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# The effect of a digital support tool on requirements elicitation in non-residential building projects

MASTER THESIS CONSTRUCTION MANAGEMENT & ENGINEERING


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## Abstract

In non-residential construction projects, a building often does not meet the demands and requirements of its users. This can be improved by managing their requirements. Requirements management is a process of elicitating, analysing, specifying and validating the requirements for a building. The end-users' requirements are often elicitated by interviewing the client and optionally the end-user. However, the results are often incomplete, inconsistent or ambiguous. Antea Group invented an elicitation method to support consultants in finding the end-users' requirements: the PvE2Go method. The PvE2Go method uses an end-user centred process and a digital support tool during elicitation workshops. This method was tested in a quasi-experiment in which 3 topics were investigated and compared to the 'interview' elicitation method: 1) understandability, 2) end-user involvement and 3) completeness. The study shows that the understandability and involvement improve when compared to the interview method. The completeness is lower than in the interview method. It was found in literature that an increased understanding of the process will increase the involvement of the end-user, which is supported by this research. Secondly, it was found in literature that better involvement leads to higher completeness and 'buildings that match the needs of the client better'. This suggests that the PvE2Go method leads to better buildings for its users, but not to higher completeness. Future research could investigate whether or not completeness actually leads to better buildings for its users. The new elicitation method turns out to have a positive effect on 2 of the 3 indicators of the requirements management process, and no significant negative effect. It is thus recommended to use the method in more projects and to monitor the effect of project characteristics on the usability of the PvE2Go method.



**Keywords**: Construction management; Requirements management; Requirements elicitation; Non-residential construction projects.


## Introduction

Each year, over 70 billion euros is spent on construction projects in the Netherlands (Bouwend Nederland, 2020). It is important to understand the aim of each project well, so that a sustainable building is built for the client and the money is spent well. Understanding the client's aim and demand is however difficult due to complex functions, conflicting interests, and lack of information. There is no single solution or strategy to tackle this.

The wishes and requirements of a building are described in the 'requirements brief'. This document is used to determine and communicate the client's question to architects, engineers, and executers. In previous research, methods have been developed for gathering the requirements (CORDIS Europe, 2003; Sarshar & Christiansson, 2004; Carrillo De Gea et al., 2011; Kamara, 2017). It turns out however that such methods are barely used in practice, because of unknown reasons. Possible reasons are that they are awkward to use or users are unaware of the existence of the methods. This research will use a different approach: the starting point is a method that was developed in practice, this research focuses on substantiating how the method works based on theoretical knowledge. This approach could lead to a scientifically proven elicitation method that is being used in practice as well.

Antea Group is a consultancy that writes requirements briefs, among other things. They found out that the quality of the requirements brief depends on experience of both the consultant and client, and on the method they use to gather the requirements. Moreover, experience from other projects is barely used. This may lead to requirements briefs of varying quality and incompleteness, making misunderstanding between parties likely. This causes unwanted design changes, additional costs, delay and dissatisfied end-users.

That is why Antea Group invented the PvE2Go project. They picked up on the trend of digitalisation and applied this in the phase of writing the requirements brief. The PvE2Go project has set up a method to elicitate requirements from end-users, and a tool was developed to support the consultant in the process. Early involvement of end-users distinguishes this method from previous methods, as well as the interactive communication using the tool.

The process is divided into 6 phases: the client's question, exploration, ambition, end-user workshop, conceptual requirements brief and the final requirements brief (Figure 1). These phases aim to organise and standardise the requirements elicitation process, in order to involve end-users early in the process and to obtain briefs of equal quality when made by different consultants.

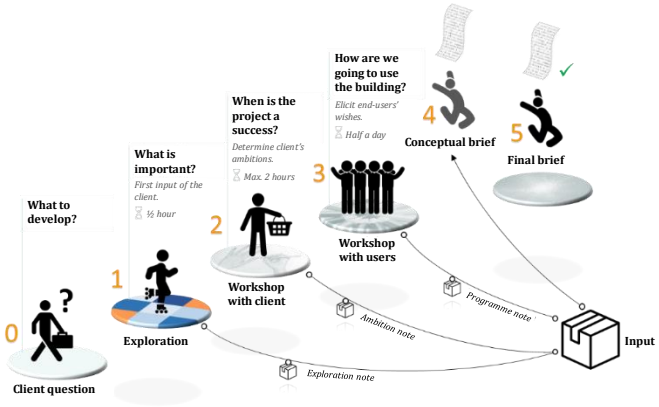


*Figure 1: PvE2Go structure (Antea Group, 2020)*

The PvE2Go tool will be used in phase 3, during a workshop with end-users. Such a workshop is organised in 3 steps: 1) enumerate the users of the future building; 2) their activities; 3) the needed spaces. The PvE2Go tool is an online platform in which the users and user requirements can be gathered and organised visually ( Figure 2). Each circle represents a requirement, the colour indicates it's category (user/activity/space). The circles can be organised in groups and connected to each other. The end-users can immediately check the consultant's notes of their requirements on the shared screen and correct them if necessary. Besides, the tool has an AI algorithm that suggests requirements that often occur together with previously mentioned requirements. For example if the end-users mention a sports hall, the tool can propose dressing rooms and showers. The aim of the tool is to involve the end-user in a interactive and fun way, and to ease communication with the consultant. The AI suggestions help to create complete requirements documents by utilising knowledge from previous projects.

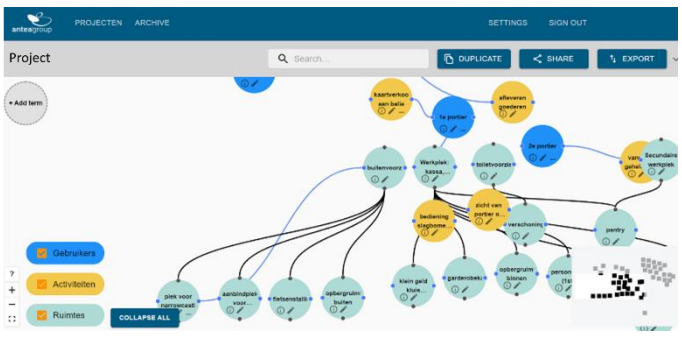


*Figure 2: PvE2Go tool screenshot*

The aim of the research is to examine the effect of the PvE2Go method on the elicitation process and on the requirements brief. The research question is:

> *"What effect does the PvE2Go method have on the process of eliciting user requirements and on the requirements brief of a non-residential building, compared to the current elicitation method?"*

The PvE2Go method has been developed, but it is yet unknown what the effect is on the process of eliciting user requirements. It has been proven that the requirements' quality depends on the used tools (Matulevicius, 2004). This research is designed to examine and explain the effect of the PvE2Go tool. First, the research looks into what has already been investigated in literature. Then a quasi-experiment is performed and the results will be discussed.

## Theoretical background

The theoretical background will first look into the role of requirements in non-residential construction projects. The next paragraph will focus on the specific process of eliciting these requirements.

### *Requirements in non-residential construction projects*

Non-residential buildings are buildings without a residential function, for example a school, hospital or town hall. Non-residential buildings often accommodate several functions and users, which can make projects complex. Other challenges in non-residential building projects are the unique character of each building, the often large scale, many stakeholders, often conflicting interests, many regulations and limited time and budget (Pegoraro & Paula, 2017). It is thus important to manage such projects well.

A building project lifecycle is divided into 5 phases (Alshubbak et al., 2015):

1. Planning phase;
2. Design phase;
3. Construction phase;
4. Use phase;
5. Renovation or demolition.

An important step in the planning phase is to evaluate the demands and needs of the client and users. This results in a document that explains these: the 'requirements brief'. This document is used as a means of communication towards the design phase. It is used for contracting and budgeting as well (van der Voordt & van Wegen, 2005). During the design phase, architects and engineers use the document as a basis to create and develop a building design. Later during the project lifecycle, the building is constructed, used and eventually renovated or demolished. During these phases, the requirements brief can be used for verification.

Requirements management is a process throughout the project. This does not only consist of searching for requirements in the definition phase, but also how these are used during the other phases. Aspects of requirements management are documentation, communication, traceability and change management.

Requirements management can be distinguished into 4 stages (Pegoraro & Paula, 2017):

1. Elicitation;
2. Analysis and prioritisation;
3. Specification;
4. Validation.

Traditionally, these 4 stages were consecutive, but nowadays the requirements brief is seen as a dynamic document that can still change during design phase (Spekkink, 2006). This is translated into three versions of the brief: the general, basis and final brief (Standard Business Reporting, 1996). Mistakes or late introduction of requirements, sometimes called 'requirements creeping', can however cause additional costs or delay in the project (Yu et al., 2010). A balance should therefore be found in sufficient elaboration of a project to explain requirements, but still being able to include it in the design (Figure 3).

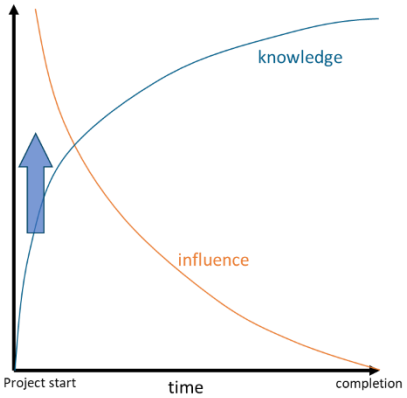


*Figure 3: Increasing knowledge but decreasing influence on the design during projects (Zeiler et al., 2006)*

As the requirements are used throughout a building project, it is important to create a 'good' brief. 66% of architects thinks this is indispensable (Bogers et al., 2008). There is however no scientific consensus on the characteristics that describe a 'good' brief. The most common characteristics are: complete, unambiguous, consistent, feasible, necessary, solution neutral, concise, correct, traceable, modifiable and verifiable (Department of Defense, 2001; Gotel et al., 2007; Matulevicius, 2004; Yu & Chan, 2010). Pohl (1994) has simplified these characteristics into three dimensions:

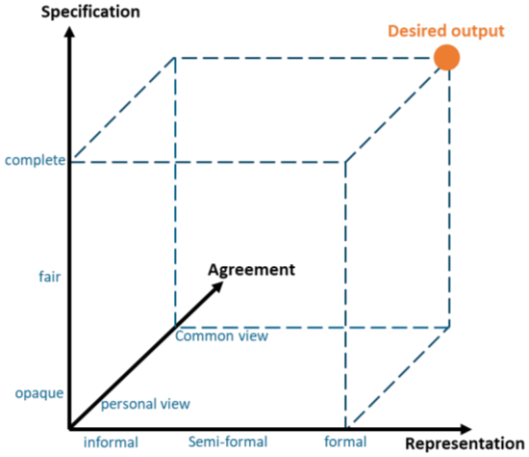


*Figure 4: The three dimensions of requirements engineering (Pohl, 1994)*

Additionally, properties of 'good requirements' are influenced by many factors, amongst which the type of project, elicitation methods, risks, evaluation, communication, business type, culture and ethics (Yu et al., 2008). Also the knowledge and experience of the project team and stakeholders affect the effectiveness and efficiency of the process. Using a systematic and centralised framework can help overcome these challenges (Pegoraro & Paula, 2017; Christiansson & Svidt, 2011).

### *Requirements elicitation*

Requirements management starts with elicitation, this stage is the starting point for the requirements management during the project life cycle. The previous paragraph explained that there are different opinions on performing successful elicitation. This

research will therefore evaluate different approaches and their pros and cons.

The elicitation of requirements stage can again be divided into 5 sub-stages according to (Fernandes & Machado, 2015) (Figure 5).


*Figure 5: 5 sub-stages of requirements elicitation (Fernandes & Machado, 2015)*

It is important to consult end-users, as one of the stakeholders in the project, as they know best what is needed in the new building (Christiansson & Svidt, 2011; Dahl et.al., 2001). Next, the selected elicitation technique(s) will affect the success of requirements engineering (Tsumaki & Tamai, 2006). It is therefore important to select a proper technique for the project. The choice of the right elicitation technique depends on many aspects, of which seven will be mentioned here, firstly the type of requirements. In building requirements, several types can be distinguished. For each type, a different elicitation method can be recommended. One way to distinguish requirement types is based on where they are obtained, for example from the client, from the engineers or from the surroundings (Kamara et.al., 2002). Figure 6 shows the requirement types and how these are related to each other:

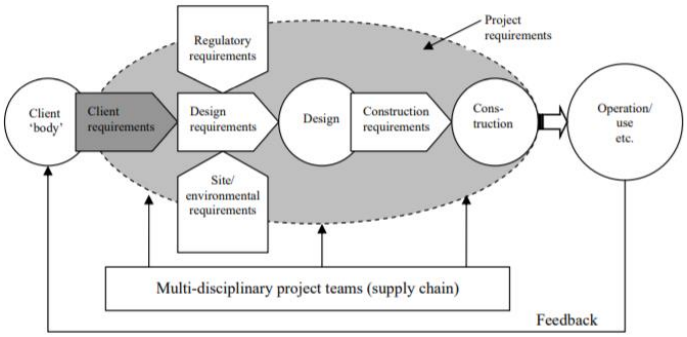


*Figure 6: Requirements types (Kamara et.al., 2002)*

Secondly, the choice of elicitation technique depends on the awareness of the client/end-user and the project team. A method to explain this is the Johari window (Figure 7):

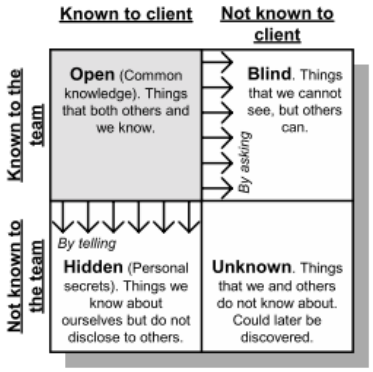


*Figure 7: Johari window (Wandahl, 2004)*

Wandahl shows that either a client or the project team can be aware or unaware of a requirement. For each quadrant, a different elicitation technique can be recommended.

Other selection criteria for choosing an elicitation technique are the type of project, number and type of stakeholders, the preference of the consultant, the phase in the project and the available time.

***Elicitation techniques***

For selecting the right technique(s) for a project, one must first of all be familiar with the available techniques. A literature review was performed on identifying the currently used elicitation techniques. It was found that there is no standard procedure for identification: 25-30% of projects use a standard elicitation method (Kamara & Anumba, 2002) and around two thirds of architects have no formal briefing procedure. Attempts have been made to use standard methods and checklists, but did not succeed due to the complex and creative design process (Rezgui et al., 2019). The technique that is used the most is 'the interview', over 80% of all requirements follow from this technique (Silva et al., 2018). An interview is easy to perform, but the results depend highly on the interviewer. An advantage of interviews is that both the interviewer and interviewee can have a conversation and ask for clarification when needed, to prevent miscommunication. This is a major disadvantage when using questionnaires.

People often forget to tell the interviewer about basic needs, that they consider obvious or do not even think of. To get insight into the standard processes, methods such as observation, evaluation and analysis can be used. A consultant can for example evaluate the customer journey of a user or visit their current location and observe the user's working processes. Especially observations can however be time consuming. Another disadvantage of these methods is the focus on the current way of working. A new building can be an opportunity to change the way of working.
(Kamara et.al., 2000; Robertson, 2001; Young, 2002)

To cover such an opportunity, creativity is needed. Several elicitation methods were found that focus on creativity and interaction. Examples are discussions, brainstorming, using perspectives or scenarios, often performed in a workshop setting. These methods promote creativity, solution oriented thinking and mutual understanding. These are especially suitable for complex problems. It can however be challenging to find agreement between the attendees and to keep working towards the goal. Someone who guides the conversation is therefore essential. (Anwar & Razali, 2014; Harman et.al., 2016; Laudan et.al., 2009)

An issue that often occurs during the requirements elicitation is miscommunication caused by explaining physical objects verbally. If there is talk about a window, people will probably imagine different shapes, colours and sizes. The consultant can use visual communication as a support in conversations. Example methods are example projects, drawings and (virtual) prototypes. Pictures can help for inspiration or communication (Haumer et.al., 1998). A risk is however that the users lose sight of their specific problem and wish for solutions that they actually do not need (Davis et.al., 2006).

***Current challenges***

Although (or possibly because) there are many elicitation methods, the requirements process is not always sufficient. This is the case in two thirds of construction projects (Kamara et al., 2002). Besides, 50% of requirement briefs is incomplete and 60% has an either too high or too low level of detail (Bogers et al., 2008). Misunderstanding between parties in communication and the requirements' explanation often leads to incomplete or inconsistent documents (Yu et al., 2010). Next to this, the design teams often do not manage the requirements adequately, causing unsatisfied clients and users (Arayici & Aouad, 2005).

Many factors were found that can cause these problems: inadequate involvement, insufficient time, wrong perspectives, bad communication, no/insufficient change management, inexperienced team, unstructured approach, lack of traceability and little attention to the requirements (Jensen, 2011; Yu et. al., 2010; Luck & McDonnell, 2006; Wandahl, 2004; Yu & Shen, 2013).

There are recommendations that can improve the process as well. It is recommended to first of all pay attention to the requirements process, with a competent project manager (Yu & Shen, 2013). Also the importance of clear agreements, procedures and responsibilities is emphasised (Yu et al., 2010). This can lead to better understanding and involvement of the client and end-users (Luck & McDonnell, 2006). It was found that this increased involvement leads to buildings that match the needs of the client better, which is eventually the goal of a non-residential construction project (Jensen, 2011).

The new PvE2Go method is a combination of a discussion and workshop and it gives the opportunity of using different workshop techniques. It is therefore suitable for both conversations and creative meetings. Different from the prementioned methods, the PvE2Go method uses visual communication as well as suggestions from the tool, and it uses a predetermined and structured approach. These features create a different way of communication with the end-user and with other consultants: the suggestions are basically the experience of all Antea Group consultants combined. This makes the process less dependent on experience of the specific consultant. In previous paragraphs, it was found that involvement and communication (both on the process and on the content) are often causing problems in requirements elicitation. The PvE2Go method was designed such that it could support the consultant on these issues.

## Methodology

This research combines different methods to investigate the effect of the PvE2Go elicitation method. A quasi-experiment is used to test the elicitation method in practice and to compare this to the interview elicitation method. A scientific experiment is not feasible due to a small group of participants and limited control of the research conditions. A quasi-experiment was therefore selected, containing a case in which two elicitation methods will be examined. In the case, a combination of quantitative data, qualitative data (from questionnaires) and observations is used to gather information on the two elicitation methods. The results in the quasi-experiment can be compared to each other and used to endorse their conclusions. Finally, the results will be compared to and explained by the theoretical background.

### *Aim and scope*

The aim of this research was introduced in the introduction: examining the effect of the PvE2Go elicitation method on the requirements elicitation process and on the requirements brief. The question that the research intends to answer is:

> *"What effect does the PvE2Go method have on the process of eliciting user requirements and on the requirements brief of a non-residential building, compared to the current elicitation method?"*

The research focusses on three topics to answer this question: 'understandability', 'involvement of the end-users' and 'completeness'. In the 'Current challenges' section of the theoretical background, it was found that communication and involvement issues often cause problems in the requirements elicitation process. Besides, these are issues that the elicitation method can influence. Issues like 'limited time' or 'clear responsibilities' can influence the elicitation process, but are not affected by the PvE2Go method.

The last paragraph of the theoretical background explains that the PvE2Go method focusses on improving the involvement and communication/understanding of the end-users. In the paragraph before that, previous research has suggested that better understanding of the process and requirements of the project, will lead more complete and consistent briefs (Yu et al., 2010) and to better involvement of the client and end-user (Luck & McDonnell, 2006). Better involvement can lead to a building that matches the client's needs better (Jensen, 2011). As this is the purpose of requirements management and the goal of the new PvE2Go method, 'involvement' and 'understanding' will be focussed on in the research. The characteristic of a good requirements brief that was mentioned most in literature, is completeness. This is however not measurable: the knowledge keeps increasing during the project (Zeiler et al., 2006), at a certain point of time 'complete' might have a different meaning than a month later. Therefore, a measurable equivalent will be added to the research: 'number of requirements'.

Due to limited time and possibilities, it is important to have clear boundaries for the research, therefore the scope is limited to:

- **Non-residential building projects** in **the Netherlands**. No residential buildings and different cultures.
- **Planning phase**, no design or construction phase.
- Only **elicitation** of requirements, no prioritising or analysis.
- The involvement of **end-users** of the building, no clients.
- The **conceptual brief**, with **functional requirements**.
- **User requirements**, no location/ environmental /legal requirements.
- The PvE2Go and the interview elicitation method are studied in the **quasi-experiment**. Other elicitation methods are only studied from literature.

### *Case*

The case in the quasi-experiment consists of 2 workshops with users of one project, using two different requirement elicitation methods. The project aim is to design a building for serving customers. There is a group of users that will make use of the building in the same way, for the same purpose and with equal experience. The users are not the client in this case.

Two workshops are organised. In each workshop, 4 people are present: a consultant from Antea Group who guides the meeting, 2 users that will share their requirements, and the researcher who observes the participants. The workshops are set up in such a way that the results can be compared and relied on as well as possible. For these reasons, the workshops have the following characteristics:

- A real project is used, this gives a realistic result.
- The project must be in the definition phase and have at least 4 users to participate in the workshops. One suitable project was found, so for this reason no other projects were tested.
- The workshops are performed within a short period of time, such that the information level in the project is equal.
- Different people participate in the 2 workshops, to prevent the learning effect. They must have comparable prior knowledge.
- Both user groups have the same background: they share the same job and one of each group has been involved in the particular project before.
- The consultants that guide the workshops are equally experienced in conversations with stakeholders and similar projects.
- The workshops have the same goal, explanation and steps to reach the goal: inventory of the users, activities and then space. They also have the same duration.

During the two workshops, the attendees sit around a table. In the interview workshop, the consultant takes notes during the conversation. In the PvE2Go workshop, a large screen is present on which the tool is displayed. The consultant controls the tool, the

other attendees can see the results on the screen and request entries or changes.

The workshops last for 2 hours. They consist of 3 main parts: 1. introduction, 2. requirements elicitation and 3. evaluation. In the introduction, the attendees introduce themselves and the researcher explains the workshop's content. For the PvE2Go workshop, this method and the corresponding tool are explained. In the requirements elicitation part, the consultant takes over the lead. He follows the 3 previously mentioned steps (users, activities, space) to collect the end-users' requirements. This happens either by an interview method, or a PvE2Go method. In the evaluation part, the attendees will fill out a questionnaire and give verbal feedback on the session.

### *Data gathering*

A mix of three methods is used to gather data on three topics during the quasi-experiment, which is called a mixed method research (Wheeldon, 2010). This results in a combination of qualitative and quantitative data for each topic (Figure 8).

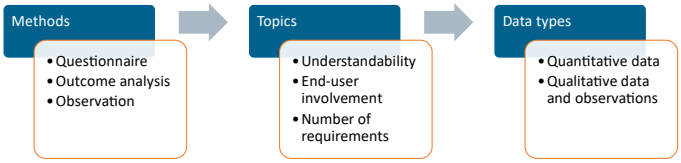


*Figure 8: Methods, topics and data types in this research*

Both the qualitative and quantitative data are gathered using a **questionnaire**. The consultants and end-users fill out the questionnaire during the evaluation of the workshops (see complete questionnaires in appendix A and B). The questionnaires focus on the 3 topics within the research.

The qualitative data is gathered using open questions and comments of the participants. During the evaluation, the participants also get the chance to give verbal feedback on the session. This is treated similar to the written comments.

The quantitative data is gathered by scoring criteria. Per topic, 2 or 3 criteria are used to assign value to the topics (Table 1).

*Table 1: Criteria per topic*

| Topic 1: Understandability | Topic 2: End-user involvement | Topic 3: Completeness |
|---|---|---|
| Understandable process | Engagement | Number of requirements |
| Understandable document | Inspiring | Perception of completeness |
| | Fun to do | |

As these criteria cannot be expressed as an absolute number, a Likert scale is suitable to assign a score to the criteria (Bougie et al., 2017). On the one hand, it is important to keep the number of options in the Likert scale clear and therefore use a maximum of 5 options. On the other hand, more options give a more accurate result (Tarka, 2015). Therefore, a scale from 1 to 5 is chosen. Often, several questions concern one criterion. Appendix C shows which questions belong to which criterion. As the respondents answer using the same scale, their answers are easily combined during data analysis.

One criterion is an exception: the number of requirements. This is not evaluated using the questionnaire, but by **analysis of the workshops' outcomes**. The outcomes will be compared, the requirements counted and divided into categories. It can then be concluded whether both workshops lead to the same (number of) requirements and whether they cover the same categories.

The third and last method is **observation**. During the workshops, the researcher observes the participants and the process on the 3 topics. In order to focus on the same things, the researcher uses the previously mentioned criteria as points of attention (Table 1). For the purpose of reliable observations, the researcher does not actively participate in the workshops.

### *Data analysis*

The data analysis differs between the data types. First, the quantitative data. These consist of questionnaire answers on the scale from 1 to 5. Several questions are combined into the score of one criterion. The table in Appendix C shows which questions belong to which criterion. For most criteria, questions to participants and consultants are combined in one criterion. The answers of the participants on the relevant questions are combined by calculating the average value.

For the number of requirements, another method is used. The outcomes of the workshops are compared and analysed for this purpose. The requirements that are the same or have the same meaning are investigated. The remaining requirements are considered as unique for one of the workshops. The total number of requirements per workshop is now counted. Next, the requirements are divided into categories that describe a certain group of requirements. For example the 'workplace' or the 'outside area'. These are again compared and the unique categories are sought. Eventually, the number of categories per workshop is now counted.

Secondly, the qualitative data. These data are organised per topic (e.g. understandability, end-user involvement, completeness). Furthermore, the qualitative data are not analysed before they are presented in the results.

Lastly, the observations. The same applies to the observations as to the qualitative data: the observations are organised per topic, but are not processed further.

The results from the three data types are compared using triangulation: If they draw the same conclusions on one topic, this will increase the credibility and validity of the results.

## Results

The results of the quasi-experiment are presented per topic: understandability, end-user involvement and completeness. For each topic, the quantitative data, qualitative data and observations are explained. A comprehensive presentation of the results can be found in Appendix D and E.

### *Topic 1: Understandability*

Understandability explains whether the participants of the workshops understand the process and whether they think the resulting requirements document is understandable, structured and clear.

#### *Quantitative data*

The understandability of the method is described by 2 criteria: 'understandable process' and 'understandable document'. Figure 9 shows the corresponding scores from the questionnaire. Regarding the structure of the document, there is a discrepancy between the participants' and the consultants' opinion: the participants who used the PvE2Go method consider the notes less structured than the participants who used the interview method, whereas the consultants think the other way around (Appendix E).

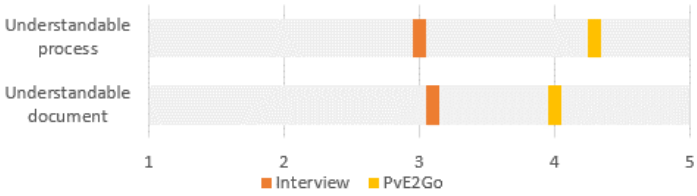


*Figure 9: Quantitative results of 'understandability'*

*Qualitative data and observations*

The participants give the following feedback on the PvE2Go method: "The explanation of the aim and the process can be improved" and "Visible notes help for understanding, keeping the overview and generating ideas". The process should thus be explained better, but the PvE2Go tool helps for understanding the requirements. This is supported by the observation that the participants know how to contribute to the workshop, the conversation is smoother than during the interview workshop. It was also observed that there was high interaction with the shared 'notes' on the screen, these are used to support the conversation and the participants refer to and react on the notes.

The participants give the following feedback on the interview method: "The aim and the process were not completely clear" and "The consultant leads the conversation clearly and to the point". The unclear process was also mentioned in the PvE2Go method. This suggests that the consultants should explain the method better, but that the PvE2Go method does not directly solve this.

***Topic 2: End-user involvement***

The topic end-user involvement explains to what extent end-users are and feel involved. Besides, it describes how the participants of the workshops are aroused, inspired and entertained.

*Quantitative data*

The end-user involvement is described by 3 criteria: 'engagement', 'inspiring' and 'fun to do'. Figure 10 shows the corresponding scores from the questionnaire. In the estimation of 'inspiring', the participants think that the PvE2Go method is more about the future, whereas the interview method talks more about the present and the past.

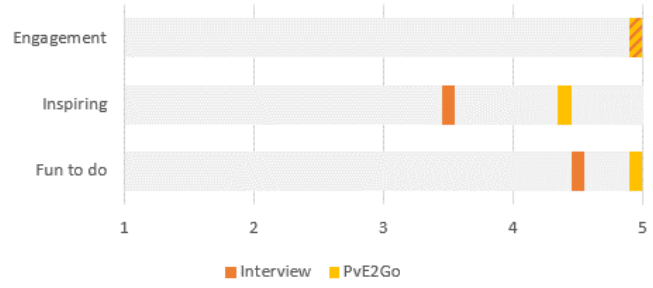


*Figure 10: Quantitative results of 'end-user involvement'*

*Qualitative data and observations*

The participants give the following feedback on the PvE2Go method: "Brainstorming with a colleague helps for new insights, more people trigger each other" and "It's great to be involved in this process as an end-user". This endorses the observation that the participants show much initiative in the conversation. There is much interaction among the participants and with the shared 'notes' on the screen. The consultant has a facilitating role in the background. When the conversation slows down, he uses suggestions from the tool.

During the interview workshop, the participants are more waiting on the questions of the consultant. The participants give the following feedback on the interview method: "It is important to hear more users as they are all different, and therefore have different needs". They feel involved and appreciate to be involved as well.

The participants of the interview workshop are shown the PvE2Go platform. Their reactions are: "It looks fun" and "It would have been great to be able to see and organise the notes". The researcher has seen that the participants become enthusiastic and get new ideas for requirements immediately.

***Topic 3: Completeness***

The third topic 'completeness' describes how many requirements are found by each method. Next to that, it entails whether the participants think the result is a complete representation of their wishes.

*Quantitative data*

The completeness of each method is described by 2 criteria: 'number of requirements/categories' and 'perception of completeness'. Figure 11 shows the corresponding scores and counts from the questionnaire and the resulting requirements. From the interview, 10% more requirements are obtained compared to the PvE2Go method. Looking at categories, both methods discussed the same categories. The requirements and the differences are indicated in Appendix D.

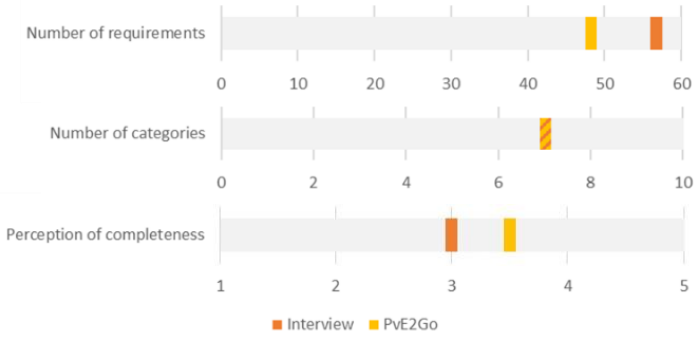


*Figure 11: Quantitative results of 'completeness''*

*Qualitative data and observations*

The participants give the following feedback on the PvE2Go method: "It feels like it's not complete yet", "The suggestions from the tool help for ideas that you consider obvious" and "It was fun to do" (by both the participants and consultant). This indicates that the tool helps participants to recognise the difficulty of identifying requirements alone and reaching completeness. The quantitative data suggests however that the interview participants considered their results less complete than the PvE2Go participants.

The participants give the following feedback on the interview method: "The participants would not have thought of many aspects themselves". This shows that also the consultant helped the participants in the interview to come up with new requirements they would not have thought of alone.

In the observation it was seen that in both workshops, the users of the building and required spaces are found, but the step of identifying activities is mostly skipped (Referring to the 3 steps in both workshops: 1. Users, 2. Activities, 3. Spaces). This is a point of interest for the consultants during future elicitation workshops.

Secondly, there was a large variation in level of detail between and throughout the workshops. Some topics are explained into detail whilst others are broad. One workshop has for example described the cash desk computer, cash desk printer, payment terminal and payment printer as 4 separate requirements, while the other workshop described these as one: 'cash desk'. At the same time, the kitchen is explained in less detail in the first mentioned workshop. This makes the difference in number of requirements less significant.

***Summary of the results***

The main results are presented in this paragraph:

**Topic 1: Understandability**
- Understandability of both the process and the document score higher in the PvE2Go workshop;
- The process should be explained better in both workshops;
- The visible notes help for understanding and to keep an overview.

**Topic 2: End-user involvement**
- Higher inspiration in the PvE2Go workshop than the interview workshop;
- Both workshops have high engagement and are fun to do;
- Much interaction between the participants and the shared notes on the screen;
- Smoother conversation during the PvE2Go workshop, the interview workshop participants are more waiting;
- Participants appreciate involvement in both workshops.

**Topic 3: Completeness**
- 10% more requirements from the interview workshop;
- The same categories are discussed;
- The PvE2Go workshop participants think their results are slightly more complete than the participants of the interview workshop think.

## Discussion

The discussion is separated into two parts: discussion of the results and methodology. First, the meaning of the results is interpretated. Then, the reliability is discussed by looking at the methodology as used.

***Discussion of the results***

The results of each topic will be discussed and then the relation between the topics is reviewed. For the 'understandability', both the qualitative and quantitative data show that the participants do not fully understand the process, but that the consultant has better understanding and thus can help them. An interesting difference is that the consultants consider the document that results from the PvE2Go workshop more structured, whilst the end-users consider the interview document (notes) more structured. This is however difficult to compare, as the end-users have not seen the interview notes. By observation it is seen that the conversation in the PvE2Go workshop is smoother than in the interview workshop. This can be explained by the remark that the visible notes help in understanding and keeping an overview. The three data types all point at a better understanding in the PvE2Go method, because of the shared notes and visible structure of the requirements. In literature it can also be found that visible information structures help for better understanding (Stouffs, 2001).

For the 'end-user involvement', the quantitative data and observations show a higher involvement of the end-users in the PvE2Go workshop than in the interview workshop. The qualitative data supports this, the participants have made remarks that they feel involved and that they consider this important as well. The three methods thus all show increased involvement and that this is appreciated by the end-users.

For the 'completeness', the interview method has elicitated 10% more requirements, the same categories were addressed. The difference could be caused by a different level of detail, as was explained in the results section. The perception of completeness is however slightly higher in the PvE2Go workshop than in the interview workshop. Although the PvE2Go workshop scores higher, the participant's comment "It feels like it's not complete yet" suggests the opposite. Therefore, there is no convincing evidence of a different perception of completeness between the workshops. Another remark of the PvE2Go method is that the suggestions of the tool help for ideas that are considered obvious. This gives requirements that can only be found in the interview workshop if the consultant asks exactly the right question. The number of requirements is higher in the interview workshop, but the PvE2Go tool can help find other information. For example, information from another quadrant of the Johari Window can be found (Wandahl, 2004). Further research could focus on the type of information that can be elicited using different methods.

The theoretical framework as explained in the aim and scope, stated that more understandability would lead to more end-user involvement, which would then lead to a higher completeness. In this research it was found that both understandability and end-user involvement have increased in the PvE2Go method, but the number of requirements shows a slight decrease. These results confirm the first relation: better understanding leads to better end-user involvement. The research does not support the second relation: better end-user involvement leads to a higher completeness. A possible explanation is the difference in level of detail. The workshops could describe the same requirements into more detail and thus cover the same objects in more requirements. Besides, the number of requirements depends on the specific participants and the circumstances. The difference of 10% and the low number of tests does however not give convincing evidence. It would be interesting to compare the number of requirements in more cases.

In literature it was found that better involvement leads to a building that matches the client's needs better (Jensen, 2011). This research shows a higher involvement in the new PvE2Go method, so that suggests that it also leads to a building that matches the client's needs better. If that is the case, the question arises from this research whether more requirements are actually better. In the 'Current challenges' paragraph of the theoretical background, it can be read that many researchers mention 'completeness' as an important characteristic of a good requirements document. This research suggests however that completeness is not necessarily better. An interesting research would be to investigate whether or not more requirements lead to a building that matches the client's needs better.

***Discussion of the methodology***

The second part of the discussion will look into the reliability of the results. The main factor in this research is that the elicitation methods are tested in just one case. A case shows how the methods can be used and what the results can be, but it cannot be concluded that another case will give the same results. Non-residential building projects differ in many aspects, amongst which the type of building, stakeholders, regulations and available resources. Also, the consultants in the workshops were experienced in the interview method, but not in the PvE2Go method. Each of these factors can affect the requirements elicitation process. In order to draw reliable conclusions on the effect of the PvE2Go method, it must be tested in many projects and the project differences must be monitored accurately.

Not all types of projects are thus studied within the scope of this research, but also not all aspects of the process are monitored. The research has focussed on 3 topics, but these are not exhaustive. Further research should critically reconsider the topics that are used.

Lastly, the subject of requirements engineering uses many immeasurable criteria, such as 'completeness', 'successful' and 'good quality'. This limits the possibilities of research on this subject and makes hard evidence of assumptions challenging.

## Conclusion and recommendations

The research has shown the following conclusions on the PvE2go method, when compared to the interview method:

1. PvE2Go is a more understandable elicitation method;
2. Participants are more involved in the process;
3. The PvE2Go method gives a lower completeness.

These conclusions confirm the relation from literature that better understanding of the process by participants will increase their involvement. It does however not confirm that this will lead to more requirements. As discussed in the previous section, the difference is not convincing and several reasons for this difference were explained. Further research is necessary to draw more reliable conclusions on whether the number of requirements is indeed lower and whether that is actually a problem. It can still be true that better involvement leads to 'a building that matches the client's needs better', as Jensen proved.

Misunderstanding during the requirements process can cause incomplete and inconsistent briefs, late design changes and thus additional costs and delay (Yu et al., 2010). If this new elicitation method can prevent misunderstanding, eventually time and costs are saved during the construction process. It can contribute to a more efficient construction industry.

Insufficient involvement of the end-user can cause missing client/user wishes and thus lead to a building that does not match the client's/user's needs. If this elicitation method can support involvement, the buildings suit its users better. This can lead to a pleasant use on the long term and contribute to a more durable construction industry.

From this research it is therefore recommended to start using the PvE2Go method in practice in the planning phase of new construction projects. For the consultants, it is suggested to get familiar with the process and the software. It is interesting to keep track of the experience in each project, to compare the resulting briefs and satisfaction with the buildings, to get insight how the method can be improved and which project characteristics could affect the use of the PvE2Go method (for example type/size of the project or the people).

The application of the tool could also be extended to for example stakeholder identification. It has been shown that stakeholder mapping can support this process (Walker et.al., 2008). The tool can help in visualising the stakeholders' roles, influence and/or dependencies.

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