First a translation is made from source to target language. Next a second translator reverses the process and translates the questionnaire "back" to the source language. After that the translation is compare with the original and this process is repeated until both translators are satisfied with the result. A modification to the direct method to overcome the shortcomings is to present the translation to a committee and discuss the translation. This is a hybrid form with the committee translation procedure. However according to Census, the modifications still fail to compensate for a lack of collaboration.

The committee translation procedure is a comprehensive and collaborative method of translation. The entails a committee comprising of multiple translators, reviewers, subject-matter specialists, questionnaire design specialists and at least one adjudicator (Pan & De La Puente, 2005). These committee members than translate and evaluate the produced translation together until consensus is achieved. This method is however fairly labour, time and cost intensive and requires multiple knowledgeable actors and translators. A modification to this method to decrease these drawback is to let all translators translate a different section. This then requires less time and is the committee translation procedural version of the hybrid form presented in the previous section.

Unfortunately there are time and costs constrains, as well as the constrains on knowledgeable actors in this master thesis. This leads to the conclusion that the committee translation procedure or a modified version is not feasible and that the direct translation method will be used. So to summarize this paragraph, both critical questions before translation of Bahling & Law(2000) can be answered positive in this study which indicates that translation is valid. During translation however, close attention should be kept at semantic equivalence issues. Furthermore, a direct translation method will be used to translate the original tools from English to Dutch. This method has its drawbacks which will have to be mitigated as much as possible, within the practical constrains of this master thesis.

B.6 Adaptation of the ICA audit

Again, lets first review the goal of the use of the ICA audit questionnaire presented in chapter 3. From the literature it followed that the ICA audit questionnaire should be used to measure the perception of employees on the level of communication failure, correctness of information, the availability of information and the actuality of information in projects. The original ICA audit questionnaire consisted of 118 questions, divided in eight sections ((Goldhaber, Porter, & Yates, 1977)(Franklin, 2004)). These sections are:

A. Receiving information about the work and your performance from others
B. Sending information about the work and your performance to others
C. The sources of information
D. The amount of follow-up or action taken on information you send to others

E. The quality of information
F. The channels of information used
G. The organizational communication relationships
H. Satisfaction with organizational outcomes

Every section measures different aspects of communication within a organization. Not all of these aspects are interesting in view of the goal of this research. This lead to the first major adaptation. A more recent use of the ICA audit questionnaire by Antonis (2005) provides a clear structure on which a adaptation decision can be made. Antonis (2005), in her work of developing a tool to measure interorganizational communication, restructured these eight sections based on new perspectives from integrated communication theories. This perspective says that there are four distinct levels between which communication exists. The most basic level is the individual communications, both internal as external. Next there are teams within an organization which comprise of multiple individuals and which has its own communication aspects. The organization itself is again comprised of multiple teams and also has its own aspects. Finally there is a more general communication system and structure in the organization. Antonis (2005) explains these levels and the questions within as follows:

- Communication system and structure in general: These questions focus on the actual communication related infrastructure, such as communication channels that are used, including issues such as information load and media richness, the levels at which communication takes place, the directions in which communication flows, as well as the communication networks that exist in a organization.(Antonis, 2005, p. 180). Especially questions of section C,E and F are found on this level.
- Communication aspects on an individual level: These are focused on individual satisfaction with communication, as well as how the interpersonal communication skills and abilities of the individual impact on the effectiveness of the team and ultimately the organization as a whole(Antonis, 2005, p. 181). Especially questions of section A,B,D and H are found on this level.
- Communication aspects on a team level. These questions are especially focused on the immediate work group and the interdepartmental contact situations with team competence, capabilities, integration and needs or blockages impacting on the individual as well as the organization as a whole(Antonis, 2005, p. 181). Especially questions of section G is found on this level.
- Communication aspects impacting on a organizational level: These are focused on the overall systemic view of the organization, including its environment and culture and how communication affects it in terms of achieving its strategic objectives and goals whilst providing an enabling working environment for its employees(Antonis, 2005, p. 181). This level was inserted by Antonis (2005) herself and has no reference to the original ICA audit.

This structure clearly shows that especially the communication system and structure in general level suites the goals of this research. A clearer investigation into the particular questions also showed that this section was best suited to measure the concepts of level of communication failure, correctness, and actuality of information. It also measure the sources of information and channels of information which could be used for exploratory purposes to see if BIM changes these aspects as well. Some other exploratory questions, like the level of interaction and collaboration and the dependency between departments and colleagues have been included for exploratory purposes.

Following this initial selection the questions themselves where examined closer. For example, availability of information was not regarded sufficiently in the questionnaire for the purpose of this study. A set of questions which asked about this concept was added, based on the questions which assessed the actuality of information, to ensure that the concept was measured as well. Also, as this study focuses on communication in projects, some of the sources and channels where changed. For example, information from the grapevine and top management where excluded and external clients and subcontractors where added as a source of information. Furthermore, e-mail and both digital as paper drawings where added as channels of information. After this first major adaptation, the questionnaire consisted of 86 questions divided over two sections.

Another major adaptation to the tool follows from what the tool should actually measure in this research. The original questionnaire is used to assess the current and desired states of communication according to the respondents. This helps organizations determine (and audit) the areas where improvement of communication is desired. This information could then for example be used to write new organizational communication protocols. The goal of this study, however, is to determine if the current state of communication perceived by employees who worked with BIM is different from the current state of communication perceived by employees who did not work with BIM. As this explanation shows, is the desired state of less importance for this thesis. Therefore all desired state questions were excluded from the questionnaire which resulted in a questionnaire consisting of 60 questions.

The third and final major adaptation concerns the response format and answer possibilities used in the questionnaire. The original ICA questionnaire uses a five point Likert type response format which only included the possibilities: very little, little, some, great and very great. Antonis (2005) already changed the answer possibilities to better fit the questions. For example, she changed the scale for statements to a strongly agree to strongly disagree scale ,and added the possibility of not receiving information instead of little being the least information load. These changes have been adopted as well. However, Antonis (2005) also include “enough” as the highest amount of information load, but the concept of “enough” is independent of the amount of information and therefore does not fit the scale. Simply put, when someone receives “little” information it can still be “enough”. The option “enough” is therefore changed into the option “many/a lot” which also suits better in the “amount” continuum.

Also, the response format was adapted. According to Goodwin (2009), a general advice in using Likert type response formats is to avoid mixing formats(Goodwin, 2009, p. 477). As the JDS consisted of seven-point response formats and the ICA audit questionnaire consisted of five-point response formats, one of the two should be adapted. There are arguments for both response formats which indicate a preference for one or the other (see an evaluation in(Colman, Norris, & Preston, 1997) and (Friedman & Amoo, 1999)). Nevertheless, there are indications that respondents are reluctant to choose the extremes as their answer (see for example (Friedman & Amoo, 1999), (Goodwin, 2009) and (Cohen, Manion, & Morrison, 2007)). When a five-point response format is used it effectively results in a three point response format. There is also evidence that the more points the more reliable the response becomes, up until the point that there are too many for respondents to handle. Research suggests that this would be around a eleven-point scale(Friedman & Amoo, 1999). These arguments would support a decision of increasing the response format of the ICA audit questionnaire to a seven-point response format like the JDS.

However, research shows that a ten-point response format is more accurate to determine the overall mean score among respondents than a five or seven point response format and does not significantly differ from five or seven point response format in terms of other data characteristics like variation about the mean, skewness or kurtosis (Dawes, 2008). The overall mean score is an important factor in both parametric and non-parametric statistical methods. The increased accuracy of the overall mean score could therefore especially be useful in assessing the difference between BIM and non-BIM on the concepts of correctness of information, the availability of information and the actuality of information. It is also believed that the Dutch respondents will be more used to numerically rate an aspect on a scale from 1 to 10 than from 1 to 7, as the Dutch educational system uses this rating scale as well. The reasons why it is useful for these three of the four goal concept and not all four, is that these concepts measure the quality of information in general where the level of communication failure requires the respondents to rate their own performance as well. Common sense provides the argument that measuring one's own performance on a numerical scale is prone to positive bias. However, there has been no evidence found of both of these believes in the literature. An even point scale, like the ten-point scale, also removes the option for respondents to answer neutral and forces them to make a thoughtful decision whether they are more positive or negative to the concepts. Using an even response format has its drawbacks, like for example the argument that some respondents might very well stand natural on a particular subject. However for these particular concepts, the question is not about the respondents opinion about a external statement, but about the opinion based on their own expectations about the quality of information and communication. Because it is about their own expectation, the absents of a neutral standpoint is believed to be less of an issue.

To summarize these last two sections, following the advice of Goodwin (2009) the decision was made to change the response format of either the JDS of the ICA questionnaire. Arguments for this change where that the more points in the format the more reliable the response becomes(Friedman & Amoo, 1999), and the indications that respondents are reluctant to choose the extremes as their answer (see references above). Based on these arguments the decision was made to adjust the ICA five-point response format to a seven-response format. Furthermore, arguments where presented that ten-point response format is more accurate to determine the overall mean score which is important in both parametric and non-parametric statistical methods(Dawes, 2008). Together with the earlier presented argument that the more points in the format the more reliable the response becomes, lead to the decision to change the response format for the concepts of correctness of information, the availability of information and the actuality of information to a ten-point response format.

The three major adaptations done to the ICA audit questionnaire resulted in a visually substantially different measurement tool. The amount of questions where decreased from 118 to 60, and the response formats where increased form a five-point scale to a seven-point scale. Three of the four goal concepts are even measured on a numerical ten-point scale. Besides the visual difference, the measured concepts are still similar to the original ICA audit questionnaire. The following variables be measured by the questionnaire.

- The level of communication failure in projects
- The correctness of information in projects
- The availability of information in projects
- The actuality of information in projects
- The information quantity from different sources
- The information quantity via different channel
- The level of interaction between colleagues of the same and of other department
- The level of collaboration interaction between colleagues of the same and of other department
- The dependency between departments and colleagues

B.7 Discussion towards interpreting a Likert Scale

All of the response formats of the questions, except the demographic questions, are Likert type response formats. A Likert type response format consists of several response points, usually between two and eleven, which asks about the respondents feeling or opinion about a certain concept. Examples of Likert type response continuum are: Agree – Disagree, Always – Never, Excellent – Poor. The well known Likert type response format is based on the Likert scale items, developed by psychologist Rensis Likert in 1932. In the past sixty years there has been a heated debate between two camps about what type of measurement scale a Likert scale is, and what type of data it actually generates. This discussion is important as the justification of using parametric statistical analysis or not is base on the type of measurement scale.

The first camp claims that a Likert scale only produces categorical data which is ordered in some fashion, and therefore the Likert scale should be interpreted as an ordinal scale. There is a certain continuum from which the scale points are derived, but it is illegitimate to claim that the "distance" between two points is equal for the entire scale ((Jamieson, 2004), (Cohen, Manion, & Morrison, 2007), (Blaikie, 2003)). After all, one cannot infer that the intensity of feeling in the Likert scale between 'strongly agree' and 'agree' somehow matches the intensity of feeling between 'strongly disagree' and 'disagree' ((Cohen, Manion, & Morrison, 2007, p. 327)). This camp therefore claims that only non-parametric statistical analysis, like the chi^2 test or the Kruskal–Wallis test can be used.

The second camp goes as far to claim that the articles from the first camp are only ""historical curiosities" to anyone who has actually read Likert in the original or constructed and empirically developed a "Likert scale" according to his theoretical model and writings" (Carifio & Perla, 2007, p. 106). The major concern from the second camp is based on the linguistic error from the first camp, namely the difference between a “Likert scale” and a “Likert type item”. With the latter, refers to the response format of a single question. This single item is similar to the “scale”, mentioned in the first camp, and both sides agree that this data should be considered as ordinal data ((Carifio & Perla, 2007), (Norman, 2010)). However, the first pertains a set of Likert type items, usually about eight or more, in which all question a similar attitude (Carifio & Perla, 2007). The set of items comprises the actual “Likert scale” as intended by Likert himself, and can be treated as interval data when summed ((Carifio & Perla, 2007), (Norman, 2010)). The use of a “Likert scale” in this format would allow for parametric analysis to be used.

Norman (2010) performed a study where he tested the statistical robustness of parametric analysis methods to violation of certain assumption, among which the use of ordinal Likert type item data. He concluded that the use of a single item as base for a parametric analysis should be avoided, but that the combination of items can be used as interval data. He further concludes that parametric analysis methods are highly robust to things like skewness and non-normality, which is expected from ordinal data as well. Therefore, in this research data from single questions will be interpreted as ordinal data, and data from a combination of items questioning a similar attitude will be interpreted as interval data. Now the type of analysis methods that are used are explained.

Appendix C. Survey evaluation rounds

The first review committee consisted of the following people:

Bart van Oosterhout (teamleader engineering Rotterdam), Sjoerd Klaver (teamleader engineering Alkmaar), Hanneke Schrage (teamleader engineering Houten), John Jansson (teamleader projectmanagement Rotterdam), Arjan Groot (teamleader projectmanagement Alkmaar), Herman Vianen (teamleader projectmanagement Houten).

The committee provided the following comments on the initial questionnaire. Note that the comments are in Dutch as the questionnaire was translated in Dutch

Bart van Oosterhout

- In de een na laatste zin misschien 'af te vallen' vervangen door 'beoordelen'? Misschien er aan toevoegen dat de antwoorden anoniem worden verwerkt.
- Misschien nog even duidelijk vermelden dat het gaat om de huidige situatie, en dat verstand van BIM dus niet nodig is bij het invullen?
- Verklaring voor het rode sterretje toevoegen?
- Mij is niet helemaal duidelijk wat een-op-een-communicatie is, zeker niet als in de vraag daarna gesproken wordt over oog-in-oog-communicatie.
- Bij vraag twee ben ik geneigd om alleen maar te kiezen voor antwoorden 'soms', 'zelden' en 'nooit'. 'Altijd' en 'frequent' zullen niet of nauwelijks voorkomen denk ik. Niet omdat de antwoorden niet van toepassing zijn, maar omdat je bij zo'n antwoord feitelijk moet toegeven dat je niet goed communiceert. Misschien de verdeling van de antwoorden iets aanpassen?
- Bij vraag 2.15: ik denk dat veel communicatie misloopt als gevolg van verschil in uitleg van gesproken of geschreven dingen. Is dat niet een aparte oorzaak?
- Projectinformatie is één woord (komt meerdere keren voor in de lijst). Dat geldt ook voor projectteam en projectcommunicatie
- Vraag 2.16 en 2.22: de afdeling heet Stedelijk Gebied
- Boven 2.16: ieder → iedere
- Boven 2.22: uw → u
- Uitleggen wat je bedoelt met 'accuraat' en 'relevant'. Klinkt als een open deur maar zeker over accuraat kan ik me voorstellen dat dat op verschillende manieren wordt uitgelegd.
- Bij 2.42: bedoel je hier beheren of beheersen?
- Vraag 3.3: ander → andere
- Vraag 3.4: word → worden
- Boven vraag 3.6: plaats → plaatsvindt
- Boven vraag 3.6: duidelijk onderscheid maken tussen 'collega's' en 'afdelingen'. Wat als het een collega van een andere afdeling is? Een afdeling bestaat ook uit collega's.
- Als ik de antwoorden van 3.6 t/m 3.10 bekijk dan betekent 'niveau' in de vraag eigenlijk 'frequentie'. Is 'niveau' niet beter vergelijkbaar met 'kwaliteit', dat je uitdrukt met antwoorden als 'slecht' en 'goed'?

Arjan Groot

- De vragenlijst die bij jouw eerste mailtje zit en gaat over communicatie snap ik, is leesbaar en begrijpelijk en is in een korte periode in te vullen.
- Wat ik niet snap, is de tweede vragenlijst die gaat over werkmotivatie. Ik snap de relatie niet met het onderzoek. Mijn teamleden zullen dit ook niet snappen.
- Ook de vragen daarin zijn veelal niet duidelijk voor mij. Een nadere uitleg is misschien op z'n plaats.

Hanneke Schrage

- Hoe is geborgd dat de vragenlijst hun privacy niet aantast? Vragen die behoorlijk ver gaan en berusten op veel vertrouwen dat dit alleen bij jou blijft.
- Voor het overige vind ik de tijd die er mee gemoeid is acceptabel. Kort maar krachtig.

Sjoerd Klaver

- Ik sluit mij aan bij Hanneke. Vooral het motivatie gedeelte is van te persoonlijke aard.
- Ik kan mij voorstellen dat een groot gedeelte van de mensen (waaronder ik zelf) zich af zal vragen wat dit met BIM te maken heeft.
- Het communicatie gedeelte zal waarschijnlijk minder vragen oproepen.
- Ten aanzien van de anonimiteit is het heel vreemd dat eerst om een naam wordt gevraagd. Dit roept een barrière op waardoor mensen deze vragenlijst niet in zullen vullen.
- Al met al ben ik bang dat in deze vorm de respons erg zal tegenvallen.

John Jannson

- Terminologie duidelijker maken, wat zijn kanalen bijvoorbeeld. Wat is bijvoorbeeld presteren (motivatie verhaal) is dat financieel presteren of persoonlijke prestatie?
- Vooral nog een heikel punt zijn de vragen mbt task identity

Heman van Vianen

- Did not replay

Summary of important points of attention and their resolution (in Dutch)

Nr	Point	Who
1	Aangeven dat kennis van BIM niet nodig is	BvO
2	Verklaring Rode Sterretjes	BvO
3	Verdeling van de antwoorden vraag 2.8 tot 2.14 (mogelijk onwerkelijke antwoorden)	Bvo
4	Vorm van de antwoorden vraag 3.6 tot 3.10 (niveau is goed/slecht nu meer/minder)	Bvo

5	Miscommunicatie vanwege verschil in uitleg van gesproken of geschreven dingen toevoegen	BvO
6	Kijken naar onderscheid tussen collega’s en afdelingen	BvO
7	Sommige termen verduidelijken (een-op-een com, acuraat, relevant, kanaal)	BvO, JJ, HV
8	Duidelijkere omschrijving waarom onderzoek naar werkmotivatie (persoonlijke vragen dus waarom)	AG, HS, SK, HV
9	Hoe is de anonimiteit gewaarborgd	HS, SK

Punt 1: Toegevoegd aan intro dat er geen specifieke informatie nodig is. BIM kan nog niet genoemd worden omdat dat niet is toegevoegd

Punt 2: uitleg Toegevoegd aan intro

Punt 3: Antwoorden is niet aan te passen omdat dan afgeweken wordt van de originele lijst en de mogelijk op vaak miscommunicatie. Vervolgens is er gekeken of de bewoording veranderd kan worden van de vraag. Na analyse blijkt de vertaling mogelijk te grof. In de concept versie was misunderstood vertaald als misverstand. Dit is nu vertaald als “verkeerd begrepen” om de lading iets minder gewicht/lading te geven en daarmee mogelijk een eerlijker antwoord.

Punt 4: is niveau is aangepast naar mate om de antwoorden beter over te laten komen.

Punt 5: is toegevoegd aan formulier

Punt 6: Is naar gekeken en onderscheid duidelijker gemaakt. In sommige gevallen heeft dit geleidt tot het herschrijven naar 2 vragen

Punt 7: Sommige termen verduidelijken/operationaliseren. De vragenlijst is opnieuw doorgenomen en “termen” zijn gehighlight. Termen zijn volgens mijn classificatie woorden die voor meerdere interpretaties vatbaar zijn en essentieel voor de vraag zijn. Vervolgens is er gekeken of de term veranderd moest worden(operationeel gemaakt) of verduidelijkt worden (toevoegen van een uitleg) Ook is er achter een aantal vragen vraag een tip geschreven over hoe de respondenten de vraag kan beantwoorden.

Punt 8: In de toelichtingen heb ik kort en bondig beschreven waarom dit onderzoek nodig zou zijn. Verder heb ik nogmaals naar de vragen gekeken om te kijken of de mate van persoonlijkheid nodig was. Initieel heb voor de adoptie gekeken naar wat het doel van de vragenlijst is, namelijk om het motivatie potentiaal van de huidige banen te bepalen.

Punt 9: Ik heb de toevoeging van de naam optioneel gemaakt naar het einde van de vragenlijst verplaatst.

The second review committee consisted of Bart van Oosterhout and Mark Ammerlaan. This review session was mainly to tests the distribution of the questionnaire. There are two reasons for the low amount of test subjects. The first was that a review of the questionnaire in person is the best way of testing a self-administered questionnaire, according to Fowler (2008). It allows for the direct feedback option and quick resolve of issues. Another reason for using a low amount of testers was that it would leave the majority of the sample unexposed to the concept questionnaires. The result of the review was that a different distribution method was needed than originally intended. The software issue between the three opted software programmes (Microsoft Infopath, Miscrosoft Access and Microsoft Outlook) and the internal sever rules where to great to overcome in this study. The decision was made to use the website thesistool.com as a alternative.

The final questionnaire was sent via e-mail to eighteen team leaders of the division Planning and Design, and they were asked to distribute the questionnaire among their team members. It was assumed that an e-mail from the team leader as introduction to the research would create more willingness to cooperate among the respondents than when the researcher would make the introduction. All but one of the team leaders complied, and within the span of two weeks 326 people were reached. The team leader, who did not complied, did fill in the form but refused to distribute the link among his team members. He argued that his team should focus on their work and not spend time on the survey. His entry was used in this questionnaire but his team members were excluded from the survey.

Appendix D. Survey (in Dutch)

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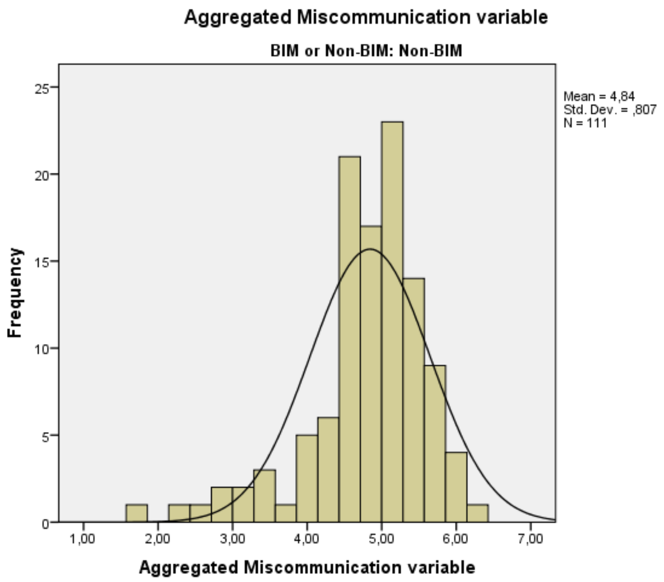
Appendix E. Assumption Tests

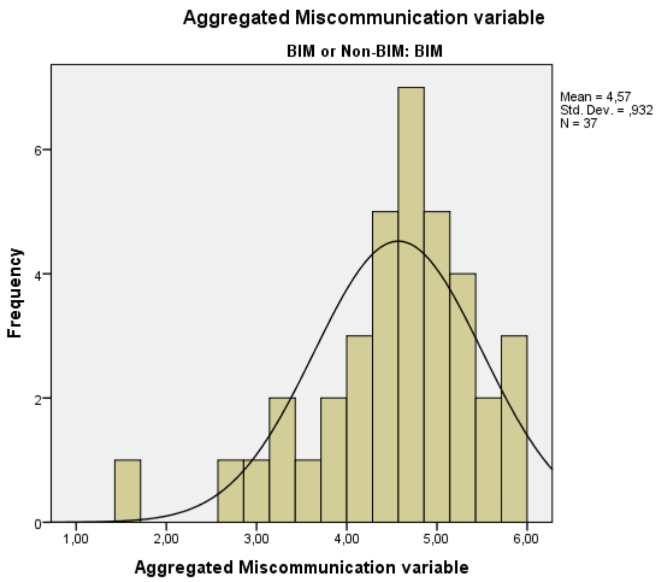
This appendix shows the assumption test from which the results are presented in table 6 of the main report. The testing follows the pattern of the decision tree in Chapter two of the main report (see figures 7 and 8), which means that the normality assumption is tested first and followed by the assumption test for equal variances. Normality is tested based on standardized z-scores of skewness and kurtosis and visual inspection of the histograms and Q-Q plots. Equal variance is tested with the standard or non-parametric Levene's test, depending on the whether the sample passes or fails the normality assumption respectively.

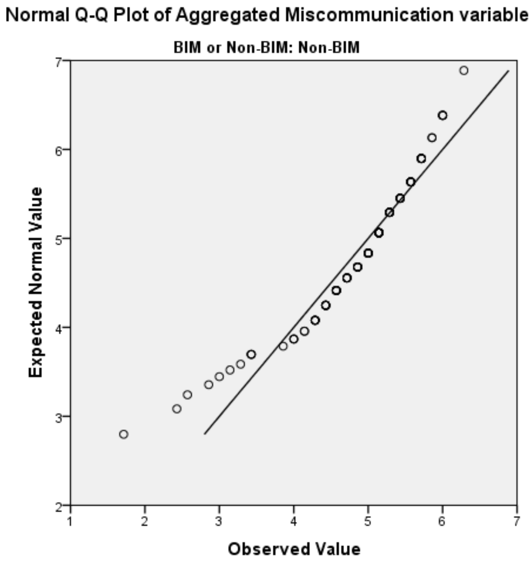
E.1 Comparative hypotheses

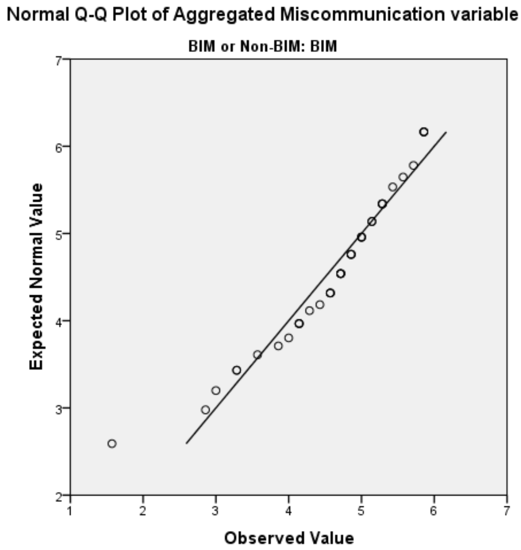
Hypothesis C1: Project participants in BIM projects will report a lower frequency of communication failure through various channels than project participants in non BIM projects.

Statistics			
		Aggregated Miscommunication variable (Non BIM)	Aggregated Miscommunication variable (BIM)
N	Valid	111	37
	Missing	4	1
Mean		4,8430	4,5714
Std. Deviation		,80650	,93192
Skewness		-1,262	-1,114
Std. Error of Skewness		,229	,388
Z-score of Skewness		*-5.51092*	*-3.29586*
Kurtosis		2,239	1,747
Std. Error of Kurtosis		,455	,759
Z-score of Kurtosis		*4.920879*	*2.301713*









The table shows that the scores for the non-BIM data set are $Z_{skewness}$=-5.51 and $Z_{kurtosis}$=4.92, and for the BIM data set $Z_{skewness}$=-3.30 and $Z_{kurtosis}$=2.30. All of these calculated scores are higher than the significant score of z=1.96 for p=0.05, so based on this method both data sets are skewed an kurtosis meaning non-normally distributed.

The histograms support the results found using the Field (2009) method as the frequency of values is skewed to the right site of the graphs. Also the high kurtosis can be seen in the non-BIM histogram where the values are highly centred around the fifth point, showing a peak in the data. The Q-Q plots show the observed quantiles in the data compared to the expected normal quantiles, represented by the straight line. If the data is normally distributed, the quantile points should be on that line, although a small deviation at the ends can be expected ((Field, Discovering statistics using SPSS, 3th Ed., 2009),(Howell, 2010)). In this case however, both data sets show deviation from the expected value in both the ends as the centre. To conclude, both the Field (2009) method as the graphical approach point to non-normally distributed data in both samples. The samples are similarly skewed.

ANOVA

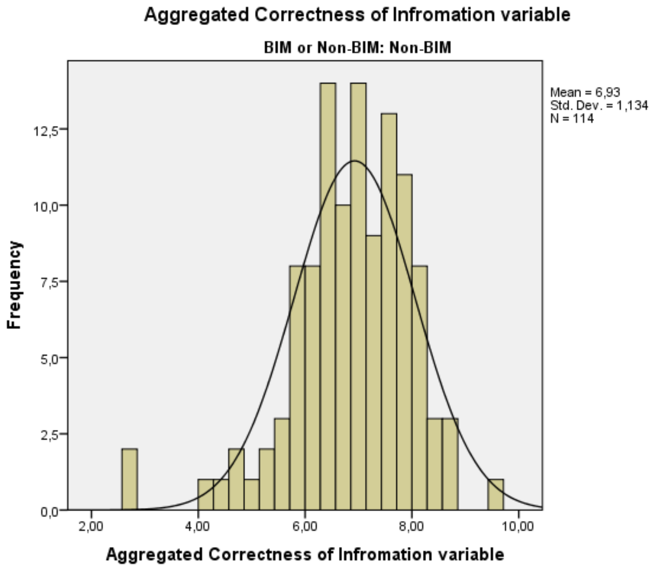
		Sum of Squares	df	Mean Square	F	Sig.
Non-parametric Levene's test for Aggregated miscommunication variable	Between Groups	,087	1	,087	,000	,989
	Within Groups	68840,316	146	471,509		
	Total	68840,404	147			

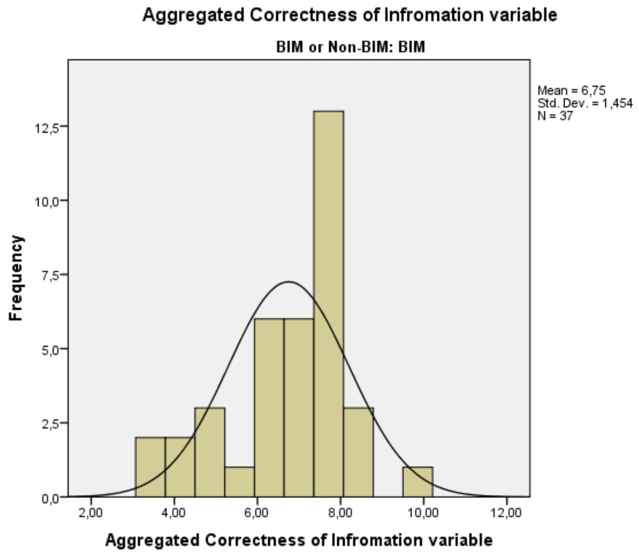
The test shows that there is no significant difference in variances, *F*(1,146)=.000, p>0.05, meaning that the null hypothesis of equal variances cannot be rejected and therefore the variance are assumed equal.

Hypothesis C2: Project participants in BIM projects will rate correctness of information through various channels higher than project participants in non BIM projects.

Statistics

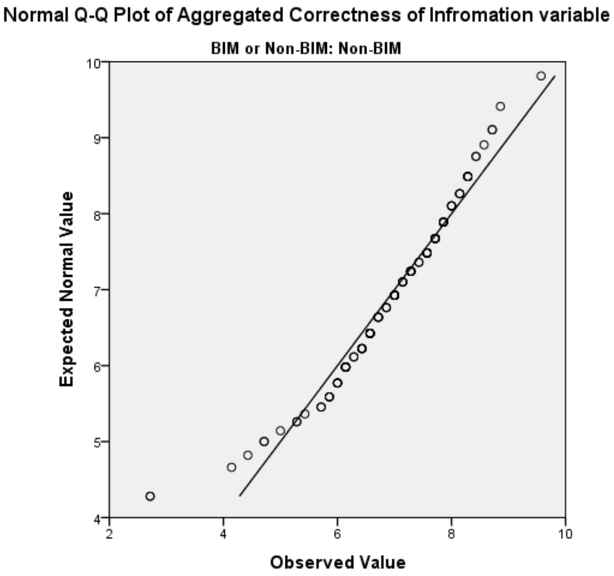
		Aggregated Correctness of Information variable (Non BIM)	Aggregated Correctness of Information variable (BIM)
N	Valid	114	37
	Missing	1	1
Mean		6.9261	6.7490
Std. Deviation		1.13449	1.45351
Skewness		-.992	-.786
Std. Error of Skewness		.226	,388
Z-score of Skewness		*-4.38938*	*-2.02577*
Kurtosis		2.345	.358
Std. Error of Kurtosis		,449	,759
Z-score of Kurtosis		*5.222717*	*0.471673*

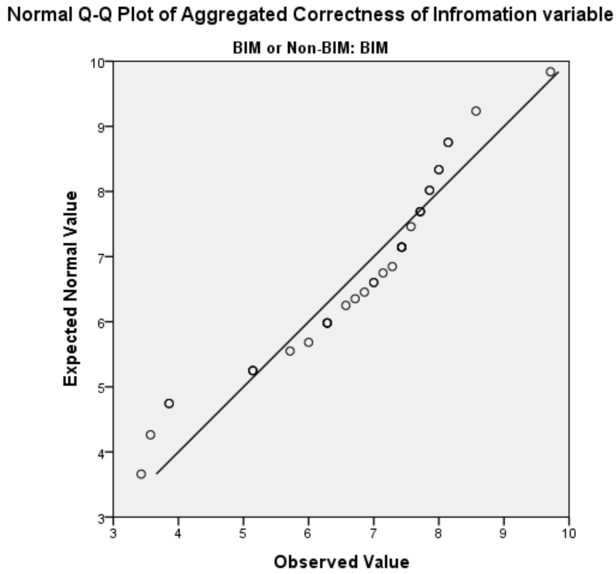




The table shows that the standardized scores for the non-BIM data set are $Z_{skewness}$=-4.39 and $Z_{kurtosis}$=5.22, and for the BIM data set $Z_{skewness}$=-2.03 and $Z_{kurtosis}$=0.47. The Field tests indicates that both BIM and no-BIM data sets are significantly skewed for p=0.05. The Field tests also indicates that the non-BIM data set is also significant positive kurtosis, but the BIM group is not. Therefore the Field test indicates that the non-BIM group is non-normally distributed, but the BIM group is inconclusive.

The histograms confirm the results from the Field test as the frequency of values for both data sets is skewed to the right site of the graphs. The histograms also show that although the BIM group was tested not significantly kurtosis, there is a clear peak in the frequencies. Last, the Q-Q plots of both data sets show clear deviations from the expected values in both the centre as the ends of the line. To conclude, both the Field (2009) method as the graphical approach point to non-normally but similarly skewed distributed data in both samples.





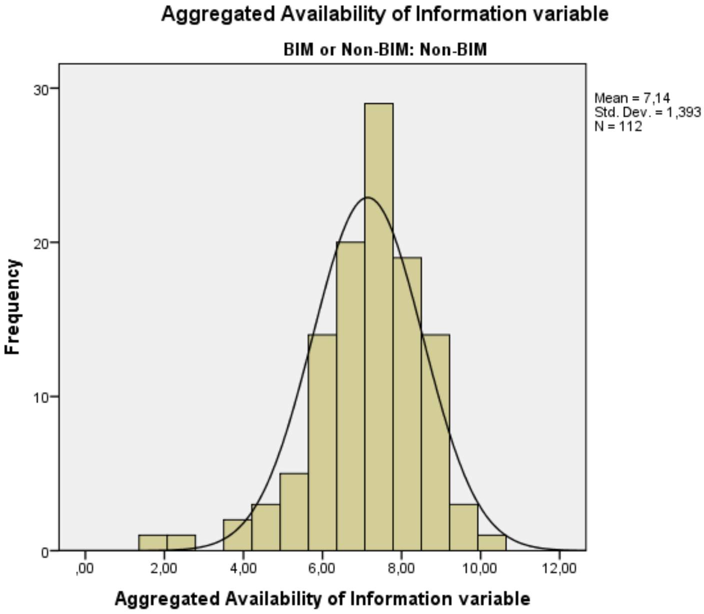
ANOVA

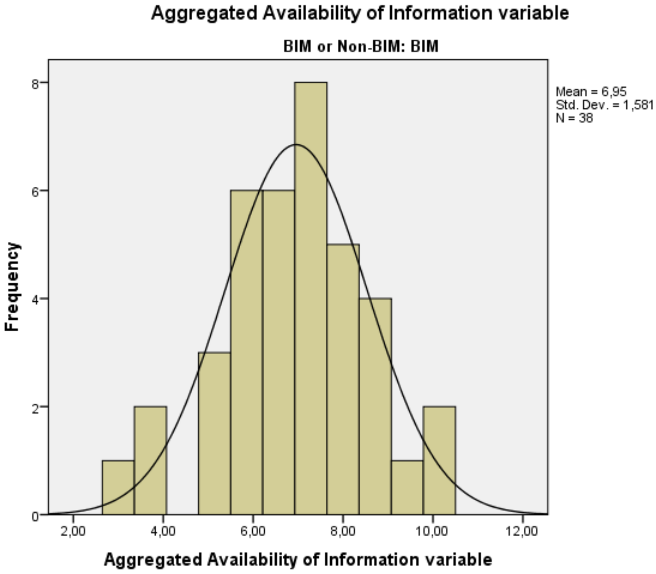
		Sum of Squares	df	Mean Square	F	Sig.
Non-parametric Levene's test for Aggregated Correctness of Information variable	Between Groups	505,353	1	505,353	1,053	,306
	Within Groups	71481,062	149	479,739		
	Total	71986,415	150			

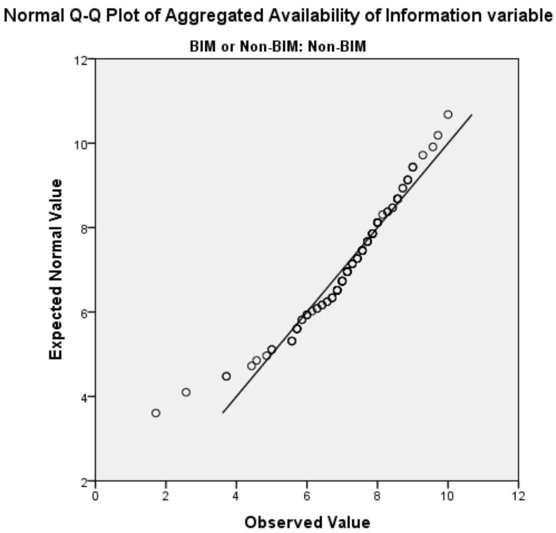
The test shows that there is no significant difference in variances, $F(1,149)=1.053$, $p>0.05$, meaning that the null hypothesis of equal variances cannot be rejected and therefore the variances should be assumed equal.

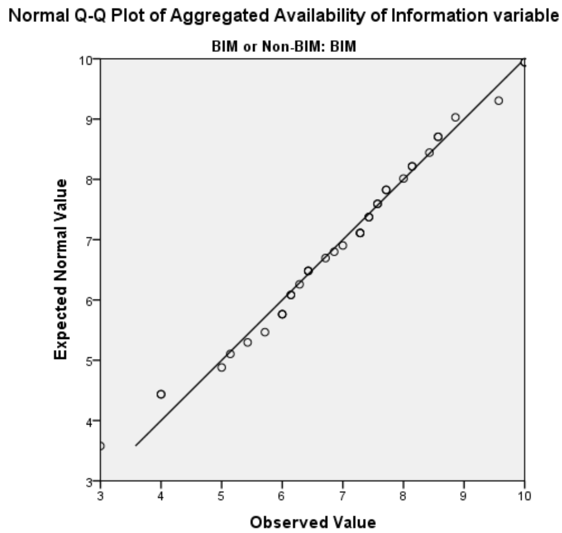
Hypothesis C3: Project participants in BIM projects will rate availability of information through various channels higher than project participants in non BIM projects.

Statistics			
		Aggregated Availability of Information variable (Non BIM)	Aggregated Availability of Information variable (BIM)
N	Valid	112	38
	Missing	3	0
Mean		7.1429	6.9549
Std. Deviation		1.39339	1.58109
Skewness		-1.035	-.272
Std. Error of Skewness		.228	,383
Z-score of Skewness		*-4.53947*	*-0.71018*
Kurtosis		2.183	.254
Std. Error of Kurtosis		,453	,750
Z-score of Kurtosis		*4.818985*	*0.338667*









The table shows that the scores for the non-BIM data set are $Z_{skewness}$=-4.54 and $Z_{kurtosis}$=4.82, and for the BIM data set $Z_{skewness}$=-0.71 and $Z_{kurtosis}$=0.34. The Field test indicates that the non-BIM is significantly skewed and kurtosis for p=0.05. However the test also indicates that the BIM data set is not significantly skewed or significantly kurtosis for p=0.05. This would indicate that the Non-BIM sample is not normally distributed, but the BIM sample is.

The histograms show a clear skewness of the non-BIM data, but the BIM data set also displays a tendency to the right side of the graph (note that a value of 5 is the centre). The Q-Q plot of the BIM sample shows deviations from the expected values in both the centre as the ends of the line, but these could be expected based on the low sample numbers. To conclude, the Field test indicates that the Non-BIM data set is non-normally distributed, but that the BIM group is normally distributed. The histogram confirms the test for the Non-BIM data set, but also indicates a skewness in the BIM data set. The Q-Q plot for the BIM groups display's some deviation but these could be expected. Therefore, the Non-BIM data set fails the normality assumption, but the BIM set passes. Nevertheless, due to the failure of one set, the compassion will be more robust if non-normality is assumed for both groups.

ANOVA

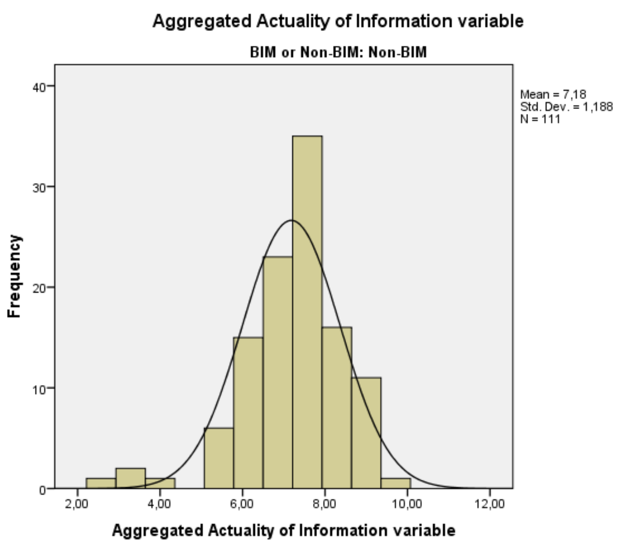
		Sum of Squares	df	Mean Square	F	Sig.
Non-parametric Levene's test for Aggregated Availability of Information variable	Between Groups	432,491	1	432,491	,932	,336
	Within Groups	68707,268	148	464,238		
	Total	69139,759	149			

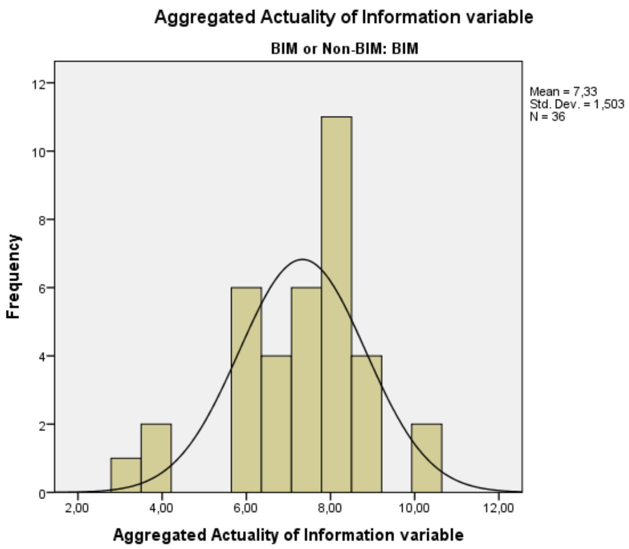
The test shows that there is no significant difference in variances, $F(1,148)=0.932$, $p>0.05$, meaning that the null hypothesis of equal variances cannot be rejected and therefore the variances should be assumed equal.

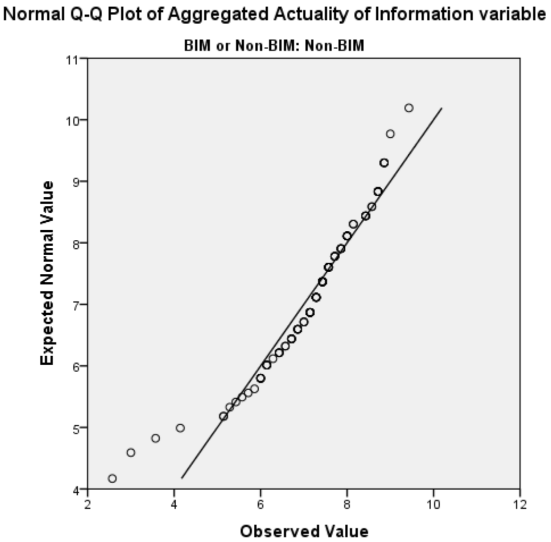
Hypothesis C4: Project participants in BIM projects will rate actuality of information through various channels higher than project participants in non BIM projects.

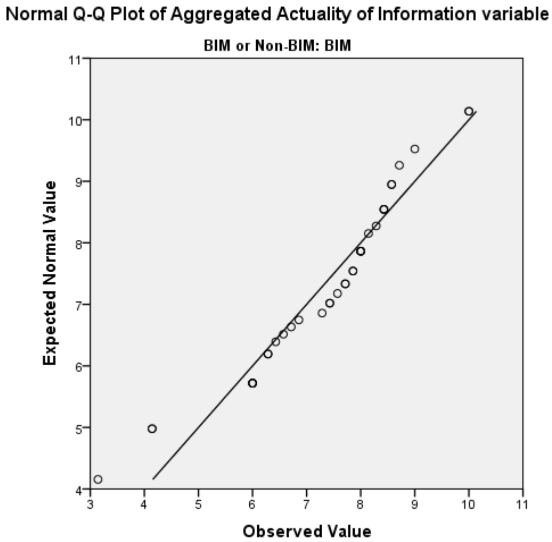
Statistics

		Aggregated Actuality of Information variable (Non BIM)	Aggregated Actuality of Information variable (BIM)
N	Valid	111	36
	Missing	4	2
Mean		7.1802	7.33333
Std. Deviation		1.18755	1.50296
Skewness		-1.222	-.855
Std. Error of Skewness		.229	,393
Z-score of Skewness		*-5.33624*	*-2.17557*
Kurtosis		2.827	1.083
Std. Error of Kurtosis		,455	,768
Z-score of Kurtosis		*6.213187*	*1.410156*









The table shows that the z-scores for the non-BIM data set are $Z_{skewness}$=-5.34 and $Z_{kurtosis}$=6.21, and for the BIM data set $Z_{skewness}$=-2.18 and $Z_{kurtosis}$=1.41. The Field test indicates that the non-BIM data set is significantly skewed and kurtosis for p=0.05. The test also indicates that the BIM data set significantly skewed for p=0.05 but not significantly kurtosis. This would indicate that the Non-BIM sample is not normally distributed, but the BIM sample is inconclusive.

The histograms confirm the skewness of the data set, but BIM histogram also clearly shows a peak in the frequencies. This contradicts the Field test for the not significant kurtosis of the BIM data set. The Q-Q plot of the BIM sample show clear deviations from the expected values in both the centre as the ends of the line. The Non-BIM group however only shows deviations at the ends, but these are large deviations. To conclude, the Field test indicates that the Non-BIM data set is non-normally distributed, but that the BIM group is inconclusive. The histogram confirms the test for the Non-BIM data set, but also indicates a kurtosis in the BIM data set. The Q-Q plot for the BIM data set also indicates a non-normal distributed sample. Therefore the Non-BIM data set is assumed to be non-normally distributed as well as the BIM data set.

ANOVA

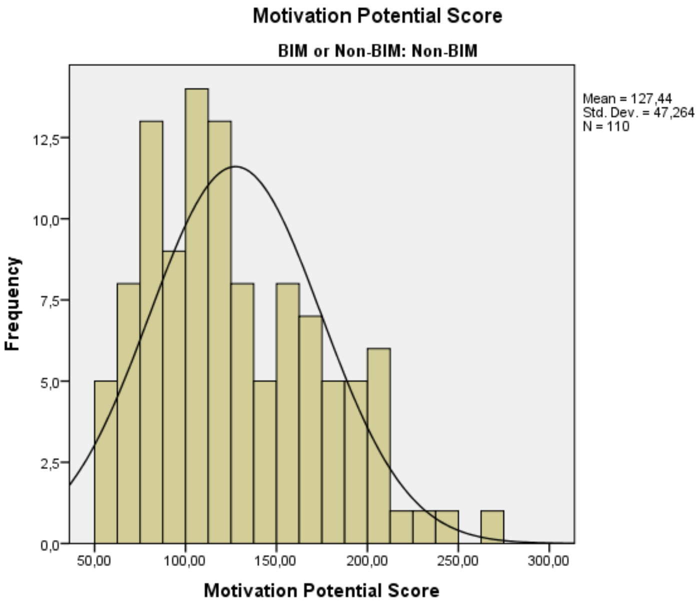
		Sum of Squares	df	Mean Square	F	Sig.
Non-parametric Levene's test for Aggregated Actuality of Information variable	Between Groups	1502,539	1	1502,539	3,302	,071
	Within Groups	65982,067	145	455,049		
	Total	67484,605	146			

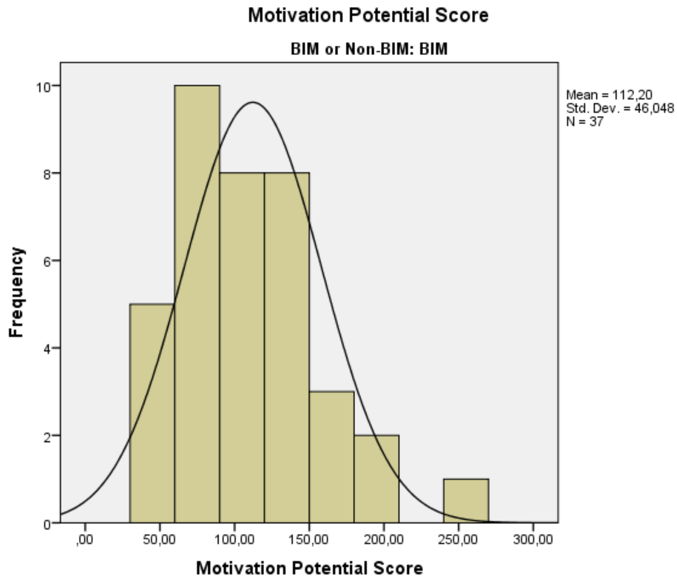
The test shows that there is no significant difference in variances, *F*(1,145)=3.302, p>0.05, meaning that the null hypothesis of equal variances cannot be rejected and therefore the variances should be assumed equal.

Hypothesis M1: Project participants in BIM projects will score a higher MPS than project participants in non BIM projects.

Statistics

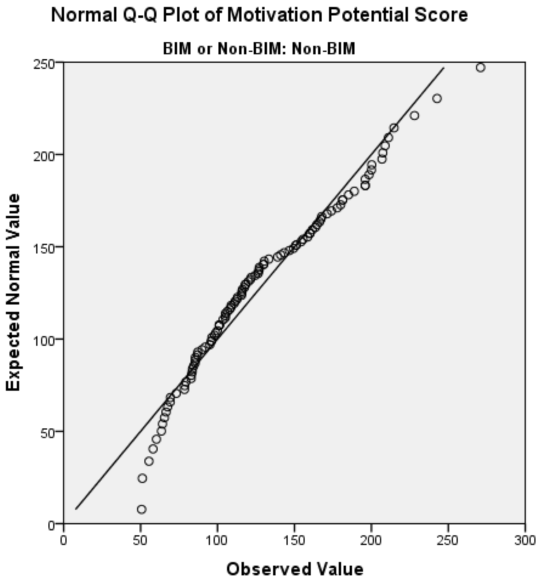
		MPS (Non BIM)	MPS (BIM)
N	Valid	110	37
	Missing	5	1
Mean		127.4359	112.1972
Std. Deviation		47.26436	46.04751
Skewness		.608	.917
Std. Error of Skewness		.230	.388
Z-score of Skewness		*2.643478*	*2.363402*
Kurtosis		-.255	.996
Std. Error of Kurtosis		.457	.759
Z-score of Kurtosis		*-0.55799*	*1.312253*

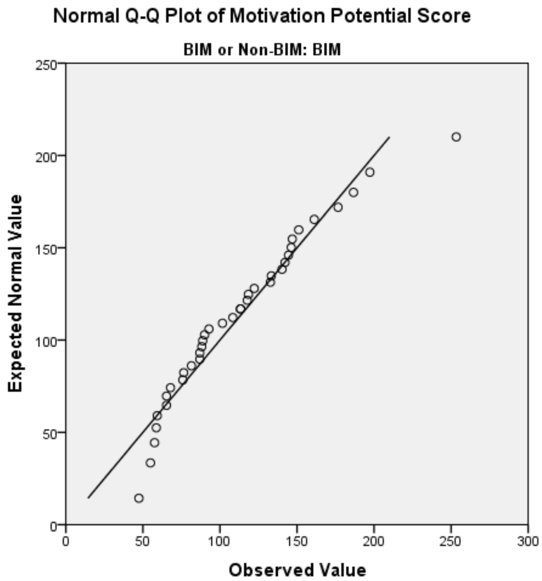




The table shows that the z-scores for the non-BIM data set are $Z_{skewness}$=2.64 and $Z_{kurtosis}$=-0.56, and for the BIM data set $Z_{skewness}$=2.36 and $Z_{kurtosis}$=1.31. The Field test indicates that both the non-BIM and BIM data sets are significantly skewed for p=0.05. The test also indicates that both sets are not significantly kurtosis. This means that the Field test does not provide a clear indication about the distributions of the data sets.

The histograms confirm the skewness of the data set found in the Field test. Although the histogram also shows a form of peakeness it is not clearly identifiable. Last, the Q-Q plot of both data sets show clear deviations from the expected values in both the centre as the ends of the line. To conclude, the Field test is inconclusive. The histograms confirm skewness and the Q-Q plots show clear deviations from the expected values. Therefore, it is assumed that both non-BIM and BIM data sets are non-normally distributed.





ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Non-parametric Levene's test for MPS	Between Groups	71,305	1	71,305	,165	,685
	Within Groups	62500,046	145	431,035		
	Total	62571,351	146			

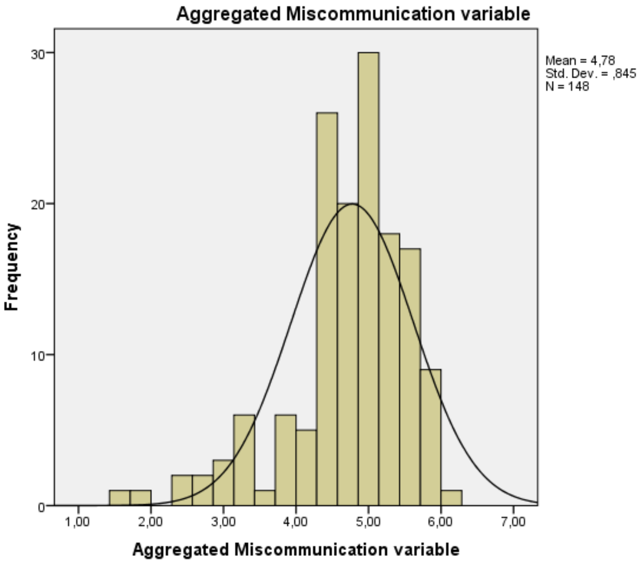
The test shows that there is no significant difference in variances, $F(1,145)=0.165$, $p>0.05$, meaning that the null hypothesis of equal variances cannot be rejected and therefore the variances should be assumed equal.

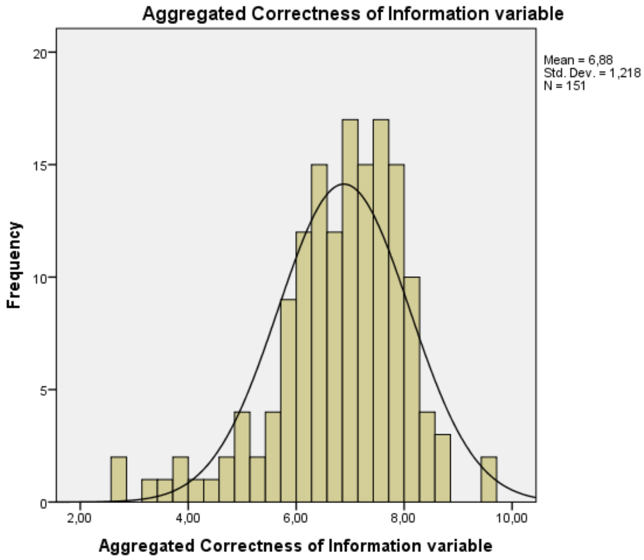
E.2 Validation hypotheses

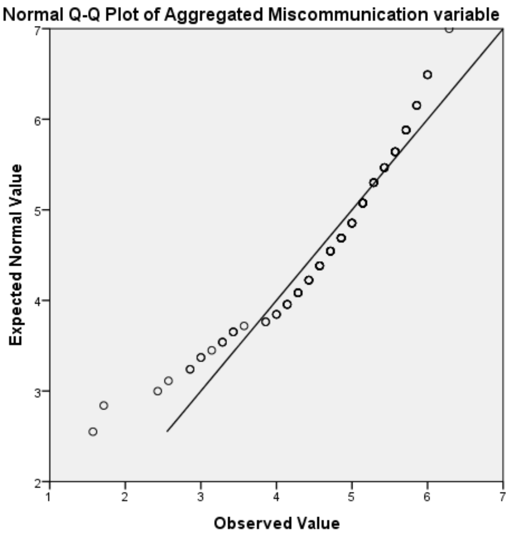
Hypothesis IV1: There is a negative relationship between the perception of communication failure and the height of rating correctness of information by project participants.

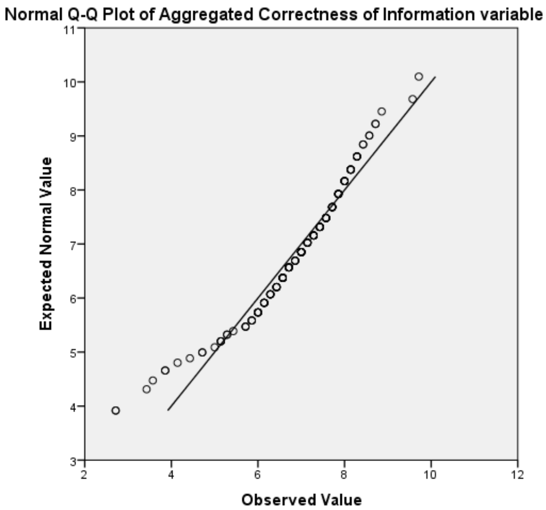
Statistics

		Aggregated Miscommunication variable	Aggregated Correction of Information variable
N	Valid	148	151
	Missing	5	2
Mean		4,7751	6,8827
Std. Deviation		,84459	1,21757
Skewness		-1,225	-0,953
Std. Error of Skewness		,199	,197
Z-score of Skewness		*-6.15578*	*-4.83756*
Kurtosis		2,024	1,618
Std. Error of Kurtosis		,396	,392
Z-score of Kurtosis		*5.11111*	*4.127551*









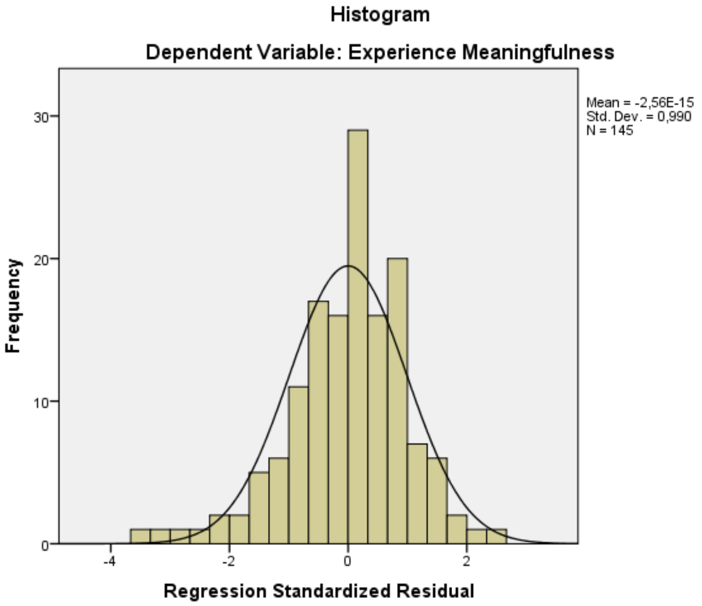
The skweness and kurtosis calculation show that both data sets are significantly skewed and kurtosis at p=0.05 as $Z_{skewness}$=-6.16 and $Z_{kurtosis}$=5.11 for Miscommunication, and $Z_{skewness}$=-4.84 and $Z_{kurtosis}$=4.13 for correctness of information. Again the histograms and Q-Q plots confirm these findings and so it should be concluded that both data sets violate the normality assumption and Spearman's ρ should be used as correlation coefficient.

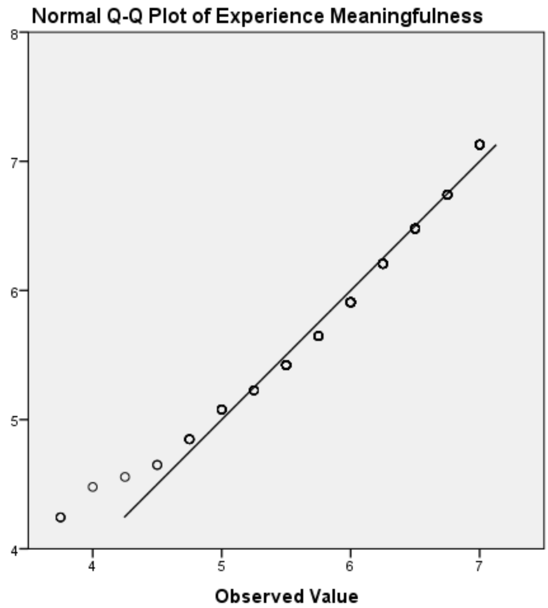
Hypothesis IV2 and IV3 also assume a relationship with the perception of miscommunication variable. When one of the data sets violates the normality assumption a comparison will be more robust when non-parametric test statistics are used. As the perception of miscommunication variable already violates the normality assumption, there is no need to test the rating of availability or actuality for normality. Also for these two hypothesis Spearman's ρ will be used to assess the correlation between the variables.

Hypothesis IV4: There is a positive relationship between the perception of Skill variety, Task identity, Task Significance and the experience of meaningfulness of the work.

Statistics

		Task Identity	Skill Variety	Task Significance	Experience Meaningfulness
N	Valid	149	151	150	151
	Missing	4	2	3	2
Mean		4,0134	5,3841	5,3689	5,9272
Std. Deviation		,68432	,91226	,84535	,73234
Skewness		-,112	-,413	-,532	-,724
Std. Error of Skewness		,199	,197	,198	,197
Z-score of Skewness		-0.56281	-2.09465	-2.68687	3.675127
Kurtosis		-,279	-,170	,052	,455
Std. Error of Kurtosis		,395	,392	,394	,392
Z-score of Kurtosis		-0.70633	-0.43367	1.319797	1.160714





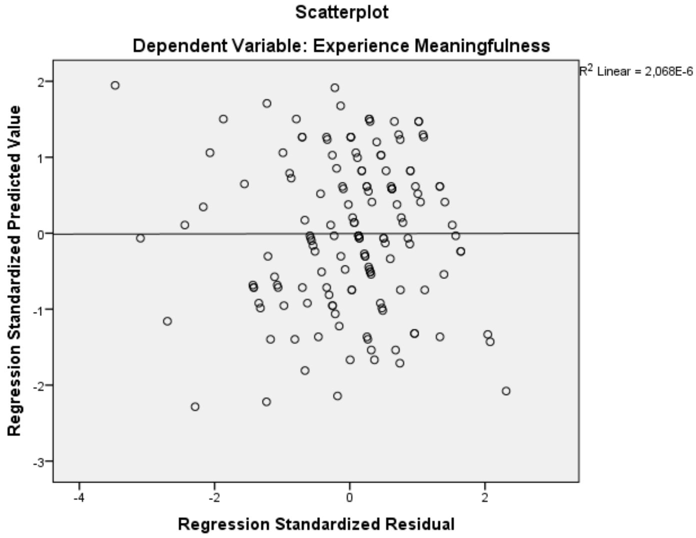
Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,367[a]	,135	,116	,69122	1,900

a. Predictors: (Constant), Task Significance, Task Identity, Skill Variety

b. Dependent Variable: Experience Meaningfulness

The Field test shows that Skill variety, Task significance and Experience meaningfulness al are significantly skewed, where Task identity is not. Furthermore all the data sets not significantly kurtosis. The histogram of the main depended variable does not confirm the skweness of the data, and also the Q-Q plot does not show clear deviations, expect for at the ends. This indicates that although the Field tests found a significant skweness, the data can still be assumed to be normally distributed.

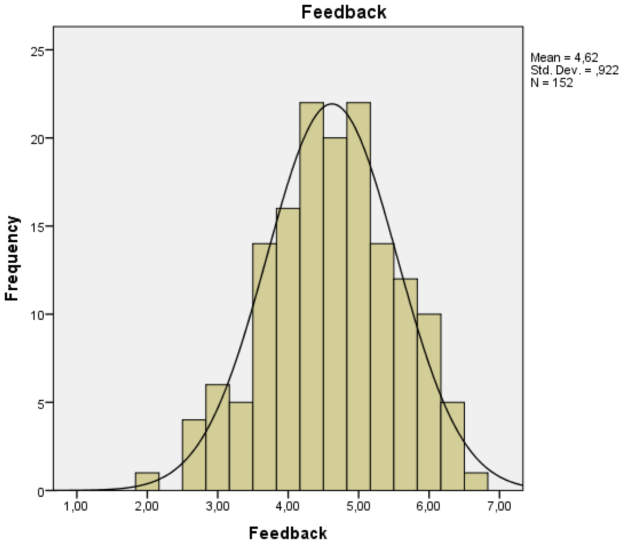


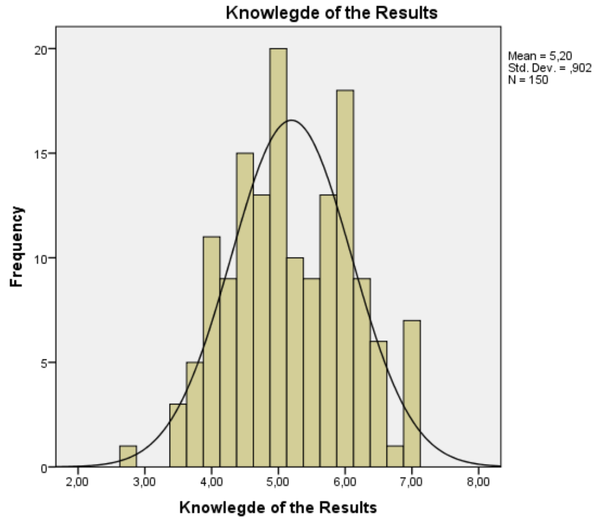
Next is the assumption of equal variances. This can be assessed by examining the scatterplot of residuals. With homoscadasticy, the data points should be equally spread across the plot. The plot shows the spread of data points. Although there is a clump around the 0, the dispersion of data points is rather equal. Therefore, equality of variances is assumed. The Durbin-Whatson statistic lies between 1 and 3 meaning independence of errors is also assumed. Based on the partial regression plots, the linearity of the model can also be assumed.

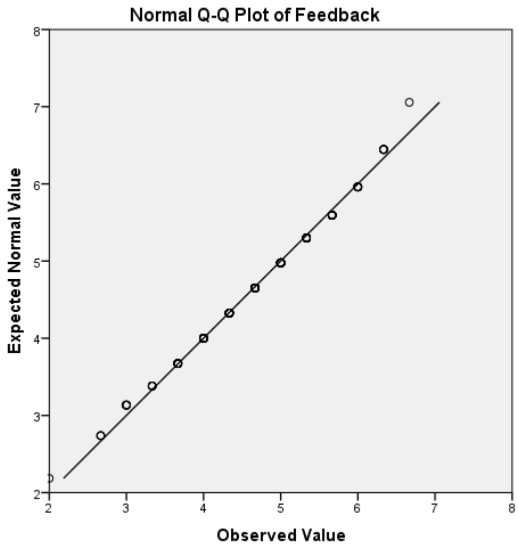
Hypothesis IV5: There is a positive relationship between the perception of feedback from the job itself and the experience of knowledge of the actual results of the work activities.

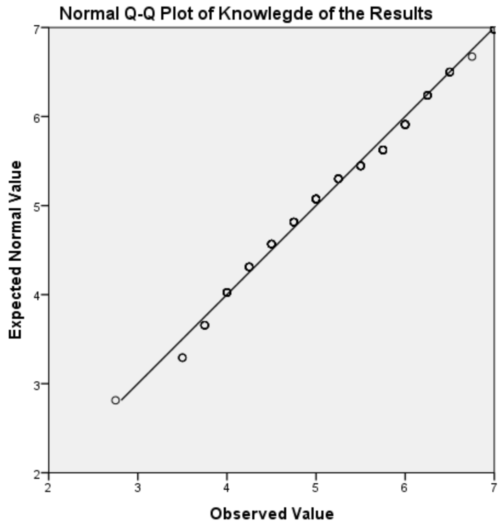
Statistics

		Feedback	Knowlegde of the Results
N	Valid	152	150
	Missing	1	3
Mean		4,6206	5,1950
Std. Error of Mean		,07475	,07369
Std. Deviation		,92153	,90249
Skewness		-,177	,034
Std. Error of Skewness		,197	,198
Z-score of Skewness		*-0.89848*	*0.171717*
Kurtosis		-,291	-,602
Std. Error of Kurtosis		,391	,394
Z-score of Kurtosis		*-0.74425*	*-1.52792*







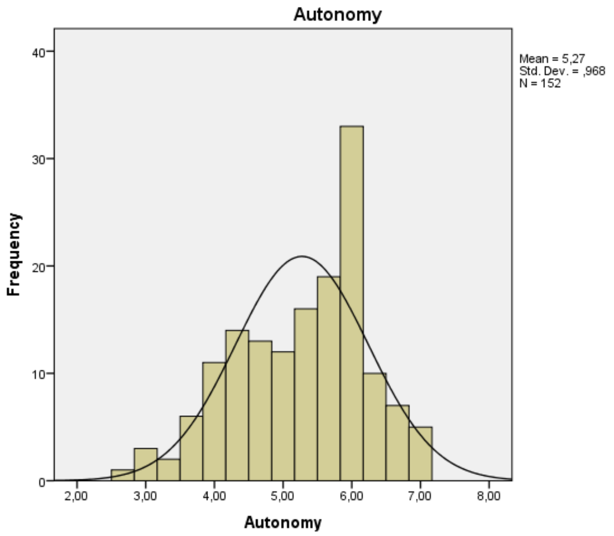


The skweness and kurtosis calculation show that both data sets are not significantly skewed and kurtosis at p=0.05 as $Z_{skewness}$=-0.9 and $Z_{kurtosis}$=0.17 for Feedback, and $Z_{skewness}$=-0.74 and $Z_{kurtosis}$=-1.53 for Knowledge of results. The histograms and Q-Q plots confirm these findings and so it should be concluded that both data sets are normally distributed. Therefore Pearsons's *r* is used to determine the relationship between these two variables.

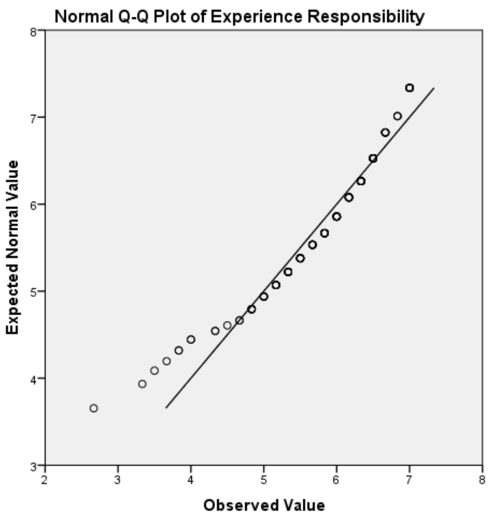
Hypothesis IV6: There is a positive relationship between the perception of autonomy and the experience of responsibility for the outcomes of the work.

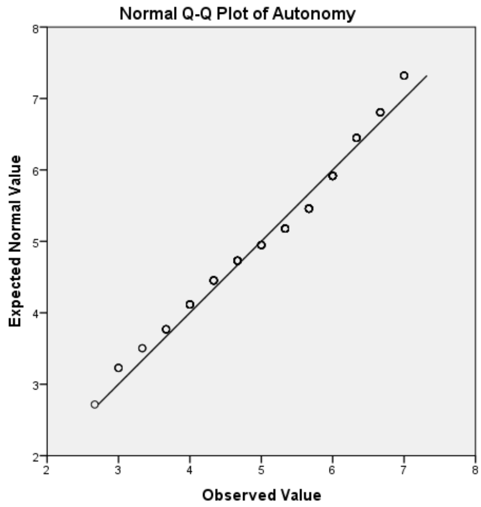
Statistics

		Experience Responsibility	Autonomy
N	Valid	151	152
	Missing	2	1
Mean		5,8091	5,2741
Std. Error of Mean		,06638	,07848
Std. Deviation		,81568	,96754
Skewness		-1,083	-,444
Std. Error of Skewness		,197	,197
Z-score of Skewness		*-5.49746*	*-2.2335*
Kurtosis		1,523	-,469
Std. Error of Kurtosis		,392	,391
Z-score of Kurtosis		*3.885204*	*-1.199949*



The Field test shows that both data sets are significantly skewed at p=0.05 as $Z_{skewness}$=-5.5 and for the experience of responsibility, and $Z_{skewness}$=-2.23 for Autonomy. The test also shows a significant kurtosis for responsibility, but not for the autonomy data set, with $Z_{kurtosis}$=3.89 and $Z_{kurtosis}$=-1.20 respectively.



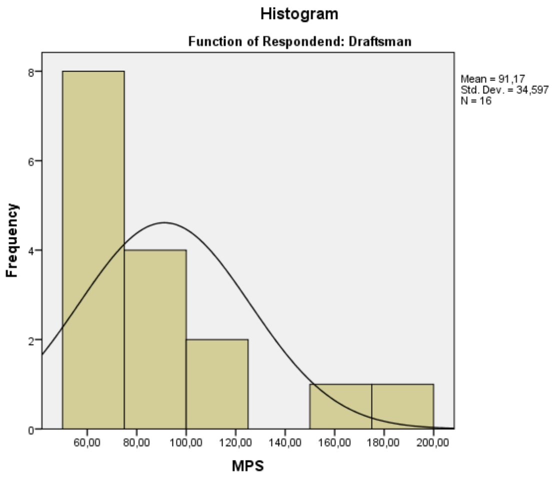


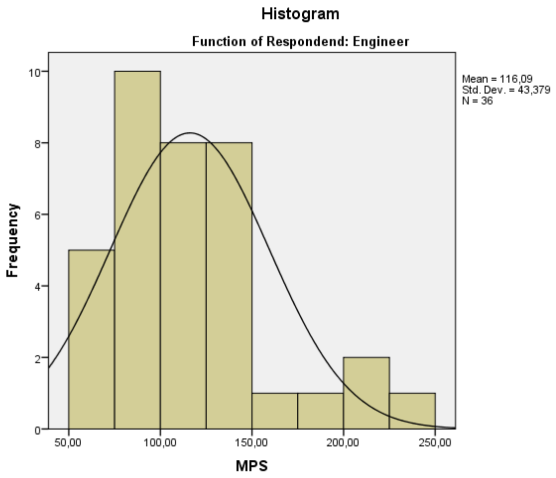
The histogram of responsibility clearly shows the skewness, but this is much less visible for the autonomy histogram. A similar observation can be done based on the Q-Q plots, where the Responsibility plot clearly shows deviations from the expected values, but the Autonomy plot is less clear. This means that although the autonomy data set can be assumed normal, the responsibility data set cannot. To prevent errors, the more robust coefficient of Spearman will be used.

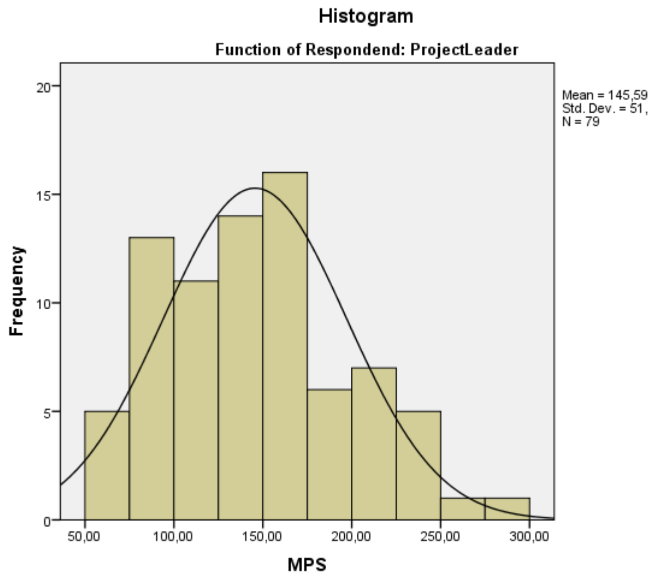
Hypothesis CV1, CV2 and CV3. The difference in MPS between job functions.

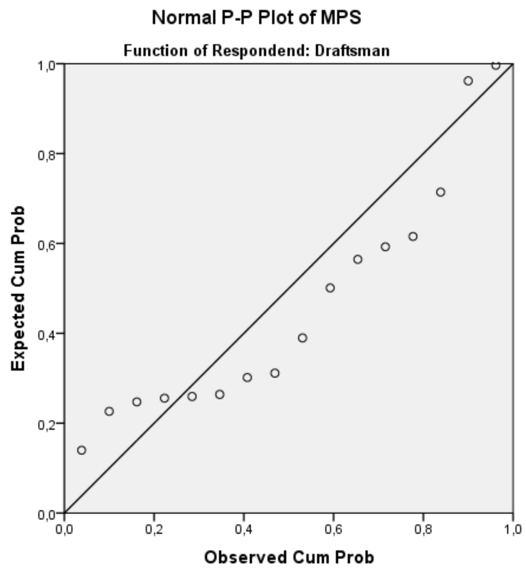
Statistics

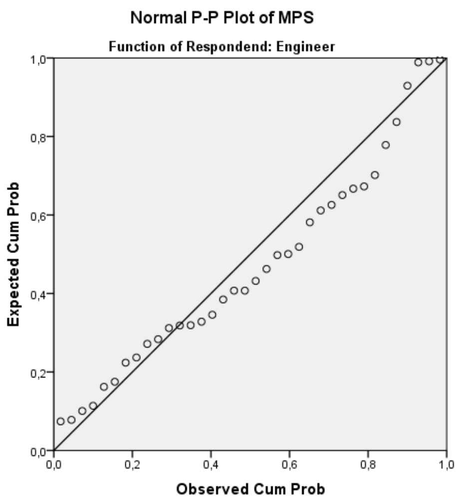
		Project Leader	Engineer	Draftsman
N	Valid	79	36	16
	Missing	2	0	3
Mean		145,5865	116,0885	91,1698
Std. Error of Mean		5,80052	7,22991	8,64914
Std. Deviation		51,56611	43,37946	34,59657
Skewness		,488	1,110	1,720
Std. Error of Skewness		,271	,393	0,564
Z-score of Skewness		*1,801*	*2,824*	*3,049*
Kurtosis		-,165	1,264	2,904
Std. Error of Kurtosis		,535	,768	1,091
Z-score of Kurtosis		*-0,308*	*1,646*	*2,662*

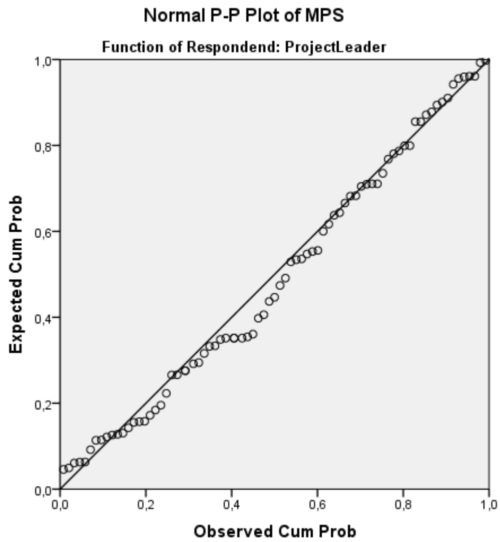

Histogram
Function of Respondend: Draftsman
Mean = 91,17
Std. Dev. = 34,597
N = 16
Frequency
MPS


Histogram
Function of Respondend: Engineer
Mean = 116,09
Std. Dev. = 43,379
N = 36
Frequency
MPS


Histogram
Function of Respondend: ProjectLeader
Mean = 145,59
Std. Dev. = 51,
N = 79
Frequency
MPS


Normal P-P Plot of MPS
Function of Respondend: Draftsman
Expected Cum Prob
Observed Cum Prob


Normal P-P Plot of MPS
Function of Respondend: Engineer
Expected Cum Prob
Observed Cum Prob


Normal P-P Plot of MPS
Function of Respondend: ProjectLeader
Expected Cum Prob
Observed Cum Prob

The Field test shows that the project leaders group is not significantly skewed or kurtosis, with $Z_{skewness}$=1.801 and $Z_{kurtosis}$=-0.308. The Engineers group is significantly skewed but not kurtosis, with $Z_{skewness}$=2.824 and $Z_{kurtosis}$=1.646, and the draftsman group is both significantly skewed and kurtosis, with $Z_{skewness}$=3.049 and $Z_{kurtosis}$=2.662.

The histograms confirm the skewness of the engineers and draftsman group, but also shows a left-sided tendency of the data for the project leaders group. The Q-Q plots of all three groups show clear deviations from the expected values. To conclude, even though the Field test do not indicate non-normality for the project leaders group and is inconclusive for the engineers group, do the histograms and Q-Q plots indicate non-normality for all three groups. Therefore, all data sets are assumed to be non-normally distributed.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Non-parametric Levene's test for Draftsman vs Engineers	Between Groups	353,697	1	353,697	,759	,388
	Within Groups	23311,861	50	466,237		
	Total	23665,558	51			

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Non-parametric Levene's test for Draftsman vs Project leaders	Between Groups	1204,259	1	1204,259	2,733	.102
	Within Groups	40975,971	93	440,602		
	Total	42180,230	94			

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Non-parametric Levene's test for Engineers vs Project leaders	Between Groups	369.031	1	369,031	,827	,365
	Within Groups	50409,849	113	446,105		
	Total	50778,881	114			

All three Levene's tests show that there is no significant difference in variances ($F(1,50)=0.759$, $p>0.05$, $F(1,93)=2.733$, $p>0.05$, $F(1,113)=0.827$, $p>0.05$) meaning that the null hypothesis of equal variances cannot be rejected and therefore the variances should be assumed equal.

Appendix F. Comparative hypotheses between BIM and non BIM groups

Hypothesis C1: BIM respondents will report a lower frequency of communication failure than non BIM respondents

The following box plot report the answers provided by the respondents to the survey. Note that a low value, means a high frequency as the values represent the following categories: 1 = Always, 2=Usually, 3=Frequent, 4=Sometimes, 5=Occasionally, 6= Rarely and 7= Never.

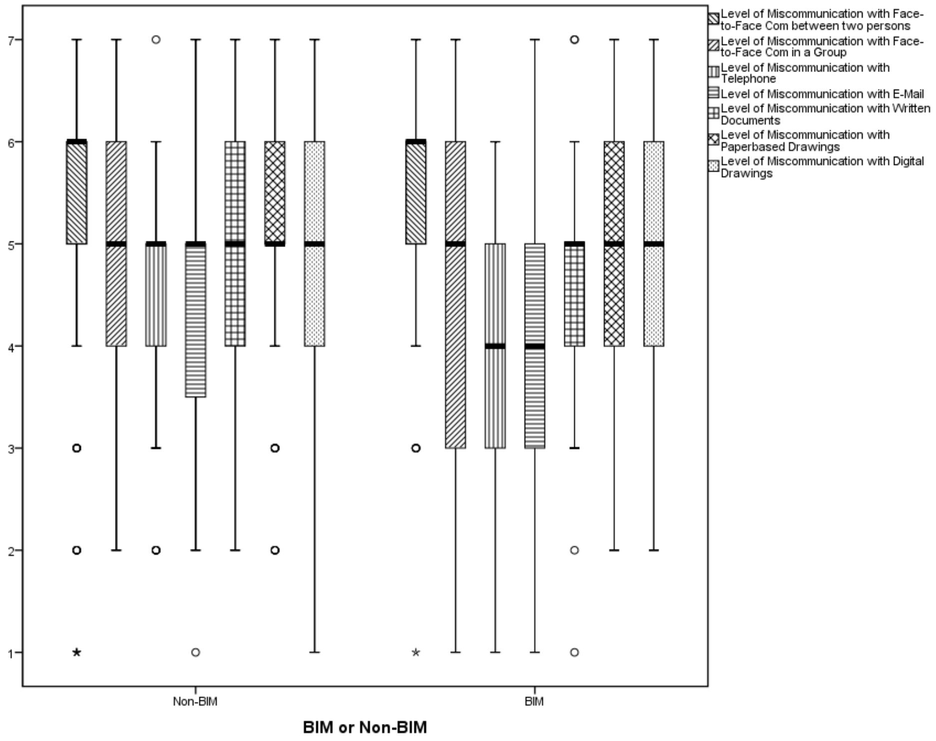


Figure 7: Box-plot of the responses on the Level of miscommunication split between BIM and non BIM

The box plot only shows the measures for central tendency and dispersion. A more exact distribution of responses is found in appendix G. The first thing to notice is that the median scores (the thick horizontal line) for the values of miscommunication via telephone and e-mail channels are lower in the BIM group, than in the non BIM group. This indicates that, in contradiction to the hypothesis, BIM respondents experience a higher level of miscommunication in those channels than the non BIM respondents. In general, both BIM and non BIM groups experience low levels of miscommunication as the scores are above the average of 4.

It is explained that multiple Likert type items can be aggregated to a single interval variable, by summing the responses over the seven channels per case. This single variable can then be used as an indication of the frequency of miscommunication experienced by the respondent. The table below shows the measures of central tendency and dispersion for this variable for both BIM and Non BIM groups.

	Total N	Valid N	Missing	Mean	Standard Deviation
Aggregated miscommunication variable (Non BIM)	115	111	4	4,84	,81
Aggregated miscommunication variable (BIM)	38	37	1	4,57	,93

Table 6: Aggregated miscommunication variable, split between BIM and non BIM

Again, the aggregated variable shows that on average non BIM respondents experience a lower frequency of miscommunication than the BIM respondents. The data indicates that the original hypothesis should be rejected based on the data found in the survey, and even suggests that BIM causes a higher level of miscommunication. Although the original hypothesis is rejected, a comparison of means can still provide a useful insight into the data.

	t-test for Equality of Means						
	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Independent Samples Test	1,705	146	,090	,27156	,15930	-,04328	,58639

	N	Mann-Whitney U	Non BIM N	BIM N	PS
Probability of Superiority	148	1.673,5	111	37	.40

On average, respondents of the non BIM group experienced a lower frequency of miscommunication (M= 4.84, SE=0.08) than respondents of the BIM group (M=4.57, SE=0.15). This difference was not significant with *t*(146)=1.71, p>0.5. The PS=0.4 which indicates a very small-sized effect following the conversion table to Cohen's *d* by (Grissom & Kim, 2005) (see Table 4). This means that the data does not confirm hypothesis C1, and that project participant in BIM projects do not report a different level of communication failure through various channels than project participants in non BIM projects.

Hypothesis C2: BIM respondents will rate correctness of information higher than non BIM respondents

The data does not confirm the hypothesis that BIM respondents will experience less communication failure, but now the hypothesis about the underlying constructs is tested starting with the construct of correctness of information. The following box plot reports the answers provided by the respondents to the survey. Note that the higher the value, the higher a respondents rates the correctness of information in projects.

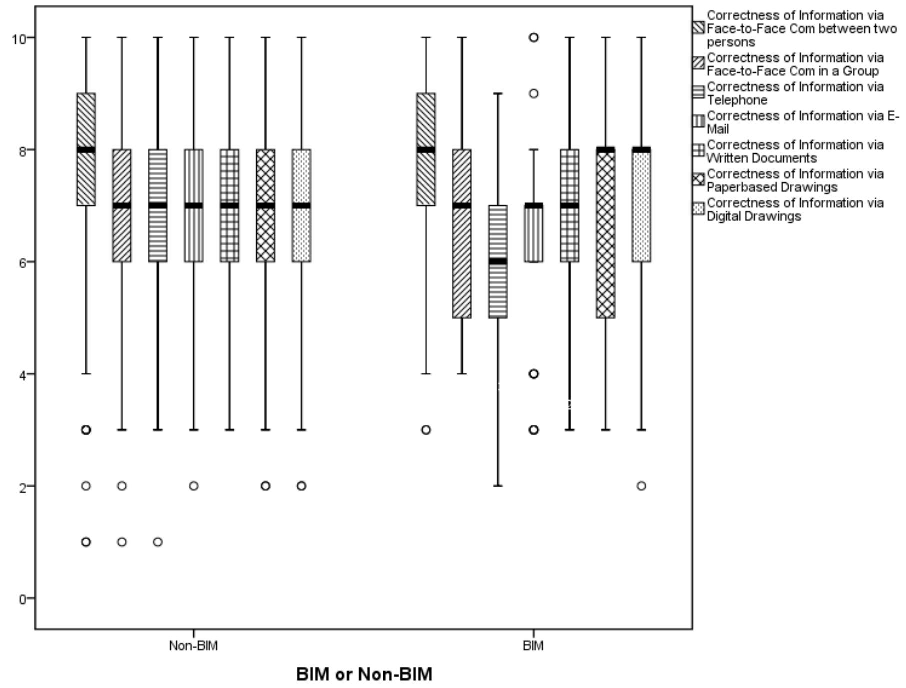


Figure 8: Box-plot of the rating of the correctness of information, split between BIM and non BIM

An observation of the plot show that on average BIM respondents report a lower correctness of information via the telephone, but higher correctness of information for both paper based and digital drawings. The increased correctness of information via drawings agrees with the BIM theory concerning the enhanced capabilities of the BIM media. On a more general note, one can also notice the correctness of information is rated a 7 out of 10 for most of the channels. It is also interesting to see that the answers of non BIM respondents are fairly equal among the different channels.

To examine the difference further the aggregated variable is calculated and shown below.

	Total N	Valid N	Missing	Mean	Standard Deviation
Aggregated correctness of information variable (Non BIM)	115	114	1	6,93	1,13
Aggregated correctness of information variable (BIM)	38	37	1	6,75	1,45

Table 7: Aggregated correctness of information variable, split between BIM and non BIM

The aggregated variables show that, even though the median scores are higher for both paper based and digital drawings, on average non BIM respondents rate correctness of information via various channels higher than the BIM respondents. The data indicates that the original hypothesis should be rejected based on the data found in the survey, and even suggests that BIM causes the correctness of information to be lower. Again, the statistical test will indicate whether this difference is significant or due to chance.

	t-test for Equality of Means						
	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Independent Samples Test	,767	149	,444	,17703	,23069	-,27881	,63287

	N	Mann-Whitney U	Non BIM N	BIM N	PS
Probability of Superiority	151	2.051,5	114	37	.49

On average, respondents of the non BIM group rate the correctness of information trough different channels higher (M= 6.93, SE=0.11) than respondents of the BIM group (M=6.75, SE=0.24). This difference was not significant with *t*(149)=0.767, p>0.5. The PS= 0.49 which indicates a very small-sized effect following the conversion table to Cohen's *d* by (Grissom & Kim, 2005). This means that the data does not confirm hypothesis C2, and that project participant in BIM projects do not rate correctness of information through various channels differently, than project participants in non BIM projects.

Hypothesis C3: BIM respondents will rate availability of information higher than non BIM respondents

The testing procedure for this hypothesis will follow an identical process as hypothesis C1 and C2. The following box plot reports the answers provided by the respondents to the survey. Note that the higher the value, the higher a respondents rates the availability of information in projects.

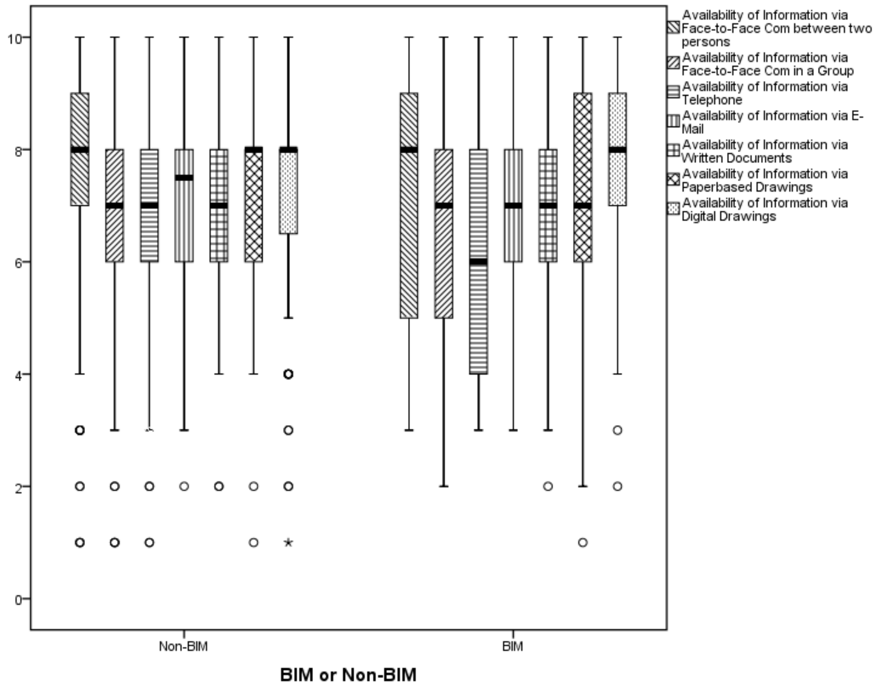


Figure 9: Box-plot of the rating of the Availability of information, split between BIM and non BIM

The plot shows that BIM respondents rate the availability of information lower than the non BIM respondents on 3 out of 7 channels. Nevertheless, the range of both telephone and drawing responses for the BIM group indicate that the lower median can be caused by the lower sample size. Even so, it does contradict the hypothesis and its underlying theoretical basis. On a more general note, one can also notice the availability of information is rated a 8 out of 10 for 3 of the 7 channels by the non BIM group, and the BIM group rates availability of information 7 out of 10. To examine the difference further the aggregated variable is calculated and shown below.

	Total N	Valid N	Missing	Mean	Standard Deviation
Aggregated availability of information variable (Non BIM)	115	112	3	7.14	1.39
Aggregated availability of information variable (BIM)	38	38	0	6.95	1.58

Table 8: Aggregated Availability of information variable, split between BIM and non BIM

The aggregated variables confirms the before observed contradiction to the hypothesis. The data indicates that the original hypothesis should be rejected based on the data found in the survey, and even suggests that BIM causes the correctness of information to be lower. The statistical test provided the following result.

	t-test for Equality of Means						
	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Independent Samples Test	,694	148	,489	,18797	,27083	-,34722	,72316

	N	Mann-Whitney U	Non BIM N	BIM N	PS
Probability of Superiority	150	1.931,5	112	38	.45

On average, respondents of the non BIM group rate the availability of information trough different channels higher (M= 7.14, SE=0.13) than respondents of the BIM group (M=6.95, SE=0.26). This difference was not significant with $t(148)=0.694$, $p>0.5$. The PS= 0.45 indicates a very small-sized effect following the conversion table to Cohen's *d* by (Grissom & Kim, 2005).This means that the data does not confirm hypothesis C3, and that project participant in BIM projects do not rate availability of information through various channels differently, than project participants in non BIM projects.

Hypothesis C4: BIM respondents will rate actuality of information higher than non BIM respondents

Hypothesis C4 is the last comparative communication hypothesis. The following tables and graphs report the answers provided by the respondents to the survey. Note that the higher the value, the higher a respondents rates the actuality of information in projects.

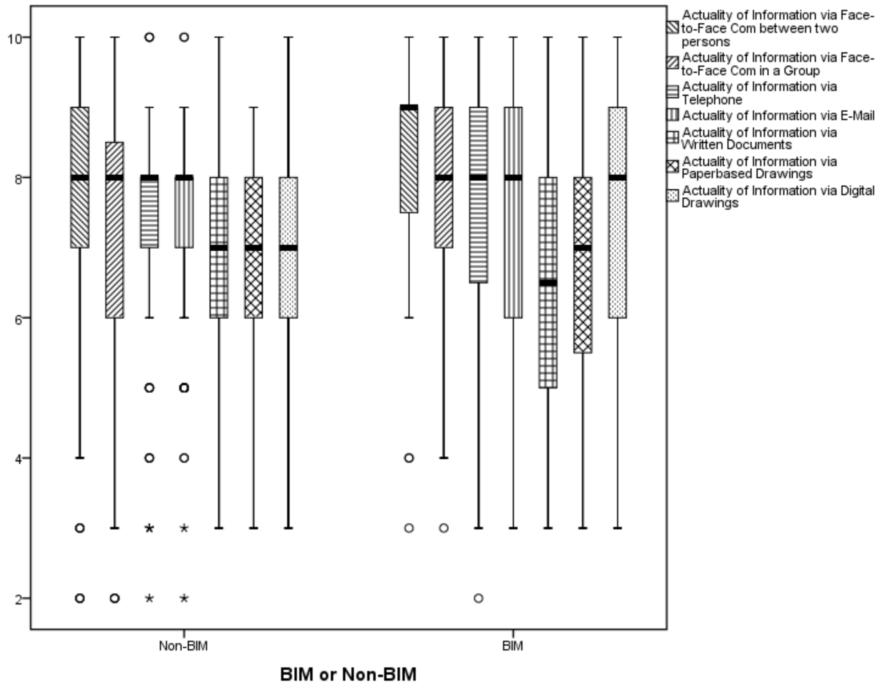


Figure 10: Box-plot of the rating of the Actuality of information, split between BIM and non BIM

An observation of these values shows that BIM respondents rate the actuality of information via face-to-face communication between two persons and digital drawings higher than the non BIM group. These observations support the hypothesis. Also the range of answers is lower for the face-to-face between two persons channel, which could indicate a higher consensus among respondents on that subject in respect the non BIM respondents. The range of responses on the actuality of information via telephone and e-mail for the non BIM group indicate a high consensus among the respondents with only outliers in the lower region. To examine the difference further the aggregated variable is calculated and shown below.

	Total N	Valid N	Missing	Mean	Standard Deviation
Aggregated actuality of information variable (Non BIM)	115	111	4	7.18	1.19
Aggregated actuality of information variable (BIM)	38	36	2	7.33	1.50

Table 9: Aggregated actuality of information variable, split between BIM and non BIM

The aggregated variables confirms the before observed support to the hypothesis. On average non BIM respondents rate actuality of information via various channels lower than the BIM respondents. The data indicates that the original hypothesis is confirmed based on the data found in the survey. However, the difference in mean and standard deviation is still very small and it is expected that the difference between means is not caused by BIM, but due to probability of sampling. A comparison of means can provide a useful insight whether the observed difference is significant or not.

	t-test for Equality of Means						
	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Independent Samples Test	-,628	145	,531	-,15315	,24375	-,63492	,32861

	N	Mann-Whitney U	Non BIM N	BIM N	PS
Probability of Superiority	147	2,229.5	111	36	.56

On average, respondents of the non BIM group rate the availability of Information trough different channels lower (M= 7.18, SE=0.11) than respondents of the BIM group (M=7.33, SE=0.25). This difference was not significant with *t*(145)=0.628, p>0.5. The PS= 0.56 still indicates a small-sized effect, but it is on the border of a medium-sized effect following the conversion table to Cohen's *d* by (Grissom & Kim, 2005). This means that the data does not confirm hypothesis C4, and that project participant in BIM projects do not rate actuality of information through various channels differently, than project participants in non BIM projects.

Appendix G. Results of the study

G.1 Non-BIM Group

		Department of Respondend	Function of Respondend	Time in Function	Time in Sector	Level of Miscommunication with Face-to-Face Com between two persons	Level of Miscommunication with Face-to-Face Com in a Group	Level of Miscommunication with Telephone
N	Valid	115	115	114	115	114	113	114
	Missing	0	0	1	0	1	2	1
Median		2,00	3,00	2,00	3,00	6,00	5,00	5,00
Variance		,236	,910	1,279	,767	1,808	1,278	1,119

		Level of Miscommunication with E-Mail	Level of Miscommunication with Written Documents	Level of Miscommunication with Paperbased Drawings	Level of Miscommunication with Digital Drawings	Correctness of Information via Face-to-Face Com between two persons	Correctness of Information via Face-to-Face Com in a Group	Correctness of Information via Telephone
N	Valid	115	113	113	114	115	114	115
	Missing	0	2	2	1	0	1	0
Median		5,00	5,00	5,00	5,00	8,00	7,00	7,00
Variance		1,665	1,254	1,212	1,397	3,457	2,929	2,479

		Correctness of Information via E-Mail	Correctness of Information via Written Documents	Correctness of Information via Paperbased Drawings	Correctness of Information via Digital Drawings	Actuality of Information via Face-to-Face Com between two persons	Actuality of Information via Face-to-Face Com in a Group	Actuality of Information via Telephone
N	Valid	115	115	115	115	112	112	112
	Missing	0	0	0	0	3	3	3
Median		7,00	7,00	7,00	7,00	8,00	8,00	8,00
Variance		2,360	2,213	2,424	2,473	2,964	3,185	2,432

		Actuality of Information via E-Mail	Actuality of Information via Written Documents	Actuality of Information via Paperbased Drawings	Actuality of Information via Digital Drawings	Availability of Information via Face-to-Face Com between two persons	Availability of Information via Face-to-Face Com in a Group	Availability of Information via Telephone
N	Valid	113	113	113	113	114	113	115
	Missing	2	2	2	2	1	2	0
Median		8,00	7,00	7,00	7,00	8,00	7,00	7,00
Variance		2,157	2,066	2,444	2,499	4,482	4,267	3,264

		Availability of Information via E-Mail	Availability of Information via Written Documents	Availability of Information via Paperbased Drawings	Availability of Information via Digital Drawings	AutonomieDir	TaskidentitieDir	TaskVariatyDir
N	Valid	115	114	115	115	115	114	114
	Missing	0	1	0	0	0	1	1
Median		8,00	7,00	8,00	8,00	5,00	5,00	5,00
Variance		2,418	2,402	2,761	3,337	1,097	1,353	1,201

		Task Significance Dir	FeedbackDir	Eigen Baan Karakteristieken stelling 1	Eigen Baan Karakteristieken stelling 2	Eigen Baan Karakteristieken stelling 3	Eigen Baan Karakteristieken stelling 4	Eigen Baan Karakteristieken stelling 5
N	Valid	115	115	114	114	114	114	113
	Missing	0	0	1	1	1	1	2
Median		5,00	4,00	2,00	1,50	6,00	6,00	7,00
Variance		,881	1,096	,799	1,452	1,679	1,915	2,342

		Eigen Baan Karakteristieken stelling 6	Eigen Baan Karakteristieken stelling 7	Eigen Baan Karakteristieken stelling 8	Eigen Baan Omschrijving stelling 1	Eigen Baan Omschrijving stelling 2	Eigen Baan Omschrijving stelling 3	Eigen Baan Omschrijving stelling 4
N	Valid	114	114	114	114	114	114	113
	Missing	1	1	1	1	1	1	2
Median		2,00	6,00	6,00	6,00	6,00	5,00	2,00
Variance		2,675	2,522	2,270	,887	1,290	1,201	1,654

		Eigen Baan Omschrijving stelling 5	Eigen Baan Omschrijving stelling 6	Eigen Baan Omschrijving stelling 7	Eigen Baan Omschrijving stelling 8	Eigen Baan Omschrijving stelling 9	Eigen Baan Omschrijving stelling 10	Andermans Baan Stelling 1
N	Valid	113	114	113	114	114	113	115
	Missing	2	1	2	1	1	2	0
Median		5,00	2,00	5,00	3,00	6,00	2,00	2,00
Variance		1,174	2,100	2,018	1,983	1,146	1,508	1,050

		Andermans Baan Stelling 2	Andermans Baan Stelling 3	Andermans Baan Stelling 4	Andermans Baan Stelling 5	Andermans Baan Stelling 6
N	Valid	115	114	115	115	114
	Missing	0	1	0	0	1
Median		6,00	5,00	6,00	6,00	3,00
Variance		1,486	1,275	1,182	1,357	2,379

Department of Respondend[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Stedelijk Gebied	43	37,4	37,4	37,4
	Bouw & Vastgoed	72	62,6	62,6	100,0
	Total	115	100,0	100,0	

a. BIM or Non-BIM = Non-BIM

Function of Respondend[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Draftsman	11	9,6	9,6	9,6
	Engineer	23	20,0	20,0	29,6
	ProjectLeader	67	58,3	58,3	87,8
	Teamleader	5	4,3	4,3	92,2
	Work Supervisor	9	7,8	7,8	100,0
	Total	115	100,0	100,0	

a. BIM or Non-BIM = Non-BIM

Time in Sector[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	less than 5 years	6	5,2	5,2	5,2
	between 5 and 15 years	30	26,1	26,1	31,3
	between 15 and 30 years	45	39,1	39,1	70,4
	more than thirty years	34	29,6	29,6	100,0
	Total	115	100,0	100,0	

a. BIM or Non-BIM = Non-BIM

Level of Miscommunication with Face-to-Face Com between two persons[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Altijd	3	2,6	2,6	2,6
	Meestal	5	4,3	4,4	7,0
	Frequent	6	5,2	5,3	12,3
	Gemiddeld	9	7,8	7,9	20,2
	Soms	26	22,6	22,8	43,0
	Zelden	59	51,3	51,8	94,7
	Nooit	6	5,2	5,3	100,0
	Total	114	99,1	100,0	
Missing	System	1	,9		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Level of Miscommunication with Face-to-Face Com in a Group[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Meestal	5	4,3	4,4	4,4
	Frequent	9	7,8	8,0	12,4
	Gemiddeld	26	22,6	23,0	35,4
	Soms	36	31,3	31,9	67,3
	Zelden	36	31,3	31,9	99,1
	Nooit	1	,9	,9	100,0
	Total	113	98,3	100,0	
Missing	System	2	1,7		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Level of Miscommunication with Telephone[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Meestal	5	4,3	4,4	4,4
	Frequent	12	10,4	10,5	14,9
	Gemiddeld	37	32,2	32,5	47,4
	Soms	40	34,8	35,1	82,5
	Zelden	19	16,5	16,7	99,1
	Nooit	1	,9	,9	100,0
	Total	114	99,1	100,0	
Missing	System	1	,9		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Level of Miscommunication with E-Mail[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Altijd	1	,9	,9	,9
	Meestal	10	8,7	8,7	9,6
	Frequent	17	14,8	14,8	24,3
	Gemiddeld	27	23,5	23,5	47,8
	Soms	34	29,6	29,6	77,4
	Zelden	25	21,7	21,7	99,1
	Nooit	1	,9	,9	100,0
	Total	115	100,0	100,0	

a. BIM or Non-BIM = Non-BIM

Level of Miscommunication with Written Documents[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Meestal	4	3,5	3,5	3,5
	Frequent	10	8,7	8,8	12,4
	Gemiddeld	24	20,9	21,2	33,6
	Soms	38	33,0	33,6	67,3
	Zelden	35	30,4	31,0	98,2
	Nooit	2	1,7	1,8	100,0
	Total	113	98,3	100,0	
Missing	System	2	1,7		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Level of Miscommunication with Paperbased Drawings[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Meestal	4	3,5	3,5	3,5
	Frequent	5	4,3	4,4	8,0
	Gemiddeld	16	13,9	14,2	22,1
	Soms	32	27,8	28,3	50,4
	Zelden	52	45,2	46,0	96,5
	Nooit	4	3,5	3,5	100,0
	Total	113	98,3	100,0	
Missing	System	2	1,7		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Level of Miscommunication with Digital Drawings[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Altijd	2	1,7	1,8	1,8
	Meestal	2	1,7	1,8	3,5
	Frequent	10	8,7	8,8	12,3
	Gemiddeld	16	13,9	14,0	26,3
	Soms	41	35,7	36,0	62,3
	Zelden	40	34,8	35,1	97,4
	Nooit	3	2,6	2,6	100,0
	Total	114	99,1	100,0	
Missing	System	1	,9		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Correctness of Information via Face-to-Face Com between two persons[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal Oncorrect	2	1,7	1,7	1,7
	2	1	,9	,9	2,6
	3	5	4,3	4,3	7,0
	4	2	1,7	1,7	8,7
	5	5	4,3	4,3	13,0
	6	5	4,3	4,3	17,4
	7	27	23,5	23,5	40,9
	8	34	29,6	29,6	70,4
	9	29	25,2	25,2	95,7
	Helemaal Correct	5	4,3	4,3	100,0
	Total	115	100,0	100,0	

a. BIM or Non-BIM = Non-BIM

Correctness of Information via Face-to-Face Com in a Group[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal Oncorrect	1	,9	,9	,9
	2	1	,9	,9	1,8
	3	6	5,2	5,3	7,0
	4	6	5,2	5,3	12,3
	5	6	5,2	5,3	17,5
	6	17	14,8	14,9	32,5
	7	31	27,0	27,2	59,6
	8	35	30,4	30,7	90,4
	9	10	8,7	8,8	99,1
	Helemaal Correct	1	,9	,9	100,0
	Total	114	99,1	100,0	
Missing	System	1	,9		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Correctness of Information via Telephone[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal Oncorrect	1	,9	,9	,9
	3	4	3,5	3,5	4,3
	4	8	7,0	7,0	11,3
	5	11	9,6	9,6	20,9
	6	27	23,5	23,5	44,3
	7	32	27,8	27,8	72,2
	8	23	20,0	20,0	92,2
	9	8	7,0	7,0	99,1
	Helemaal Correct	1	,9	,9	100,0
	Total	115	100,0	100,0	

a. BIM or Non-BIM = Non-BIM

Correctness of Information via E-Mail[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	1	,9	,9	,9
	3	1	,9	,9	1,7
	4	7	6,1	6,1	7,8
	5	13	11,3	11,3	19,1
	6	19	16,5	16,5	35,7
	7	31	27,0	27,0	62,6
	8	27	23,5	23,5	86,1
	9	15	13,0	13,0	99,1
	Helemaal Correct	1	,9	,9	100,0
	Total	115	100,0	100,0	

a. BIM or Non-BIM = Non-BIM

Correctness of Information via Written Documents[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	3	2,6	2,6	2,6
	4	6	5,2	5,2	7,8
	5	12	10,4	10,4	18,3
	6	18	15,7	15,7	33,9
	7	31	27,0	27,0	60,9
	8	33	28,7	28,7	89,6
	9	11	9,6	9,6	99,1
	Helemaal Correct	1	,9	,9	100,0
	Total	115	100,0	100,0	

a. BIM or Non-BIM = Non-BIM

Correctness of Information via Paperbased Drawings[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	2	1,7	1,7	1,7
	3	2	1,7	1,7	3,5
	4	5	4,3	4,3	7,8
	5	7	6,1	6,1	13,9
	6	14	12,2	12,2	26,1
	7	33	28,7	28,7	54,8
	8	35	30,4	30,4	85,2
	9	16	13,9	13,9	99,1
	Helemaal Correct	1	,9	,9	100,0
	Total	115	100,0	100,0	

a. BIM or Non-BIM = Non-BIM

Correctness of Information via Digital Drawings[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	2	1,7	1,7	1,7
	3	2	1,7	1,7	3,5
	4	6	5,2	5,2	8,7
	5	8	7,0	7,0	15,7
	6	13	11,3	11,3	27,0
	7	33	28,7	28,7	55,7
	8	36	31,3	31,3	87,0
	9	14	12,2	12,2	99,1
	Helemaal Correct	1	,9	,9	100,0
	Total	115	100,0	100,0	

a. BIM or Non-BIM = Non-BIM

Actuality of Information via Face-to-Face Com between two persons[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	3	2,6	2,7	2,7
	3	3	2,6	2,7	5,4
	4	2	1,7	1,8	7,1
	5	1	,9	,9	8,0
	6	7	6,1	6,3	14,3
	7	19	16,5	17,0	31,3
	8	36	31,3	32,1	63,4
	9	33	28,7	29,5	92,9
	Helemaal Correct	8	7,0	7,1	100,0
	Total	112	97,4	100,0	
Missing	System	3	2,6		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Actuality of Information via Face-to-Face Com in a Group[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	3	2,6	2,7	2,7
	3	4	3,5	3,6	6,3
	4	1	,9	,9	7,1
	5	7	6,1	6,3	13,4
	6	16	13,9	14,3	27,7
	7	21	18,3	18,8	46,4
	8	32	27,8	28,6	75,0
	9	23	20,0	20,5	95,5
	Helemaal Correct	5	4,3	4,5	100,0
	Total	112	97,4	100,0	
Missing	System	3	2,6		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Actuality of Information via Telephone[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	1	,9	,9	,9
	3	3	2,6	2,7	3,6
	4	3	2,6	2,7	6,3
	5	4	3,5	3,6	9,8
	6	12	10,4	10,7	20,5
	7	20	17,4	17,9	38,4
	8	41	35,7	36,6	75,0
	9	25	21,7	22,3	97,3
	Helemaal Correct	3	2,6	2,7	100,0
	Total	112	97,4	100,0	
Missing	System	3	2,6		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Actuality of Information via E-Mail[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	1	,9	,9	,9
	3	1	,9	,9	1,8
	4	2	1,7	1,8	3,5
	5	9	7,8	8,0	11,5
	6	14	12,2	12,4	23,9
	7	28	24,3	24,8	48,7
	8	32	27,8	28,3	77,0
	9	24	20,9	21,2	98,2
	Helemaal Correct	2	1,7	1,8	100,0
	Total	113	98,3	100,0	
Missing	System	2	1,7		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Actuality of Information via Written Documents[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	2	1,7	1,8	1,8
	4	8	7,0	7,1	8,8
	5	10	8,7	8,8	17,7
	6	27	23,5	23,9	41,6
	7	31	27,0	27,4	69,0
	8	25	21,7	22,1	91,2
	9	9	7,8	8,0	99,1
	Helemaal Correct	1	,9	,9	100,0
	Total	113	98,3	100,0	
Missing	System	2	1,7		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Actuality of Information via Paperbased Drawings[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	4	3,5	3,5	3,5
	4	8	7,0	7,1	10,6
	5	12	10,4	10,6	21,2
	6	22	19,1	19,5	40,7
	7	28	24,3	24,8	65,5
	8	26	22,6	23,0	88,5
	9	13	11,3	11,5	100,0
	Total	113	98,3	100,0	
Missing	System	2	1,7		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Actuality of Information via Digital Drawings[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	3	2,6	2,7	2,7
	4	7	6,1	6,2	8,8
	5	5	4,3	4,4	13,3
	6	22	19,1	19,5	32,7
	7	23	20,0	20,4	53,1
	8	33	28,7	29,2	82,3
	9	17	14,8	15,0	97,3
	Helemaal Correct	3	2,6	2,7	100,0
	Total	113	98,3	100,0	
Missing	System	2	1,7		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Availability of Information via Face-to-Face Com between two persons[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal Oncorrect	3	2,6	2,6	2,6
	2	2	1,7	1,8	4,4
	3	5	4,3	4,4	8,8
	4	3	2,6	2,6	11,4
	5	3	2,6	2,6	14,0
	6	6	5,2	5,3	19,3
	7	17	14,8	14,9	34,2
	8	36	31,3	31,6	65,8
	9	27	23,5	23,7	89,5
	Helemaal Correct	12	10,4	10,5	100,0
	Total	114	99,1	100,0	
Missing	System	1	,9		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Availability of Information via Face-to-Face Com in a Group[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal Oncorrect	3	2,6	2,7	2,7
	2	2	1,7	1,8	4,4
	3	5	4,3	4,4	8,8
	4	2	1,7	1,8	10,6
	5	12	10,4	10,6	21,2
	6	12	10,4	10,6	31,9
	7	22	19,1	19,5	51,3
	8	31	27,0	27,4	78,8
	9	17	14,8	15,0	93,8
	Helemaal Correct	7	6,1	6,2	100,0
	Total	113	98,3	100,0	
Missing	System	2	1,7		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Availability of Information via Telephone[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal Oncorrect	2	1,7	1,7	1,7
	2	2	1,7	1,7	3,5
	3	3	2,6	2,6	6,1
	4	8	7,0	7,0	13,0
	5	8	7,0	7,0	20,0
	6	13	11,3	11,3	31,3
	7	31	27,0	27,0	58,3
	8	37	32,2	32,2	90,4
	9	9	7,8	7,8	98,3
	Helemaal Correct	2	1,7	1,7	100,0
	Total	115	100,0	100,0	

a. BIM or Non-BIM = Non-BIM

Availability of Information via E-Mail[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	1	,9	,9	,9
	3	2	1,7	1,7	2,6
	4	3	2,6	2,6	5,2
	5	10	8,7	8,7	13,9
	6	13	11,3	11,3	25,2
	7	28	24,3	24,3	49,6
	8	37	32,2	32,2	81,7
	9	16	13,9	13,9	95,7
	Helemaal Correct	5	4,3	4,3	100,0
	Total	115	100,0	100,0	

a. BIM or Non-BIM = Non-BIM

Availability of Information via Written Documents[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	2	1,7	1,8	1,8
	4	4	3,5	3,5	5,3
	5	13	11,3	11,4	16,7
	6	15	13,0	13,2	29,8
	7	29	25,2	25,4	55,3
	8	35	30,4	30,7	86,0
	9	12	10,4	10,5	96,5
	Helemaal Correct	4	3,5	3,5	100,0
	Total	114	99,1	100,0	
Missing	System	1	,9		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Availability of Information via Paperbased Drawings[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal Oncorrect	1	,9	,9	,9
	2	1	,9	,9	1,7
	4	4	3,5	3,5	5,2
	5	12	10,4	10,4	15,7
	6	13	11,3	11,3	27,0
	7	20	17,4	17,4	44,3
	8	36	31,3	31,3	75,7
	9	24	20,9	20,9	96,5
	Helemaal Correct	4	3,5	3,5	100,0
	Total	115	100,0	100,0	

a. BIM or Non-BIM = Non-BIM

Availability of Information via Digital Drawings[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal Oncorrect	1	,9	,9	,9
	2	2	1,7	1,7	2,6
	3	2	1,7	1,7	4,3
	4	8	7,0	7,0	11,3
	5	6	5,2	5,2	16,5
	6	10	8,7	8,7	25,2
	7	22	19,1	19,1	44,3
	8	40	34,8	34,8	79,1
	9	19	16,5	16,5	95,7
	Helemaal Correct	5	4,3	4,3	100,0
	Total	115	100,0	100,0	

a. BIM or Non-BIM = Non-BIM

AutonomieDir[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Weinig/klein/laag	2	1,7	1,7	1,7
	Betrekkelijk weinig/klein/laag	2	1,7	1,7	3,5
	Gemiddeld	20	17,4	17,4	20,9
	Betrekkelijk veel/groot/hoog	36	31,3	31,3	52,2
	Veel/groot/hoog	43	37,4	37,4	89,6
	Zeer veel/groot/hoog	12	10,4	10,4	100,0
	Total	115	100,0	100,0	

a. BIM or Non-BIM = Non-BIM

TaskidentitieDir[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Zeer weinig/klein/laag	1	,9	,9	,9
	Weinig/klein/laag	3	2,6	2,6	3,5
	Betrekkelijk weinig/klein/laag	7	6,1	6,1	9,6
	Gemiddeld	23	20,0	20,2	29,8
	Betrekkelijk veel/groot/hoog	39	33,9	34,2	64,0
	Veel/groot/hoog	35	30,4	30,7	94,7
	Zeer veel/groot/hoog	6	5,2	5,3	100,0
	Total	114	99,1	100,0	
Missing	System	1	,9		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

TaskVariatyDir[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Weinig/klein/laag	1	,9	,9	,9
	Betrekkelijk weinig/klein/laag	7	6,1	6,1	7,0
	Gemiddeld	19	16,5	16,7	23,7
	Betrekkelijk veel/groot/hoog	42	36,5	36,8	60,5
	Veel/groot/hoog	32	27,8	28,1	88,6
	Zeer veel/groot/hoog	13	11,3	11,4	100,0
	Total	114	99,1	100,0	
Missing	System	1	,9		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Task Significance Dir[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Weinig/klein/laag	2	1,7	1,7	1,7
	Betrekkelijk weinig/klein/laag	3	2,6	2,6	4,3
	Gemiddeld	18	15,7	15,7	20,0
	Betrekkelijk veel/groot/hoog	49	42,6	42,6	62,6
	Veel/groot/hoog	39	33,9	33,9	96,5
	Zeer veel/groot/hoog	4	3,5	3,5	100,0
	Total	115	100,0	100,0	

a. BIM or Non-BIM = Non-BIM

FeedbackDir[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Weinig/klein/laag	6	5,2	5,2	5,2
	Betrekkelijk weinig/klein/laag	15	13,0	13,0	18,3
	Gemiddeld	40	34,8	34,8	53,0
	Betrekkelijk veel/groot/hoog	38	33,0	33,0	86,1
	Veel/groot/hoog	16	13,9	13,9	100,0
	Total	115	100,0	100,0	

a. BIM or Non-BIM = Non-BIM

Eigen Baan Karakteristieken stelling 1[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal oneens	55	47,8	48,2	48,2
	Oneens	48	41,7	42,1	90,4
	Betrekkelijk oneens	5	4,3	4,4	94,7
	Neutraal	4	3,5	3,5	98,2
	Betrekkelijk eens	1	,9	,9	99,1
	Eens	1	,9	,9	100,0
	Total	114	99,1	100,0	
Missing	System	1	,9		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Eigen Baan Karakteristieken stelling 2[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal oneens	57	49,6	50,0	50,0
	Oneens	45	39,1	39,5	89,5
	Betrekkelijk oneens	5	4,3	4,4	93,9
	Neutraal	2	1,7	1,8	95,6
	Betrekkelijk eens	1	,9	,9	96,5
	Eens	1	,9	,9	97,4
	Helemaal eens	3	2,6	2,6	100,0
	Total	114	99,1	100,0	
Missing	System	1	,9		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Eigen Baan Karakteristieken stelling 3[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal oneens	2	1,7	1,8	1,8
	Oneens	5	4,3	4,4	6,1
	Neutraal	4	3,5	3,5	9,6
	Betrekkelijk eens	16	13,9	14,0	23,7
	Eens	55	47,8	48,2	71,9
	Helemaal eens	32	27,8	28,1	100,0
	Total	114	99,1	100,0	
Missing	System	1	,9		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Eigen Baan Karakteristieken stelling 4[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal oneens	3	2,6	2,6	2,6
	Oneens	5	4,3	4,4	7,0
	Betrekkelijk oneens	1	,9	,9	7,9
	Neutraal	1	,9	,9	8,8
	Betrekkelijk eens	18	15,7	15,8	24,6
	Eens	51	44,3	44,7	69,3
	Helemaal eens	35	30,4	30,7	100,0
	Total	114	99,1	100,0	
Missing	System	1	,9		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Eigen Baan Karakteristieken stelling 5[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal oneens	6	5,2	5,3	5,3
	Oneens	3	2,6	2,7	8,0
	Betrekkelijk eens	5	4,3	4,4	12,4
	Eens	38	33,0	33,6	46,0
	Helemaal eens	61	53,0	54,0	100,0
	Total	113	98,3	100,0	
Missing	System	2	1,7		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Eigen Baan Karakteristieken stelling 6[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal oneens	18	15,7	15,8	15,8
	Oneens	45	39,1	39,5	55,3
	Betrekkelijk oneens	18	15,7	15,8	71,1
	Neutraal	10	8,7	8,8	79,8
	Betrekkelijk eens	9	7,8	7,9	87,7
	Eens	12	10,4	10,5	98,2
	Helemaal eens	2	1,7	1,8	100,0
	Total	114	99,1	100,0	
Missing	System	1	,9		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Eigen Baan Karakteristieken stelling 7[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal oneens	7	6,1	6,1	6,1
	Oneens	2	1,7	1,8	7,9
	Betrekkelijk oneens	2	1,7	1,8	9,6
	Neutraal	6	5,2	5,3	14,9
	Betrekkelijk eens	18	15,7	15,8	30,7
	Eens	44	38,3	38,6	69,3
	Helemaal eens	35	30,4	30,7	100,0
	Total	114	99,1	100,0	
Missing	System	1	,9		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Eigen Baan Karakteristieken stelling 8[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal oneens	3	2,6	2,6	2,6
	Oneens	6	5,2	5,3	7,9
	Betrekkelijk oneens	4	3,5	3,5	11,4
	Neutraal	7	6,1	6,1	17,5
	Betrekkelijk eens	21	18,3	18,4	36,0
	Eens	44	38,3	38,6	74,6
	Helemaal eens	29	25,2	25,4	100,0
	Total	114	99,1	100,0	
Missing	System	1	,9		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Eigen Baan Omschrijving stelling 1[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Betrekkelijk onaccuraat	5	4,3	4,4	4,4
	Neutraal	6	5,2	5,3	9,6
	Betrekkelijk accuraat	40	34,8	35,1	44,7
	Accuraat	48	41,7	42,1	86,8
	Zeer Accuraat	15	13,0	13,2	100,0
	Total	114	99,1	100,0	
Missing	System	1	,9		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Eigen Baan Omschrijving stelling 2[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Onaccuraat	3	2,6	2,6	2,6
	Betrekkelijk onaccuraat	5	4,3	4,4	7,0
	Neutraal	9	7,8	7,9	14,9
	Betrekkelijk accuraat	38	33,0	33,3	48,2
	Accuraat	42	36,5	36,8	85,1
	Zeer Accuraat	17	14,8	14,9	100,0
	Total	114	99,1	100,0	
Missing	System	1	,9		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Eigen Baan Omschrijving stelling 3[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Onaccuraat	3	2,6	2,6	2,6
	Betrekkelijk onaccuraat	4	3,5	3,5	6,1
	Neutraal	23	20,0	20,2	26,3
	Betrekkelijk accuraat	36	31,3	31,6	57,9
	Accuraat	40	34,8	35,1	93,0
	Zeer Accuraat	8	7,0	7,0	100,0
	Total	114	99,1	100,0	
Missing	System	1	,9		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Eigen Baan Omschrijving stelling 4[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Zeer onaccuraat	20	17,4	17,7	17,7
	Onaccuraat	47	40,9	41,6	59,3
	Betrekkelijk onaccuraat	21	18,3	18,6	77,9
	Neutraal	11	9,6	9,7	87,6
	Betrekkelijk accuraat	12	10,4	10,6	98,2
	Accuraat	2	1,7	1,8	100,0
	Total	113	98,3	100,0	
Missing	System	2	1,7		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Eigen Baan Omschrijving stelling 5[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Onaccuraat	2	1,7	1,8	1,8
	Betrekkelijk onaccuraat	3	2,6	2,7	4,4
	Neutraal	23	20,0	20,4	24,8
	Betrekkelijk accuraat	37	32,2	32,7	57,5
	Accuraat	36	31,3	31,9	89,4
	Zeer Accuraat	12	10,4	10,6	100,0
	Total	113	98,3	100,0	
Missing	System	2	1,7		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Eigen Baan Omschrijving stelling 6[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Zeer onaccuraat	21	18,3	18,4	18,4
	Onaccuraat	47	40,9	41,2	59,6
	Betrekkelijk onaccuraat	20	17,4	17,5	77,2
	Neutraal	9	7,8	7,9	85,1
	Betrekkelijk accuraat	10	8,7	8,8	93,9
	Accuraat	6	5,2	5,3	99,1
	Zeer Accuraat	1	,9	,9	100,0
	Total	114	99,1	100,0	
Missing	System	1	,9		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Eigen Baan Omschrijving stelling 7[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Onaccuraat	12	10,4	10,6	10,6
	Betrekkelijk onaccuraat	14	12,2	12,4	23,0
	Neutraal	27	23,5	23,9	46,9
	Betrekkelijk accuraat	29	25,2	25,7	72,6
	Accuraat	22	19,1	19,5	92,0
	Zeer Accuraat	9	7,8	8,0	100,0
	Total	113	98,3	100,0	
Missing	System	2	1,7		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Eigen Baan Omschrijving stelling 8[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Zeer onaccuraat	8	7,0	7,0	7,0
	Onaccuraat	25	21,7	21,9	28,9
	Betrekkelijk onaccuraat	29	25,2	25,4	54,4
	Neutraal	22	19,1	19,3	73,7
	Betrekkelijk accuraat	22	19,1	19,3	93,0
	Accuraat	7	6,1	6,1	99,1
	Zeer Accuraat	1	,9	,9	100,0
	Total	114	99,1	100,0	
Missing	System	1	,9		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Eigen Baan Omschrijving stelling 9[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Onaccuraat	3	2,6	2,6	2,6
	Betrekkelijk onaccuraat	3	2,6	2,6	5,3
	Neutraal	19	16,5	16,7	21,9
	Betrekkelijk accuraat	29	25,2	25,4	47,4
	Accuraat	53	46,1	46,5	93,9
	Zeer Accuraat	7	6,1	6,1	100,0
	Total	114	99,1	100,0	
Missing	System	1	,9		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Eigen Baan Omschrijving stelling 10[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Zeer onaccuraat	27	23,5	23,9	23,9
	Onaccuraat	56	48,7	49,6	73,5
	Betrekkelijk onaccuraat	13	11,3	11,5	85,0
	Neutraal	9	7,8	8,0	92,9
	Betrekkelijk accuraat	5	4,3	4,4	97,3
	Accuraat	2	1,7	1,8	99,1
	Zeer Accuraat	1	,9	,9	100,0
	Total	113	98,3	100,0	
Missing	System	2	1,7		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Andermans Baan Stelling 1[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal oneens	42	36,5	36,5	36,5
	Oneens	54	47,0	47,0	83,5
	Betrekkelijk oneens	6	5,2	5,2	88,7
	Neutraal	9	7,8	7,8	96,5
	Betrekkelijk eens	4	3,5	3,5	100,0
	Total	115	100,0	100,0	

a. BIM or Non-BIM = Non-BIM

Andermans Baan Stelling 2[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal oneens	1	,9	,9	,9
	Oneens	4	3,5	3,5	4,3
	Betrekkelijk oneens	1	,9	,9	5,2
	Neutraal	11	9,6	9,6	14,8
	Betrekkelijk eens	22	19,1	19,1	33,9
	Eens	53	46,1	46,1	80,0
	Helemaal eens	23	20,0	20,0	100,0
	Total	115	100,0	100,0	

a. BIM or Non-BIM = Non-BIM

Andermans Baan Stelling 3[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Oneens	2	1,7	1,8	1,8
	Betrekkelijk oneens	4	3,5	3,5	5,3
	Neutraal	24	20,9	21,1	26,3
	Betrekkelijk eens	29	25,2	25,4	51,8
	Eens	42	36,5	36,8	88,6
	Helemaal eens	13	11,3	11,4	100,0
	Total	114	99,1	100,0	
Missing	System	1	,9		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

Andermans Baan Stelling 4[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal oneens	1	,9	,9	,9
	Oneens	2	1,7	1,7	2,6
	Betrekkelijk oneens	2	1,7	1,7	4,3
	Neutraal	11	9,6	9,6	13,9
	Betrekkelijk eens	31	27,0	27,0	40,9
	Eens	54	47,0	47,0	87,8
	Helemaal eens	14	12,2	12,2	100,0
	Total	115	100,0	100,0	

a. BIM or Non-BIM = Non-BIM

Andermans Baan Stelling 5[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal oneens	2	1,7	1,7	1,7
	Oneens	1	,9	,9	2,6
	Betrekkelijk oneens	3	2,6	2,6	5,2
	Neutraal	18	15,7	15,7	20,9
	Betrekkelijk eens	32	27,8	27,8	48,7
	Eens	47	40,9	40,9	89,6
	Helemaal eens	12	10,4	10,4	100,0
	Total	115	100,0	100,0	

a. BIM or Non-BIM = Non-BIM

Andermans Baan Stelling 6[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal oneens	7	6,1	6,1	6,1
	Oneens	41	35,7	36,0	42,1
	Betrekkelijk oneens	12	10,4	10,5	52,6
	Neutraal	24	20,9	21,1	73,7
	Betrekkelijk eens	17	14,8	14,9	88,6
	Eens	12	10,4	10,5	99,1
	Helemaal eens	1	,9	,9	100,0
	Total	114	99,1	100,0	
Missing	System	1	,9		
Total		115	100,0		

a. BIM or Non-BIM = Non-BIM

G.2 BIM Group

		Department of Respondend	Function of Respondend	Time in Function	Time in Sector	Level of Miscommunication with Face-to-Face Com between two persons	Level of Miscommunication with Face-to-Face Com in a Group	Level of Miscommunication with Telephone
N	Valid	38	38	38	38	38	38	38
	Missing	0	0	0	0	0	0	0
Median		2,00	2,00	2,00	2,00	6,00	5,00	4,00
Variance		,245	,817	,754	,698	1,767	2,467	1,372

		Level of Miscommunication with E-Mail	Level of Miscommunication with Written Documents	Level of Miscommunication with Paperbased Drawings	Level of Miscommunication with Digital Drawings	Correctness of Information via Face-to-Face Com between two persons	Correctness of Information via Face-to-Face Com in a Group	Correctness of Information via Telephone
N	Valid	38	38	37	37	38	38	38
	Missing	0	0	1	1	0	0	0
Median		4,00	5,00	5,00	5,00	8,00	7,00	6,00
Variance		1,630	1,878	1,386	1,553	3,770	3,280	2,583

		Correctness of Information via E-Mail	Correctness of Information via Written Documents	Correctness of Information via Paperbased Drawings	Correctness of Information via Digital Drawings	Actuality of Information via Face-to-Face Com between two persons	Actuality of Information via Face-to-Face Com in a Group	Actuality of Information via Telephone
N	Valid	38	38	38	37	36	36	36
	Missing	0	0	0	1	2	2	2
Median		7,00	7,00	7,50	8,00	9,00	8,00	8,00
Variance		3,326	3,394	5,435	4,354	3,197	3,143	4,073

		Actuality of Information via E-Mail	Actuality of Information via Written Documents	Actuality of Information via Paperbased Drawings	Actuality of Information via Digital Drawings	Availability of Information via Face-to-Face Com between two persons	Availability of Information via Face-to-Face Com in a Group	Availability of Information via Telephone
N	Valid	36	36	36	36	38	38	38
	Missing	2	2	2	2	0	0	0
Median		8,00	6,50	7,00	8,00	8,00	7,00	6,00
Variance		3,387	3,159	3,507	4,193	5,186	4,718	4,803

		Availability of Information via E-Mail	Availability of Information via Written Documents	Availability of Information via Paperbased Drawings	Availability of Information via Digital Drawings	AutonomieDir	TaskidentitieDir	TaskVariaty Dir
N	Valid	38	38	38	38	38	38	38
	Missing	0	0	0	0	0	0	0
Median		7,00	7,00	7,00	8,00	5,00	5,00	5,00
Variance		3,414	4,592	4,808	3,770	2,046	1,514	2,405

		Task Significance Dir	FeedbackDir	Eigen Baan Karakteristieken stelling 1	Eigen Baan Karakteristieken stelling 2	Eigen Baan Karakteristieken stelling 3	Eigen Baan Karakteristieken stelling 4	Eigen Baan Karakteristieken stelling 5
N	Valid	38	38	38	38	38	38	38
	Missing	0	0	0	0	0	0	0
Median		6,00	4,00	1,00	1,00	6,00	6,00	7,00
Variance		1,065	1,847	1,122	,826	1,900	1,210	1,121

		Eigen Baan Karakteristieken stelling 6	Eigen Baan Karakteristieken stelling 7	Eigen Baan Karakteristieken stelling 8	Eigen Baan Omschrijving stelling 1	Eigen Baan Omschrijving stelling 2	Eigen Baan Omschrijving stelling 3	Eigen Baan Omschrijving stelling 4
N	Valid	38	38	38	38	37	38	38
	Missing	0	0	0	0	1	0	0
Median		2,00	6,00	6,00	6,00	6,00	5,00	2,00
Variance		3,627	1,372	1,875	,934	1,533	1,132	1,818

		Eigen Baan Omschrijving stelling 5	Eigen Baan Omschrijving stelling 6	Eigen Baan Omschrijving stelling 7	Eigen Baan Omschrijving stelling 8	Eigen Baan Omschrijving stelling 9	Eigen Baan Omschrijving stelling 10	Andermans Baan Stelling 1
N	Valid	38	38	38	38	38	38	38
	Missing	0	0	0	0	0	0	0
Median		5,00	2,00	4,00	4,00	5,50	2,00	2,00
Variance		1,861	1,821	2,765	2,766	1,758	2,256	1,488

		Andermans Baan Stelling 2	Andermans Baan Stelling 3	Andermans Baan Stelling 4	Andermans Baan Stelling 5	Andermans Baan Stelling 6
N	Valid	38	38	37	38	37
	Missing	0	0	1	0	1
Median		6,00	5,50	6,00	6,00	3,00
Variance		1,195	1,411	1,297	1,662	2,287

Department of Respondend[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Stedelijk Gebied	15	39,5	39,5	39,5
	Bouw & Vastgoed	23	60,5	60,5	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Function of Respondend[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Draftsman	8	21,1	21,1	21,1
	Engineer	13	34,2	34,2	55,3
	ProjectLeader	14	36,8	36,8	92,1
	Teamleader	3	7,9	7,9	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Time in Function[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 5 years	11	28,9	28,9	28,9
	Between 5 and 10 years	16	42,1	42,1	71,1
	Between 10 and 15 years	9	23,7	23,7	94,7
	Longer than 15 year	2	5,3	5,3	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Time in Sector[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	less than 5 years	6	15,8	15,8	15,8
	between 5 and 15 years	18	47,4	47,4	63,2
	between 15 and 30 years	11	28,9	28,9	92,1
	more than thirty years	3	7,9	7,9	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Level of Miscommunication with Face-to-Face Com between two persons[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Altijd	1	2,6	2,6	2,6
	Frequent	4	10,5	10,5	13,2
	Gemiddeld	3	7,9	7,9	21,1
	Soms	9	23,7	23,7	44,7
	Zelden	17	44,7	44,7	89,5
	Nooit	4	10,5	10,5	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Level of Miscommunication with Face-to-Face Com in a Group[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Altijd	1	2,6	2,6	2,6
	Meestal	4	10,5	10,5	13,2
	Frequent	5	13,2	13,2	26,3
	Gemiddeld	5	13,2	13,2	39,5
	Soms	11	28,9	28,9	68,4
	Zelden	9	23,7	23,7	92,1
	Nooit	3	7,9	7,9	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Level of Miscommunication with Telephone[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Altijd	1	2,6	2,6	2,6
	Meestal	1	2,6	2,6	5,3
	Frequent	12	31,6	31,6	36,8
	Gemiddeld	7	18,4	18,4	55,3
	Soms	14	36,8	36,8	92,1
	Zelden	3	7,9	7,9	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Level of Miscommunication with E-Mail[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Altijd	1	2,6	2,6	2,6
	Meestal	4	10,5	10,5	13,2
	Frequent	13	34,2	34,2	47,4
	Gemiddeld	7	18,4	18,4	65,8
	Soms	11	28,9	28,9	94,7
	Zelden	1	2,6	2,6	97,4
	Nooit	1	2,6	2,6	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Level of Miscommunication with Written Documents[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Altijd	1	2,6	2,6	2,6
	Meestal	1	2,6	2,6	5,3
	Frequent	7	18,4	18,4	23,7
	Gemiddeld	9	23,7	23,7	47,4
	Soms	10	26,3	26,3	73,7
	Zelden	8	21,1	21,1	94,7
	Nooit	2	5,3	5,3	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Level of Miscommunication with Paperbased Drawings[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Meestal	1	2,6	2,7	2,7
	Frequent	3	7,9	8,1	10,8
	Gemiddeld	8	21,1	21,6	32,4
	Soms	13	34,2	35,1	67,6
	Zelden	9	23,7	24,3	91,9
	Nooit	3	7,9	8,1	100,0
	Total	37	97,4	100,0	
Missing	System	1	2,6		
Total		38	100,0		

a. BIM or Non-BIM = BIM

Level of Miscommunication with Digital Drawings[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Meestal	2	5,3	5,4	5,4
	Frequent	4	10,5	10,8	16,2
	Gemiddeld	4	10,5	10,8	27,0
	Soms	12	31,6	32,4	59,5
	Zelden	14	36,8	37,8	97,3
	Nooit	1	2,6	2,7	100,0
	Total	37	97,4	100,0	
Missing	System	1	2,6		
Total		38	100,0		

a. BIM or Non-BIM = BIM

Correctness of Information via Face-to-Face Com between two persons[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	2	5,3	5,3	5,3
	4	3	7,9	7,9	13,2
	5	2	5,3	5,3	18,4
	6	2	5,3	5,3	23,7
	7	4	10,5	10,5	34,2
	8	12	31,6	31,6	65,8
	9	10	26,3	26,3	92,1
	Helemaal Correct	3	7,9	7,9	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Correctness of Information via Face-to-Face Com in a Group[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	4	8	21,1	21,1	21,1
	5	3	7,9	7,9	28,9
	6	3	7,9	7,9	36,8
	7	6	15,8	15,8	52,6
	8	15	39,5	39,5	92,1
	9	1	2,6	2,6	94,7
	Helemaal Correct	2	5,3	5,3	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Correctness of Information via Telephone[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	1	2,6	2,6	2,6
	3	1	2,6	2,6	5,3
	4	5	13,2	13,2	18,4
	5	4	10,5	10,5	28,9
	6	11	28,9	28,9	57,9
	7	9	23,7	23,7	81,6
	8	5	13,2	13,2	94,7
	9	2	5,3	5,3	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Correctness of Information via E-Mail[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	4	10,5	10,5	10,5
	4	4	10,5	10,5	21,1
	6	9	23,7	23,7	44,7
	7	12	31,6	31,6	76,3
	8	6	15,8	15,8	92,1
	9	1	2,6	2,6	94,7
	Helemaal Correct	2	5,3	5,3	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Correctness of Information via Written Documents[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	2	5,3	5,3	5,3
	4	3	7,9	7,9	13,2
	5	4	10,5	10,5	23,7
	6	5	13,2	13,2	36,8
	7	6	15,8	15,8	52,6
	8	12	31,6	31,6	84,2
	9	4	10,5	10,5	94,7
	Helemaal Correct	2	5,3	5,3	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Correctness of Information via Paperbased Drawings[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	8	21,1	21,1	21,1
	4	2	5,3	5,3	26,3
	5	1	2,6	2,6	28,9
	6	4	10,5	10,5	39,5
	7	4	10,5	10,5	50,0
	8	11	28,9	28,9	78,9
	9	6	15,8	15,8	94,7
	Helemaal Correct	2	5,3	5,3	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Correctness of Information via Digital Drawings[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	1	2,6	2,7	2,7
	3	3	7,9	8,1	10,8
	4	2	5,3	5,4	16,2
	5	1	2,6	2,7	18,9
	6	4	10,5	10,8	29,7
	7	5	13,2	13,5	43,2
	8	12	31,6	32,4	75,7
	9	7	18,4	18,9	94,6
	Helemaal Correct	2	5,3	5,4	100,0
	Total	37	97,4	100,0	
Missing	System	1	2,6		
Total		38	100,0		

a. BIM or Non-BIM = BIM

Actuality of Information via Face-to-Face Com between two persons[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	1	2,6	2,8	2,8
	4	2	5,3	5,6	8,3
	6	4	10,5	11,1	19,4
	7	2	5,3	5,6	25,0
	8	8	21,1	22,2	47,2
	9	13	34,2	36,1	83,3
	Helemaal Correct	6	15,8	16,7	100,0
	Total	36	94,7	100,0	
Missing	System	2	5,3		
Total		38	100,0		

a. BIM or Non-BIM = BIM

Actuality of Information via Face-to-Face Com in a Group[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	1	2,6	2,8	2,8
	4	2	5,3	5,6	8,3
	5	1	2,6	2,8	11,1
	6	4	10,5	11,1	22,2
	7	5	13,2	13,9	36,1
	8	11	28,9	30,6	66,7
	9	7	18,4	19,4	86,1
	Helemaal Correct	5	13,2	13,9	100,0
	Total	36	94,7	100,0	
Missing	System	2	5,3		
Total		38	100,0		

a. BIM or Non-BIM = BIM

Actuality of Information via Telephone[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	1	2,6	2,8	2,8
	3	1	2,6	2,8	5,6
	4	2	5,3	5,6	11,1
	5	2	5,3	5,6	16,7
	6	3	7,9	8,3	25,0
	7	7	18,4	19,4	44,4
	8	9	23,7	25,0	69,4
	9	6	15,8	16,7	86,1
	Helemaal Correct	5	13,2	13,9	100,0
	Total	36	94,7	100,0	
Missing	System	2	5,3		
Total		38	100,0		

a. BIM or Non-BIM = BIM

Actuality of Information via E-Mail[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	1	2,6	2,8	2,8
	4	2	5,3	5,6	8,3
	6	8	21,1	22,2	30,6
	7	4	10,5	11,1	41,7
	8	8	21,1	22,2	63,9
	9	7	18,4	19,4	83,3
	Helemaal Correct	6	15,8	16,7	100,0
	Total	36	94,7	100,0	
Missing	System	2	5,3		
Total		38	100,0		

a. BIM or Non-BIM = BIM

Actuality of Information via Written Documents[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	1	2,6	2,8	2,8
	4	2	5,3	5,6	8,3
	5	8	21,1	22,2	30,6
	6	7	18,4	19,4	50,0
	7	7	18,4	19,4	69,4
	8	7	18,4	19,4	88,9
	Helemaal Correct	4	10,5	11,1	100,0
	Total	36	94,7	100,0	
Missing	System	2	5,3		
Total		38	100,0		

a. BIM or Non-BIM = BIM

Actuality of Information via Paperbased Drawings[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	1	2,6	2,8	2,8
	4	5	13,2	13,9	16,7
	5	3	7,9	8,3	25,0
	6	7	18,4	19,4	44,4
	7	5	13,2	13,9	58,3
	8	10	26,3	27,8	86,1
	9	2	5,3	5,6	91,7
	Helemaal Correct	3	7,9	8,3	100,0
	Total	36	94,7	100,0	
Missing	System	2	5,3		
Total		38	100,0		

a. BIM or Non-BIM = BIM

Actuality of Information via Digital Drawings[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	2	5,3	5,6	5,6
	4	2	5,3	5,6	11,1
	5	4	10,5	11,1	22,2
	6	6	15,8	16,7	38,9
	7	1	2,6	2,8	41,7
	8	9	23,7	25,0	66,7
	9	8	21,1	22,2	88,9
	Helemaal Correct	4	10,5	11,1	100,0
	Total	36	94,7	100,0	
Missing	System	2	5,3		
Total		38	100,0		

a. BIM or Non-BIM = BIM

Availability of Information via Face-to-Face Com between two persons[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	3	7,9	7,9	7,9
	4	5	13,2	13,2	21,1
	5	2	5,3	5,3	26,3
	6	5	13,2	13,2	39,5
	7	3	7,9	7,9	47,4
	8	8	21,1	21,1	68,4
	9	6	15,8	15,8	84,2
	Helemaal Correct	6	15,8	15,8	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Availability of Information via Face-to-Face Com in a Group[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	1	2,6	2,6	2,6
	3	2	5,3	5,3	7,9
	4	4	10,5	10,5	18,4
	5	5	13,2	13,2	31,6
	6	5	13,2	13,2	44,7
	7	6	15,8	15,8	60,5
	8	8	21,1	21,1	81,6
	9	2	5,3	5,3	86,8
	Helemaal Correct	5	13,2	13,2	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Availability of Information via Telephone[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	4	10,5	10,5	10,5
	4	8	21,1	21,1	31,6
	5	3	7,9	7,9	39,5
	6	7	18,4	18,4	57,9
	7	4	10,5	10,5	68,4
	8	5	13,2	13,2	81,6
	9	4	10,5	10,5	92,1
	Helemaal Correct	3	7,9	7,9	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Availability of Information via E-Mail[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	3	7,9	7,9	7,9
	4	1	2,6	2,6	10,5
	5	1	2,6	2,6	13,2
	6	5	13,2	13,2	26,3
	7	10	26,3	26,3	52,6
	8	10	26,3	26,3	78,9
	9	4	10,5	10,5	89,5
	Helemaal Correct	4	10,5	10,5	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Availability of Information via Written Documents[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	1	2,6	2,6	2,6
	3	4	10,5	10,5	13,2
	5	1	2,6	2,6	15,8
	6	7	18,4	18,4	34,2
	7	7	18,4	18,4	52,6
	8	9	23,7	23,7	76,3
	9	4	10,5	10,5	86,8
	Helemaal Correct	5	13,2	13,2	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Availability of Information via Paperbased Drawings[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal Oncorrect	1	2,6	2,6	2,6
	2	1	2,6	2,6	5,3
	3	1	2,6	2,6	7,9
	4	1	2,6	2,6	10,5
	5	3	7,9	7,9	18,4
	6	7	18,4	18,4	36,8
	7	6	15,8	15,8	52,6
	8	8	21,1	21,1	73,7
	9	5	13,2	13,2	86,8
	Helemaal Correct	5	13,2	13,2	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Availability of Information via Digital Drawings[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	1	2,6	2,6	2,6
	3	1	2,6	2,6	5,3
	4	2	5,3	5,3	10,5
	5	1	2,6	2,6	13,2
	6	4	10,5	10,5	23,7
	7	7	18,4	18,4	42,1
	8	9	23,7	23,7	65,8
	9	9	23,7	23,7	89,5
	Helemaal Correct	4	10,5	10,5	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

AutonomieDir[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Zeer weinig/klein/laag	1	2,6	2,6	2,6
	Weinig/klein/laag	1	2,6	2,6	5,3
	Betrekkelijk weinig/klein/laag	4	10,5	10,5	15,8
	Gemiddeld	9	23,7	23,7	39,5
	Betrekkelijk veel/groot/hoog	11	28,9	28,9	68,4
	Veel/groot/hoog	7	18,4	18,4	86,8
	Zeer veel/groot/hoog	5	13,2	13,2	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

TaskidentitieDir[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Betrekkelijk weinig/klein/laag	5	13,2	13,2	13,2
	Gemiddeld	8	21,1	21,1	34,2
	Betrekkelijk veel/groot/hoog	12	31,6	31,6	65,8
	Veel/groot/hoog	8	21,1	21,1	86,8
	Zeer veel/groot/hoog	5	13,2	13,2	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

TaskVariatyDir[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Weinig/klein/laag	3	7,9	7,9	7,9
	Betrekkelijk weinig/klein/laag	4	10,5	10,5	18,4
	Gemiddeld	7	18,4	18,4	36,8
	Betrekkelijk veel/groot/hoog	9	23,7	23,7	60,5
	Veel/groot/hoog	7	18,4	18,4	78,9
	Zeer veel/groot/hoog	8	21,1	21,1	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Task Significance Dir[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Betrekkelijk weinig/klein/laag	1	2,6	2,6	2,6
	Gemiddeld	7	18,4	18,4	21,1
	Betrekkelijk veel/groot/hoog	9	23,7	23,7	44,7
	Veel/groot/hoog	16	42,1	42,1	86,8
	Zeer veel/groot/hoog	5	13,2	13,2	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

FeedbackDir[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Weinig/klein/laag	7	18,4	18,4	18,4
	Betrekkelijk weinig/klein/laag	3	7,9	7,9	26,3
	Gemiddeld	13	34,2	34,2	60,5
	Betrekkelijk veel/groot/hoog	9	23,7	23,7	84,2
	Veel/groot/hoog	5	13,2	13,2	97,4
	Zeer veel/groot/hoog	1	2,6	2,6	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Eigen Baan Karakteristieken stelling 1[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal oneens	26	68,4	68,4	68,4
	Oneens	10	26,3	26,3	94,7
	Betrekkelijk eens	1	2,6	2,6	97,4
	Eens	1	2,6	2,6	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Eigen Baan Karakteristieken stelling 2[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal oneens	21	55,3	55,3	55,3
	Oneens	11	28,9	28,9	84,2
	Betrekkelijk oneens	5	13,2	13,2	97,4
	Betrekkelijk eens	1	2,6	2,6	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Eigen Baan Karakteristieken stelling 3[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal oneens	1	2,6	2,6	2,6
	Betrekkelijk oneens	3	7,9	7,9	10,5
	Neutraal	1	2,6	2,6	13,2
	Betrekkelijk eens	4	10,5	10,5	23,7
	Eens	17	44,7	44,7	68,4
	Helemaal eens	12	31,6	31,6	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Eigen Baan Karakteristieken stelling 4[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal oneens	1	2,6	2,6	2,6
	Betrekkelijk eens	6	15,8	15,8	18,4
	Eens	17	44,7	44,7	63,2
	Helemaal eens	14	36,8	36,8	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Eigen Baan Karakteristieken stelling 5[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal oneens	1	2,6	2,6	2,6
	Betrekkelijk eens	1	2,6	2,6	5,3
	Eens	10	26,3	26,3	31,6
	Helemaal eens	26	68,4	68,4	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Eigen Baan Karakteristieken stelling 6[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal oneens	3	7,9	7,9	7,9
	Oneens	18	47,4	47,4	55,3
	Betrekkelijk oneens	2	5,3	5,3	60,5
	Neutraal	5	13,2	13,2	73,7
	Betrekkelijk eens	3	7,9	7,9	81,6
	Eens	3	7,9	7,9	89,5
	Helemaal eens	4	10,5	10,5	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Eigen Baan Karakteristieken stelling 7[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal oneens	1	2,6	2,6	2,6
	Betrekkelijk eens	9	23,7	23,7	26,3
	Eens	11	28,9	28,9	55,3
	Helemaal eens	17	44,7	44,7	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Eigen Baan Karakteristieken stelling 8[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal oneens	1	2,6	2,6	2,6
	Oneens	1	2,6	2,6	5,3
	Betrekkelijk oneens	1	2,6	2,6	7,9
	Neutraal	1	2,6	2,6	10,5
	Betrekkelijk eens	7	18,4	18,4	28,9
	Eens	16	42,1	42,1	71,1
	Helemaal eens	11	28,9	28,9	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Eigen Baan Omschrijving stelling 1[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Betrekkelijk onaccuraat	1	2,6	2,6	2,6
	Neutraal	2	5,3	5,3	7,9
	Betrekkelijk accuraat	14	36,8	36,8	44,7
	Accuraat	13	34,2	34,2	78,9
	Zeer Accuraat	8	21,1	21,1	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Eigen Baan Omschrijving stelling 2[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Onaccuraat	1	2,6	2,7	2,7
	Betrekkelijk onaccuraat	3	7,9	8,1	10,8
	Neutraal	3	7,9	8,1	18,9
	Betrekkelijk accuraat	6	15,8	16,2	35,1
	Accuraat	19	50,0	51,4	86,5
	Zeer Accuraat	5	13,2	13,5	100,0
	Total	37	97,4	100,0	
Missing	System	1	2,6		
Total		38	100,0		

a. BIM or Non-BIM = BIM

Eigen Baan Omschrijving stelling 3[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Betrekkelijk onaccuraat	3	7,9	7,9	7,9
	Neutraal	11	28,9	28,9	36,8
	Betrekkelijk accuraat	11	28,9	28,9	65,8
	Accuraat	11	28,9	28,9	94,7
	Zeer Accuraat	2	5,3	5,3	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Eigen Baan Omschrijving stelling 4[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Zeer onaccuraat	10	26,3	26,3	26,3
	Onaccuraat	15	39,5	39,5	65,8
	Betrekkelijk onaccuraat	5	13,2	13,2	78,9
	Neutraal	4	10,5	10,5	89,5
	Betrekkelijk accuraat	3	7,9	7,9	97,4
	Accuraat	1	2,6	2,6	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Eigen Baan Omschrijving stelling 5[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Onaccuraat	2	5,3	5,3	5,3
	Betrekkelijk onaccuraat	2	5,3	5,3	10,5
	Neutraal	6	15,8	15,8	26,3
	Betrekkelijk accuraat	10	26,3	26,3	52,6
	Accuraat	11	28,9	28,9	81,6
	Zeer Accuraat	7	18,4	18,4	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Eigen Baan Omschrijving stelling 6[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Zeer onaccuraat	8	21,1	21,1	21,1
	Onaccuraat	15	39,5	39,5	60,5
	Betrekkelijk onaccuraat	7	18,4	18,4	78,9
	Neutraal	3	7,9	7,9	86,8
	Betrekkelijk accuraat	4	10,5	10,5	97,4
	Accuraat	1	2,6	2,6	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Eigen Baan Omschrijving stelling 7[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Zeer onaccuraat	2	5,3	5,3	5,3
	Onaccuraat	5	13,2	13,2	18,4
	Betrekkelijk onaccuraat	5	13,2	13,2	31,6
	Neutraal	10	26,3	26,3	57,9
	Betrekkelijk accuraat	6	15,8	15,8	73,7
	Accuraat	7	18,4	18,4	92,1
	Zeer Accuraat	3	7,9	7,9	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Eigen Baan Omschrijving stelling 8[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Zeer onaccuraat	2	5,3	5,3	5,3
	Onaccuraat	7	18,4	18,4	23,7
	Betrekkelijk onaccuraat	9	23,7	23,7	47,4
	Neutraal	6	15,8	15,8	63,2
	Betrekkelijk accuraat	6	15,8	15,8	78,9
	Accuraat	6	15,8	15,8	94,7
	Zeer Accuraat	2	5,3	5,3	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Eigen Baan Omschrijving stelling 9[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Betrekkelijk onaccuraat	7	18,4	18,4	18,4
	Neutraal	4	10,5	10,5	28,9
	Betrekkelijk accuraat	8	21,1	21,1	50,0
	Accuraat	14	36,8	36,8	86,8
	Zeer Accuraat	5	13,2	13,2	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Eigen Baan Omschrijving stelling 10[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Zeer onaccuraat	9	23,7	23,7	23,7
	Onaccuraat	17	44,7	44,7	68,4
	Betrekkelijk onaccuraat	5	13,2	13,2	81,6
	Neutraal	3	7,9	7,9	89,5
	Betrekkelijk accuraat	1	2,6	2,6	92,1
	Accuraat	2	5,3	5,3	97,4
	Zeer Accuraat	1	2,6	2,6	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Andermans Baan Stelling 1[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal oneens	11	28,9	28,9	28,9
	Oneens	20	52,6	52,6	81,6
	Neutraal	5	13,2	13,2	94,7
	Betrekkelijk eens	1	2,6	2,6	97,4
	Eens	1	2,6	2,6	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Andermans Baan Stelling 2[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Oneens	1	2,6	2,6	2,6
	Betrekkelijk oneens	1	2,6	2,6	5,3
	Neutraal	3	7,9	7,9	13,2
	Betrekkelijk eens	5	13,2	13,2	26,3
	Eens	22	57,9	57,9	84,2
	Helemaal eens	6	15,8	15,8	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Andermans Baan Stelling 3[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Oneens	1	2,6	2,6	2,6
	Betrekkelijk oneens	2	5,3	5,3	7,9
	Neutraal	5	13,2	13,2	21,1
	Betrekkelijk eens	11	28,9	28,9	50,0
	Eens	14	36,8	36,8	86,8
	Helemaal eens	5	13,2	13,2	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Andermans Baan Stelling 4[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Oneens	1	2,6	2,7	2,7
	Betrekkelijk oneens	1	2,6	2,7	5,4
	Neutraal	3	7,9	8,1	13,5
	Betrekkelijk eens	8	21,1	21,6	35,1
	Eens	17	44,7	45,9	81,1
	Helemaal eens	7	18,4	18,9	100,0
	Total	37	97,4	100,0	
Missing	System	1	2,6		
Total		38	100,0		

a. BIM or Non-BIM = BIM

Andermans Baan Stelling 5[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Oneens	2	5,3	5,3	5,3
	Betrekkelijk oneens	2	5,3	5,3	10,5
	Neutraal	2	5,3	5,3	15,8
	Betrekkelijk eens	7	18,4	18,4	34,2
	Eens	19	50,0	50,0	84,2
	Helemaal eens	6	15,8	15,8	100,0
	Total	38	100,0	100,0	

a. BIM or Non-BIM = BIM

Andermans Baan Stelling 6[a]

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Helemaal oneens	5	13,2	13,5	13,5
	Oneens	12	31,6	32,4	45,9
	Betrekkelijk oneens	4	10,5	10,8	56,8
	Neutraal	6	15,8	16,2	73,0
	Betrekkelijk eens	9	23,7	24,3	97,3
	Eens	1	2,6	2,7	100,0
	Total	37	97,4	100,0	
Missing	System	1	2,6		
Total		38	100,0		

a. BIM or Non-BIM = BIM

Appendix H. Validity and Reliability matrices

H.1 Internal validity

Hypothesis IV1: There is a negative relationship between miscommunication and correctness of information.

Correlations

		Aggregated Correctness of Information variable	Aggregated Miscommunication variable
Aggregated correctness of Information variable	Spearman's ρ	1	.384**
	Sig. (2-tailed)		.000
	N	151	148
Aggregated miscommunication variable	Spearman's ρ	.384**	1
	Sig. (2-tailed)	.000	
	N	148	148

**. Correlation is significant at the 0.01 level (2-tailed).

Hypothesis IV2: There is a negative relationship between miscommunication and availability of information.

Correlations

		Aggregated availability of Information variable	Aggregated miscommunication variable
Aggregated availability of Information variable	Spearman's ρ	1	.352**
	Sig. (2-tailed)		.000
	N	148	146
Aggregated miscommunication variable	Spearman's ρ	.352**	1
	Sig. (2-tailed)	.000	
	N	146	150

**. Correlation is significant at the 0.01 level (2-tailed).

Hypothesis IV3: There is a negative relationship between miscommunication and actuality of information.

Correlations

		Aggregated actuality of Information variable	Aggregated miscommunication variable
Aggregated actuality of Information variable	Spearman's ρ	1	.391**
	Sig. (2-tailed)		.000
	N	147	143
Aggregated miscommunication variable	Spearman's ρ	.391**	1
	Sig. (2-tailed)	.000	
	N	143	147

**. Correlation is significant at the 0.01 level (2-tailed).

Hypothesis IV4: There is a positive relationship between skill variety, task identity and task significance, and experiencing meaningfulness.

Correlations

		Experience Meaningfulness	Task Identity	Skill Variety	Task Significance
Pearson Correlation	Experience Meaningfulness	1,000	,209	,296	,303
	Task Identity	,209	1,000	,128	,315
	Skill Variety	,296	,128	1,000	,510
	Task Significance	,303	,315	,510	1,000
Sig. (1-tailed)	Experience Meaningfulness	.	,006	,000	,000
	Task Identity	,006	.	,062	,000
	Skill Variety	,000	,062	.	,000
	Task Significance	,000	,000	,000	.
N	Experience Meaningfulness	145	145	145	145
	Task Identity	145	145	145	145
	Skill Variety	145	145	145	145
	Task Significance	145	145	145	145

Standard multiple regression outcome

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,367[a]	,135	,116	,69122	1,900

a. Predictors: (Constant), Task Significance, Task Identity, Skill Variety

b. Dependent Variable: Experience Meaningfulness

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3,706	,484		7,654	,000
	Task Identity	,118	,073	,133	1,615	,109
	Skill Variety	,161	,074	,197	2,163	,032
	Task Significance	,141	,084	,160	1,683	,094

a. Dependent Variable: Experience Meaningfulness

Backwards multiple regression outcome

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,367[a]	,135	,116	,69122	
2	,345[b]	,119	,106	,69512	1,912

a. Predictors: (Constant), Task Significance, Task Identity, Skill Variety

b. Predictors: (Constant), Task Significance, Skill Variety

c. Dependent Variable: Experience Meaningfulness

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	3,706	,484		7,654	,000
	Task Identity	,118	,073	,133	1,615	,109
	Skill Variety	,161	,074	,197	2,163	,032
	Task Significance	,141	,084	,160	1,683	,094
2	(Constant)	4,103	,419		9,785	,000
	Skill Variety	,156	,075	,191	2,089	,038
	Task Significance	,181	,081	,205	2,241	,027

a. Dependent Variable: Experience Meaningfulness

Hypothesis IV5: There is a positive relationship between feedback and knowledge of the results.

Correlations

		Feedback	Knowledge of the results
Feedback	Pearson's *r*	1	.402**
	Sig. (2-tailed)		.000
	N	152	149
Knowledge of the results	Pearson's *r*	.402**	1
	Sig. (2-tailed)	.000	
	N	149	150

**. Correlation is significant at the 0.01 level (2-tailed).

H.2 Construct validity

H.2.1 Concurrent validity

Hypothesis CV1: Project leaders will score a higher MPS than engineers.

Function of respondents		**N**	**Mean**	**Std Deviation**	**Std Error of Mean**
MPS	Project leader	79	145.5865	51.55611	5.80052
	Engineer	36	116.0885	43.37946	7.22991

	t-test for Equality of Means						
	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper
Independent Samples Test	2,983	113	,003	29,49802	9,88727	9,90956	49,08648

	N	Mann-Whitney U	Project leader	Engineer	PS
Probability of Superiority	115	1917	79	36	.56

Hypothesis CV2: Project leaders will score a higher MPS than draftsmen.

Function of respondents		N	Mean	Std Deviation	Std Error of Mean
MPS	Project leader	79	145.5865	51.55611	5.80052
	Draftsmen	16	91,1698	34,59657	8,64914

	t-test for Equality of Means						
	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Independent Samples Test	4,033	93	,000	54,41674	13,49300	27,62232	81,21117

	N	Mann-Whitney U	Project leader	Draftsman	PS
Probability of Superiority	95	1033,5	79	16	.56

Hypothesis CV3: Engineers will score a higher MPS than draftsmen.

Function of respondents		N	Mean	Std Deviation	Std Error of Mean
MPS	Engineer	36	116,0885	43,37946	7,22991
	Draftsmen	16	91,1698	34,59657	8,64914

	t-test for Equality of Means						
	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Independent Samples Test	2,026	50	,048	24,91872	12,30181	,20981	49,62764

	N	Mann-Whitney U	Engineers	Draftsmen	PS
Probability of Superiority	52	405	36	16	.56

H.2.2 Convergent validity

Hypothesis CV4: Questions leading to skill variety are related to each other.

Correlations

		Question 4.3	Question 4.14	Question 4.17
Question 4.3	Spearman's ρ	1	.569**	.442**
	Sig. (2-tailed)	.000	.000	.000
	N	152	152	151
Question 4.14	Spearman's ρ	.569**	1	.362**
	Sig. (2-tailed)	.000	.000	.000
	N	152	152	151
Question 4.17	Spearman's ρ	.442**	.362**	1
	Sig. (2-tailed)	.000	.000	.000
	N	151	151	151

**. Correlation is significant at the 0.01 level (2-tailed).

Hypothesis CV5: Questions leading to task identity are related to each other.

Correlations

		Question 4.2	Question 4.15	Question 4.20
Question 4.2	Spearman's ρ	1	.174*	.082
	Sig. (2-tailed)	.000	.034	.321
	N	152	150	150
Question 4.15	Spearman's ρ	.174*	1	.110
	Sig. (2-tailed)	.034	.000	.181
	N	150	151	150
Question 4.20	Spearman's ρ	.082	.110	1
	Sig. (2-tailed)	.321	.181	.000
	N	150	150	151

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Hypothesis CV6: Questions leading to task significance are related to each other.

Correlations

		Question 4.4	Question 4.18	Question 4.23
Question 4.4	Spearman's ρ	1	.386**	.386**
	Sig. (2-tailed)	.000	.000	.000
	N	153	151	151
Question 4.18	Spearman's ρ	.386**	1	.411**
	Sig. (2-tailed)	.000	.000	.000
	N	151	151	150
Question 4.23	Spearman's ρ	.386**	.411**	1
	Sig. (2-tailed)	.000	.000	.000
	N	151	150	151

**. Correlation is significant at the 0.01 level (2-tailed).

Hypothesis CV7: Questions leading to feedback are related to each other.

Correlations

		Question 4.5	Question 4.16	Question 4.21
Question 4.5	Spearman's ρ	1	.501**	.346**
	Sig. (2-tailed)	.000	.000	.000
	N	153	152	151
Question 4.16	Spearman's ρ	.501**	1	.244**
	Sig. (2-tailed)	.000	.000	.002
	N	152	151	150
Question 4.21	Spearman's ρ	.346**	.244**	1
	Sig. (2-tailed)	.000	.002	.000
	N	152	152	151

**. Correlation is significant at the 0.01 level (2-tailed).

Hypothesis CV8: Questions leading to autonomy are related to each other.

Correlations

		Question 4.1	Question 4.19	Question 4.22
Question 4.1	Spearman's ρ	1	.567**	.435**
	Sig. (2-tailed)	.000	.000	.000
	N	153	152	152
Question 4.19	Spearman's ρ	.567**	1	.428**
	Sig. (2-tailed)	.000	.000	.000
	N	152	152	152
Question 4.22	Spearman's ρ	.435**	.428**	1
	Sig. (2-tailed)	.000	.000	.000
	N	152	152	152

**. Correlation is significant at the 0.01 level (2-tailed).

Hypothesis CV9: Questions leading to experiencing meaningfulness are related to each other.

Correlations

		Question 4.7	Question 4.9	Question 4.24	Question 4.27
Question 4.7	Spearman's ρ	1	.455**	.260**	.160*
	Sig. (2-tailed)	.000	.000	.000	.000
	N	152	152	152	151
Question 4.9	Spearman's ρ	.455**	1	.288**	.310**
	Sig. (2-tailed)	.000	.000	.000	.000
	N	152	152	152	151
Question 4.24	Spearman's ρ	.260**	.288**	1	.552**
	Sig. (2-tailed)	.001	.000	.000	.000
	N	152	152	153	152
Question 4.27	Spearman's ρ	.160*	.310**	.552**	1
	Sig. (2-tailed)	.050	.000	.000	.000
	N	151	151	152	152

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Hypothesis CV10: Questions leading to knowledge of the results are related to each other.

Correlations

		Question 4.8	Question 4.11	Question 4.26	Question 4.29
Question 4.8	Spearman's ρ	1	.341**	.256**	.219**
	Sig. (2-tailed)	.000	.000	.001	.007
	N	152	152	151	150
Question 4.11	Spearman's ρ	.341**	1	.203*	.375**
	Sig. (2-tailed)	.000	.000	.013	.000
	N	152	152	151	150
Question 4.26	Spearman's ρ	.256**	.203*	1	.290**
	Sig. (2-tailed)	.001	.013	.000	.000
	N	151	152	152	151
Question 4.29	Spearman's ρ	.219**	.375**	.290**	1
	Sig. (2-tailed)	.007	.000	.000	.000
	N	150	150	151	151

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Hypothesis CV11: Questions leading to experiencing responsibility are related to each other.

Correlations

		Question 4.6	Question 4.10	Question 4.12	Question 4.13	Question 4.25	Question 4.28
Question 4.6	Spearman's ρ	1	.286**	.182*	.129	.203*	.173*
	Sig. (2-tailed)	.000	.000	.025	.113	.012	.033
	N	152	151	152	152	152	152
Question 4.10	Spearman's ρ	.286**	1	.203*	.506**	.129	.239**
	Sig. (2-tailed)	.000	.000	.012	.000	.115	.003
	N	151	151	152	151	151	151
Question 4.12	Spearman's ρ	.182*	.672*	1	.609**	.171*	.272**
	Sig. (2-tailed)	.025	.000	.000	.000	.035	.001
	N	152	151	152	152	152	152
Question 4.13	Spearman's ρ	.129	.506**	.609**	1	.189*	,293**
	Sig. (2-tailed)	.113	.000	.000	.000	.020	.000
	N	152	151	152	152	152	152
Question 4.25		.203*	.129	.171*	.189*	1	.715
		.012	.115	.035	.020	.000	.000
		152	151	152	152	152	153
Question 4.28		.173*	.239**	.272**	,293**	.715	1
		.033	.003	.001	.000	.000	.000
		152	151	152	152	153	152

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Hypothesis CV12: Direct channels leading to miscommunication are related

Correlations

		Question 2.8	Question 2.9	Question 2.10
Question 2.8	Spearman's ρ	1	.706**	.573**
	Sig. (2-tailed)	.000	.000	.000
	N	152	151	152
Question 2.9	Spearman's ρ	.706**	1	.537**
	Sig. (2-tailed)	.000	.000	.002
	N	151	151	151
Question 2.10	Spearman's ρ	.573**	.537**	1
	Sig. (2-tailed)	.000	.002	.000
	N	152	151	151

**. Correlation is significant at the 0.01 level (2-tailed).

Hypothesis CV13: Direct channels leading to correctness of information are related.

Correlations

		Question 2.28	Question 2.29	Question 2.30
Question 2.28	Spearman's ρ	1	.775**	.494**
	Sig. (2-tailed)	.000	.000	.000
	N	153	152	153
Question 2.29	Spearman's ρ	.775**	1	.556**
	Sig. (2-tailed)	.000	.000	.002
	N	152	151	152
Question 2.30	Spearman's ρ	.494**	.556**	1
	Sig. (2-tailed)	.000	.002	.000
	N	153	152	151

**. Correlation is significant at the 0.01 level (2-tailed).

Hypothesis CV14: Direct channels leading to actuality of information are related

Correlations

		Question 2.35	Question 2.36	Question 2.37
Question 2.35	Spearman's ρ	1	. 821**	.699**
	Sig. (2-tailed)	.000	.000	.000
	N	148	147	153
Question 2.36	Spearman's ρ	.821**	1	.674**
	Sig. (2-tailed)	.000	.000	.000
	N	147	148	147
Question 2.37	Spearman's ρ	.699**	.674**	1
	Sig. (2-tailed)	.000	.000	.000
	N	153	147	148

**. Correlation is significant at the 0.01 level (2-tailed).

Hypothesis CV15: Direct channels leading to availability of information are related

Correlations

		Question 2.42	Question 2.43	Question 2.44
Question 2.42	Spearman's ρ	1	.862**	.688**
	Sig. (2-tailed)	.000	.000	.000
	N	152	151	152
Question 2.43	Spearman's ρ	.862**	1	.707**
	Sig. (2-tailed)	.000	.000	.000
	N	151	151	151
Question 2.44	Spearman's ρ	.688**	.707**	1
	Sig. (2-tailed)	.000	.000	.000
	N	152	151	151

**. Correlation is significant at the 0.01 level (2-tailed).

Hypothesis CV16: Indirect channels leading to miscommunication are related

Correlations

		Question 2.11	Question 2.12	Question 2.13	Question 2.14
Question 2.11	Spearman's ρ	1	.581**	.373**	.453**
	Sig. (2-tailed)	.000	.000	.000	.000
	N	152	151	150	151
Question 2.12	Spearman's ρ	.581**	1	.593**	.521**
	Sig. (2-tailed)	.000	.000	.000	.000
	N	151	151	149	150
Question 2.13	Spearman's ρ	.373**	.593**	1	.724**
	Sig. (2-tailed)	.000	.000	.000	.000
	N	150	149	150	150
Question 2.14	Spearman's ρ	.453**	.521**	.724**	1
	Sig. (2-tailed)	.000	.000	.000	.000
	N	151	150	150	151

**. Correlation is significant at the 0.01 level (2-tailed).

Hypothesis CV17: Indirect channels leading to correctness of information are related.

Correlations

		Question 2.31	Question 2.32	Question 2.33	Question 2.34
Question 2.31	Spearman's ρ	1	.584**	.431**	.525**
	Sig. (2-tailed)	.000	.000	.000	.000
	N	153	153	153	152
Question 2.32	Spearman's ρ	.584**	1	.698**	.592**
	Sig. (2-tailed)	.000	.000	.000	.000
	N	153	153	153	152
Question 2.33	Spearman's ρ	.431**	.698**	1	.788**
	Sig. (2-tailed)	.000	.000	.000	.000
	N	153	153	153	152
Question 2.34	Spearman's ρ	.525**	.592**	.788**	1
	Sig. (2-tailed)	.000	.000	.000	.000
	N	152	152	152	152

**. Correlation is significant at the 0.01 level (2-tailed).

Hypothesis CV18: Indirect channels leading to actuality of information are related

Correlations

		Question 2.38	Question 2.39	Question 2.40	Question 2.41
Question 2.38	Spearman's ρ	1	.603**	.407**	.529**
	Sig. (2-tailed)	.000	.000	.000	.000
	N	149	149	149	149
Question 2.39	Spearman's ρ	.603**	1	.773**	.633**
	Sig. (2-tailed)	.000	.000	.000	.000
	N	149	149	149	149
Question 2.40	Spearman's ρ	.407**	.773**	1	.791**
	Sig. (2-tailed)	.000	.000	.000	.000
	N	149	149	149	149
Question 2.41	Spearman's ρ	.529**	.633**	.791**	1
	Sig. (2-tailed)	.000	.000	.000	.000
	N	149	149	149	149

**. Correlation is significant at the 0.01 level (2-tailed).

Hypothesis CV19: Indirect channels leading to availability of information are related.

Correlations

		Question 2.45	Question 2.46	Question 2.47	Question 2.48
Question 2.45	Spearman's ρ	1	.648**	.456**	.539**
	Sig. (2-tailed)	.000	.000	.000	.000
	N	149	149	149	149
Question 2.46	Spearman's ρ	.648**	1	.772**	.628**
	Sig. (2-tailed)	.000	.000	.000	.000
	N	149	149	149	149
Question 2.47	Spearman's ρ	.456**	.772**	1	.784**
	Sig. (2-tailed)	.000	.000	.000	.000
	N	149	149	149	149
Question 2.48	Spearman's ρ	.539**	.628**	.784**	1
	Sig. (2-tailed)	.000	.000	.000	.000
	N	149	149	149	149

**. Correlation is significant at the 0.01 level (2-tailed).

H.3 Reliability

Internal reliability assessment of Miscommunication concept

Reliability Statistics		
Cronbach's α	Cronbach's α based on standardized items	N of Items
.817	.817	7

Item-Total statistics					
	Scale Mean if item Deleted	Scale Variance if item Deleted	Corrected item –Total Correlation	Squared Multiple Correlation	Cronbach's α if item Deleted
Question 2.8	28.22	24.800	.620	.633	.781
Question 2.9	28.69	27.100	.485	.620	.805
Question 2.10	29.02	27.966	.489	.409	.803
Question 2.11	29.18	25.901	.545	.466	.795
Question 2.12	28.67	26.233	.598	.582	.785
Question 2.13	28.30	26.918	.579	.609	.789
Question 2.14	28.48	26.347	.582	.591	.788

Internal reliability assessment of correctness of information concept

Reliability Statistics		
Cronbach's α	Cronbach's α based on standardized items	N of Items
.845	.846	7

Item-Total statistics					
	Scale Mean if item Deleted	Scale Variance if item Deleted	Corrected item –Total Correlation	Squared Multiple Correlation	Cronbach's α if item Deleted
Question 2.28	40.77	52.442	.620	.730	.821
Question 2.29	41.42	54.752	.588	.715	.826
Question 2.30	41.76	57.983	.503	.403	.838
Question 2.31	41.44	54.768	.636	.499	.819
Question 2.32	41.30	54.387	.678	.609	.813
Question 2.33	41.21	53.391	.629	.729	.819
Question 2.34	41.16	55.508	.561	.677	.830

Internal reliability assessment of actuality of information concept

Reliability Statistics		
Cronbach's α	Cronbach's α based on standardized items	N of Items
.882	.883	7

Item-Total statistics					
	Scale Mean if item Deleted	Scale Variance if item Deleted	Corrected item –Total Correlation	Squared Multiple Correlation	Cronbach's α if item Deleted
Question 2.35	42.71	56.781	.728	.814	.858
Question 2.36	43.14	57.379	.691	.792	.863
Question 2.37	43.07	59.275	.648	.710	.868
Question 2.38	43.12	57.624	.789	.724	.851
Question 2.39	43.86	60.630	.671	.720	.865
Question 2.40	43.84	61.617	.566	.762	.878
Question 2.41	43.41	59.969	.605	.662	.874

Internal reliability assessment of availability of information concept

Reliability Statistics		
Cronbach's α	Cronbach's α based on standardized items	N of Items
.878	.881	7

Item-Total statistics					
	Scale Mean if item Deleted	Scale Variance if item Deleted	Corrected item –Total Correlation	Squared Multiple Correlation	Cronbach's α if item Deleted
Question 2.42	42.30	71.594	.693	.850	.857
Question 2.43	42.77	73.385	.664	.845	.860
Question 2.44	43.05	74.789	.690	.637	.856
Question 2.45	42.43	78.274	.712	.663	.856
Question 2.46	42.61	76.992	.718	.730	.854
Question 2.47	42.44	78.892	.603	.716	.867
Question 2.48	42.39	79.327	.574	.663	.871

Internal reliability assessment of skill variety concept

Reliability Statistics		
Cronbach's α	Cronbach's α based on standardized items	N of Items
.681	.697	3

Item-Total statistics					
	Scale Mean if item Deleted	Scale Variance if item Deleted	Corrected item –Total Correlation	Squared Multiple Correlation	Cronbach's α if item Deleted
Question 4.3	11.0199	3.446	.558	.368	.497
Question 4.14	10.5828	4.391	.553	.352	.546
Question 4.17	10.7020	3.744	.409	.167	.717

Internal reliability assessment of task identity concept

Reliability Statistics		
Cronbach's α	Cronbach's α based on standardized items	N of Items
.282	.298	3

Item-Total statistics					
	Scale Mean if item Deleted	Scale Variance if item Deleted	Corrected item –Total Correlation	Squared Multiple Correlation	Cronbach's α if item Deleted
Question 4.2	9.91	3.991	.157	.040	.207
Question 4.15	9.47	3.818	.211	.051	.102
Question 4.20	10.42	3.300	.112	.015	.331

Internal reliability assessment of task significance concept

Reliability Statistics		
Cronbach's α	Cronbach's α based on standardized items	N of Items
.575	.584	3

Item-Total statistics					
	Scale Mean if item Deleted	Scale Variance if item Deleted	Corrected item –Total Correlation	Squared Multiple Correlation	Cronbach's α if item Deleted
Question 4.4	10.8800	4.039	.372	.154	.503
Question 4.18	10.8933	3.264	.444	.203	.381
Question 4.23	10.4400	3.094	.357	.131	.536

Internal reliability assessment of feedback concept

Reliability Statistics		
Cronbach's α	Cronbach's α based on standardized items	N of Items
.575	.584	3

Item-Total statistics					
	Scale Mean if item Deleted	Scale Variance if item Deleted	Corrected item –Total Correlation	Squared Multiple Correlation	Cronbach's α if item Deleted
Question 4.5	9.5461	4.077	.496	.278	.342
Question 4.16	8.7697	4.589	.401	.229	.480
Question 4.21	9.4079	3.647	.318	.112	.643

Internal reliability assessment of autonomy concept

Reliability Statistics		
Cronbach's α	Cronbach's α based on standardized items	N of Items
.667	.682	3

Item-Total statistics					
	Scale Mean if item Deleted	Scale Variance if item Deleted	Corrected item –Total Correlation	Squared Multiple Correlation	Cronbach's α if item Deleted
Question 4.1	10.6184	4.317	.563	.371	.466
Question 4.19	10.5658	4.592	.522	.346	.524
Question 4.22	10.4605	4.197	.379	.146	.732

Internal reliability assessment of experiencing meaningfulness concept

Reliability Statistics		
Cronbach's α	Cronbach's α based on standardized items	N of Items
.524	.525	4

Item-Total statistics					
	Scale Mean if item Deleted	Scale Variance if item Deleted	Corrected item –Total Correlation	Squared Multiple Correlation	Cronbach's α if item Deleted
Question 4.7	17.8079	4.996	.352	.159	.415
Question 4.9	18.1656	5.792	.311	.221	.454
Question 4.24	17.4570	5.943	.242	.130	.512
Question 4.27	17.6954	5.640	.353	.225	.419

Internal reliability assessment of knowledge of the results concept

Reliability Statistics		
Cronbach's α	Cronbach's α based on standardized items	N of Items
.498	.489	4

Item-Total statistics					
	Scale Mean if item Deleted	Scale Variance if item Deleted	Corrected item –Total Correlation	Squared Multiple Correlation	Cronbach's α if item Deleted
Question 4.7	14,9400	9,426	,261	,091	,453
Question 4.9	15,8133	6,703	,381	,163	,332
Question 4.24	15,5067	10,225	,204	,051	,495
Question 4.27	16,0800	7,873	,332	,126	,387

Internal reliability assessment of experiencing responsibility for the job concept

Reliability Statistics		
Cronbach's α	Cronbach's α based on standardized items	N of Items
.686	.653	6

Item-Total statistics					
	Scale Mean if item Deleted	Scale Variance if item Deleted	Corrected item –Total Correlation	Squared Multiple Correlation	Cronbach's α if item Deleted
Question 4.6	29.2980	15.304	.560	.472	.590
Question 4.10	29.1325	14.609	.614	.663	.566
Question 4.12	28.6291	15.302	.588	.653	.580
Question 4.13	28.4967	22.932	.015	.011	.739
Question 4.25	29.2252	19.442	.294	.617	.682
Question 4.28	29.4901	18.478	.389	.630	.654

Appendix I. Unanticipated Findings

In this appendix the correlation matrices of the unanticipated findings are provided. First is the correlation tables with the four collaboration and interaction variables is provided. Next the total correlation tables.

Correlations

		Question 3.7	Question 3.8	Question 3.9	Question 3.10	Meaningfulness
Interaction within department	Spearman's ρ	1,000	,700**	,417**	,370**	,115
	Sig. (2-tailed)	.	,000	,000	,000	,162
	N	152	152	152	152	150
Collaboration within department	Spearman's ρ	,700**	1,000	,416**	,394**	,188*
	Sig. (2-tailed)	,000	.	,000	,000	,021
	N	152	152	152	152	150
Interaction between departments	Spearman's ρ	,417**	,416**	1,000	,856**	,104
	Sig. (2-tailed)	,000	,000	.	,000	,205
	N	152	152	152	152	150
Collaboration between departments	Spearman's ρ	,370**	,394**	,856**	1,000	,058
	Sig. (2-tailed)	,000	,000	,000	.	,481
	N	152	152	152	152	150
Experience meaningfulness	Spearman's ρ	,115	,188*	,104	,058	1,000
	Sig. (2-tailed)	,162	,021	,205	,481	.
	N	150	150	150	150	151

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Correlations

		Question 3.7	Question 3.8	Question 3.9	Question 3.10	Actuality
Interaction within department	Spearman's ρ	1,000	,700**	,417**	,370**	,207*
	Sig. (2-tailed)	.	,000	,000	,000	,012
	N	152	152	152	152	146
Collaboration within department	Spearman's ρ	,700**	1,000	,416**	,394**	,329**
	Sig. (2-tailed)	,000	.	,000	,000	,000
	N	152	152	152	152	146
Interaction between departments	Spearman's ρ	,417**	,416**	1,000	,856**	,032
	Sig. (2-tailed)	,000	,000	.	,000	,704
	N	152	152	152	152	146
Collaboration between departments	Spearman's ρ	,370**	,394**	,856**	1,000	,009
	Sig. (2-tailed)	,000	,000	,000	.	,914
	N	152	152	152	152	146
Aggregated Actuality of Information variable	Spearman's ρ	,207*	,329**	,032	,009	1,000
	Sig. (2-tailed)	,012	,000	,704	,914	.
	N	146	146	146	146	147

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Correlations

		Miscom	Correctness	Actuality	Availability	Autonomy	Skill Variety	Task Significance	Feedback	Meaningfulness	Responsibility
Aggregated Miscommunication variable	Pearson Correlation	1	,273**	,280**	,229**	-,003	-,098	,180*	,042	,272**	,207*
	Sig. (2-tailed)		,001	,001	,005	,971	,238	,030	,612	,001	,012
	N	148	148	143	146	148	147	146	148	147	146
Aggregated Correctness of Information variable	Pearson Correlation	,273**	1	,729**	,616**	-,040	-,041	,195*	,051	,058	-,001
	Sig. (2-tailed)	,001		,000	,000	,628	,618	,017	,530	,477	,992
	N	148	151	146	149	151	150	149	151	150	149
Aggregated Actuality of Information variable	Pearson Correlation	,280**	,729**	1	,748**	-,005	-,017	,210*	-,007	,171*	,037
	Sig. (2-tailed)	,001	,000		,000	,951	,843	,011	,932	,040	,661
	N	143	146	147	145	147	146	145	147	145	145
Aggregated Availability of Information variable	Pearson Correlation	,229**	,616**	,748**	1	-,027	,057	,213**	,139	,111	,016
	Sig. (2-tailed)	,005	,000	,000		,740	,488	,009	,089	,181	,845
	N	146	149	145	150	150	149	148	150	148	148
Autonomy	Pearson Correlation	-,003	-,040	-,005	-,027	1	,564**	,327**	,280**	,202*	,268**
	Sig. (2-tailed)	,971	,628	,951	,740		,000	,000	,000	,013	,001
	N	148	151	147	150	152	151	150	152	150	150
Skill Variety	Pearson Correlation	-,098	-,041	-,017	,057	,564**	1	,490**	,298**	,311**	,346**
	Sig. (2-tailed)	,238	,618	,843	,488	,000		,000	,000	,000	,000
	N	147	150	146	149	151	151	150	151	149	149
Task Significance	Pearson Correlation	,180*	,195*	,210*	,213**	,327**	,490**	1	,263**	,301**	,117
	Sig. (2-tailed)	,030	,017	,011	,009	,000	,000		,001	,000	,157
	N	146	149	145	148	150	150	150	150	148	148
Feedback	Pearson Correlation	,042	,051	-,007	,139	,280**	,298**	,263**	1	,253**	,192*
	Sig. (2-tailed)	,612	,530	,932	,089	,000	,000	,001		,002	,018
	N	148	151	147	150	152	151	150	152	150	150
Experience Meaningfulness	Pearson Correlation	,272**	,058	,171*	,111	,202*	,311**	,301**	,253**	1	,720**
	Sig. (2-tailed)	,001	,477	,040	,181	,013	,000	,000	,002		,000
	N	147	150	145	148	150	149	148	150	151	150
Experience Responsibility	Pearson Correlation	,207*	-,001	,037	,016	,268**	,346**	,117	,192*	,720**	1
	Sig. (2-tailed)	,012	,992	,661	,845	,001	,000	,157	,018	,000	
	N	146	149	145	148	150	149	148	150	150	151

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Correlations

		Miscom	Correctness	Actuality	Availability	Autonomy	Skill Variety	Task Significance	Feedback	Meaningfulness	Responsibility
Aggregated Miscommunication variable	Spearman's ρ	1,000	,384**	,391**	,325**	,018	-,062	,160	,102	,237**	,192*
	Sig. (2-tailed)	.	,000	,000	,000	,826	,458	,053	,216	,004	,020
	N	148	148	143	146	148	147	146	148	147	146
Aggregated Correctness of Information variable	Spearman's ρ	,384**	1,000	,731**	,635**	-,060	,005	,173*	,116	,126	,078
	Sig. (2-tailed)	,000	.	,000	,000	,465	,948	,034	,155	,124	,341
	N	148	151	146	149	151	150	149	151	150	149
Aggregated Actuality of Information variable	Spearman's ρ	,391**	,731**	1,000	,657**	-,005	,003	,221**	,029	,232**	,132
	Sig. (2-tailed)	,000	,000	.	,000	,950	,970	,008	,726	,005	,112
	N	143	146	147	145	147	146	145	147	145	145
Aggregated Availability of Information variable	Spearman's ρ	,325**	,635**	,657**	1,000	-,038	,101	,196*	,178*	,197*	,085
	Sig. (2-tailed)	,000	,000	,000	.	,644	,218	,017	,029	,016	,304
	N	146	149	145	150	150	149	148	150	148	148
Autonomy	Spearman's ρ	,018	-,060	-,005	-,038	1,000	,563**	,390**	,294**	,212**	,332**
	Sig. (2-tailed)	,826	,465	,950	,644	.	,000	,000	,000	,009	,000
	N	148	151	147	150	152	151	150	152	150	150
Skill Variety	Spearman's ρ	-,062	,005	,003	,101	,563**	1,000	,566**	,330**	,349**	,354**
	Sig. (2-tailed)	,458	,948	,970	,218	,000	.	,000	,000	,000	,000
	N	147	150	146	149	151	151	150	151	149	149
Task Significance	Spearman's ρ	,160	,173*	,221**	,196*	,390**	,566**	1,000	,313**	,373**	,169*
	Sig. (2-tailed)	,053	,034	,008	,017	,000	,000	.	,000	,000	,040
	N	146	149	145	148	150	150	150	150	148	148
Feedback	Spearman's ρ	,102	,116	,029	,178*	,294**	,330**	,313**	1,000	,300**	,269**
	Sig. (2-tailed)	,216	,155	,726	,029	,000	,000	,000	.	,000	,001
	N	148	151	147	150	152	151	150	152	150	150
Experience Meaningfulness	Spearman's ρ	,237**	,126	,232**	,197*	,212**	,349**	,373**	,300**	1,000	,688**
	Sig. (2-tailed)	,004	,124	,005	,016	,009	,000	,000	,000	.	,000
	N	147	150	145	148	150	149	148	150	151	150
Experience Responsibility	Spearman's ρ	,192*	,078	,132	,085	,332**	,354**	,169*	,269**	,688**	1,000
	Sig. (2-tailed)	,020	,341	,112	,304	,000	,000	,040	,001	,000	.
	N	146	149	145	148	150	149	148	150	150	151

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix J. References in Appendices

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