

A Work Project, presented as part of the requirements for the Award of a Master's degree in
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**A field example: Developing a digital solution for the
less digitised construction industry based on an
iterative methodology**

Benjamin Johannes Pfeiffer (43340)

Work project carried out under the supervision of:

Professor Ricardo Pereira

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Abstract

This work project develops the design and features of a digital solution for building trade businesses in the construction industry, which lags behind other economic sectors in terms of digitisation. In this regard, great potential to improve business processes with a digital solution was identified. Three loops yielded precious user feedback by utilising the iterative innovation approach *design thinking*. Based on ever refined versions of this digital solution, it was found that a hybrid application suitable for web and mobile access would satisfy the needs of the industry the best. This development process required high degrees of flexibility and pronounced willingness to adapt to changing user requests. Ultimately, the designed hybrid application should not be the sole contribution of this work project. Instead, the process should also serve as an example for future similar projects and may be consulted as a guideline.

Keywords

construction industry, building trade, digital solution, innovation, digitisation, design thinking, hybrid application

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1. Introduction

That there is no alternative to digitisation may be marked as common knowledge in 2021. However, many industries are still lacking behind other pioneers, which now regard digital tools and practices as part of their business model. In the meantime, it is agreed that the failure to implement suitable digital solutions will inevitably lead to the destruction of business models sooner than ever — one fact mainly due to an ever-accelerating pace of technological advancements and customer acceptance. The construction industry, on the contrary, serves as the perfect example of a field still being attached to old practices and reluctance to adopt digital tools. The report of EURACTIV (2019) points out that the construction sector is less digital than an overall industry average, marking it the worst-performing industry at the same time. One reason is that the advantages of new digital solutions are only slowly discovered. A surprising finding given the many benefits, including, e.g. increasing the firm's work productivity, efficiency, and organisational dynamics. It can be concluded that even though willingness to adopt digital workflows gained momentum in recent years, companies struggle to put it into action. While good performance is characterised by speed and precision in the construction industry, digital and innovative solutions could facilitate this.

Moreover, the ongoing COVID-19 pandemic has once and for all highlighted the importance of digital transformation for the construction sector, especially for SMEs. However, these enterprises are unconfident in finding the most suitable digital tools, while the implementation of digital solutions represents another great challenge, including the integration in business operations and daily processes. Nevertheless, the effort pays off in a global crisis. Digital leader SMEs are more optimistic for the post-COVID 19 times and more confident to pick up growth. Thus, their business models are more resilient, agile and value-adding for the customer (Vodafone Group Plc 2020). Hence, the willingness of SMEs to spend resources on digital transformation should be expected to rise. For the same reason, policymakers increase their

effort through campaigns and support programs to promote digitisation (e.g. EU SME Strategy for a sustainable and digital Europe) (European Commission 2020).

Initially, based on the procurement processes of small SMEs in the construction industry, this paper will describe the development of a digital solution made for several use-cases. Since the construction industry performs poorly in terms of digitisation, and value creation mainly occurs through traditional physical activity, many opportunities for business process digitisation exist. Based on an iterative approach, this work will present the development of a digital solution and answer questions about the necessary features. In general, this work project aims to contribute towards a connected construction site, eliminate redundant tasks, and reduce overall process time. Paramount importance is paid to user-friendliness and smooth integration into existing business processes.

This paper is organised as follows. First, a review of the existing literature in the field of interest will be provided. Second, the research question will be described, accompanied by the hypothesis development. Third, an overview of the selected methods and approaches will be presented. Fourth, the results will be revealed, and details listed. Lastly, the outcomes will be discussed, followed by limitations and an overall conclusion.

2. Literature Review

This study seeks to fill a gap in the existing field of literature by applying practical concepts to create relevance for the construction industry. The following definition of the construction industry is presented and valid for the complete study. As specified by Chitkara (1998), the industry is usually separated into three sectors: “building construction” (residential, non-residential), “infrastructure construction”, and “industrial construction”. Aggregated business activities under the term construction industry include the manufacturing, constructing, restoring, renovating, maintaining, repairing, and overhauling of a building. Trading and distributing of building materials are also associated with it (Foulkes and Ruddock 2007).

Accordingly, many different business models belong to the industry. However, this project focuses solely on those models in which the business competence lies in craft activities, e.g., construction companies, roofers, carpenters, plasterer, screed layers, facade builders, window fitters, tilers, bricklayers, painters, electricians, and similar others.

Further, it is essential to highlight the differences between “digitisation”, “digitalisation”, and “digital transformation” since these terms are often mistakenly used as synonyms (Bloomberg 2018). This project is mainly concerned about the former. On the one hand, “Digitisation is the process of changing from analogue to digital form, also known as digital enablement [...]” (Gartner 2021b). Further, it “takes an analogue process and changes it to a digital form without any different-in-kind changes to the process itself”, according to Gartner (2021b). Moving telephone communication to chat platforms or generating PDF documents via the smartphone scanning application are examples.

On the other hand, digitalisation is concerned with leveraging new technologies to generate new business opportunities, significantly influencing a company’s future product/service offerings (Gartner 2021a). An example would be the utilisation of generated marketing data to identify new customer segments. Lastly, digital transformation involves implementing many digitisation/digitalisation projects and IT capacity, as well as the willingness for organisational change (Davenport and Redman 2020). It refers to an overall state in which many factors come into play, while digitisation and digitalisation are part of it.

2.1 Definition of the terms program, software and application

Often used interchangeably, thereby omitting the differences, it is crucial to quickly point out the attributes of “program”, “software”, and “application”. Starting with the former, a program contains specific work instructions for the computer to run in an intended way. The software, moreover, may encompass several programs, which as a combination would also operate without user input. An application, on the contrary, runs programs designed for specific activities. To execute these, they require external information, so applications usually have a

user interface (Patel 2019). Further, it is to be distinguished between mobile/native applications and web applications. Mobile/native applications are built for the end-user platform and operating system, which is an advantage and disadvantage at the same time. Developing the application for different operating systems will make the experience more native, direct and seamless. However, this significantly increases costs. Web applications are retrieved through the browser, are not integrated into the system, have reduced functionalities but are more manageable and less costly to develop (Stevens 2018). As both types could be the outcome of this result, they are depicted here.

2.2 Digitisation of the construction industry

As already pointed out, activities aggregated under the term “construction industry” show a significantly lower degree of digitalisation than other industries. In fact, on a global level, the study of DMCC (2020) even indicated the last position of digitalisation degree both in the category operations and supply chain.

Interestingly, the EU economy is mainly characterised by SMEs (small and medium-sized enterprises with a team of fewer than 250 employees) that operate in sectors with low productivity (including building trade) (Lance Taylor 2018). Even 99% of all enterprises in the EU are SMEs (European Investment Bank 2019). Due to their importance, these entities are encouraged to transform digitally, supported by the European Union, to accomplish higher performance (i.e. increasing business efficiency) (Marchese 2020). In the academic world, however, prior research has mainly focused on the positive impacts of implementing software solutions (e.g. BIM software) for big companies in the construction industry (Khosrowshahi and Arayici 2012; Alaloul et al. 2018; Daniotti, Gianinetto, and della Torre 2020).

Consequently, other evidence demonstrated that entities with less financial and knowledge resources face higher barriers to successfully introducing cutting-edge industry technology (Hosseini et al. 2016). Most importantly, as Tezel et al. (2020) found, small SMEs have limited funds for IT projects, which prevent IT investments. Further studies observed that retrieving

the often-needed external data from stakeholders for supply-chain collaboration represents a hurdle (Tezel, Koskela, and Aziz 2018). These findings point to enormous logistical and administrative challenges during a BIM (or similar software) adoption, especially for small SMEs with a small staff. If all digital projects were of that size, it would simply render the digital transformation of small SMEs impracticable. Unfortunately, academic research underrepresented the possibility of replacing the introduction of comprehensive software (e.g. BIM) by adopting software applications solely for specific business processes. Hence, instead of digitally mapping the entire value chain, small SMEs could digitise only the most critical or problematic processes. One reason for digitising only selected processes would be the less required financial and time resources, while changes and results could be observed quickly. However, as Hosseini et al. (2016) documented, missing theoretical coverage may contribute to SMEs' being unaware of the positive impacts of digital solutions.

As this section points out, it is interesting to investigate whether tailored software solutions for individual business processes improve the workflow for small SMEs in the construction industry. The goal would be to drive digitisation while avoiding great resource-spending of comprehensive software implementation.

2.3 Procurement process

The following paragraph serves as an example of a critical SME process that could be better coordinated and presented more clearly with the help of this project's solution. Since this is a process of great importance for building trade business models in the construction industry, a dedicated section will follow.

One of the most important activities during a successful construction project remains the procurement process (The Chartered Institute of Building 2010; Pesämaa, Eriksson, and Hair 2009). Finishing the work within the schedule in top quality whilst staying within the budget limits requires precise procurement. This process may vary in complexity depending on the type and size of the construction project (Sarker et al. 2012) as well as the size of the firm and

segment of the construction works (f:data GmbH 2016). Other researchers, such as Gulghane and Khandve (2015) or Patil and Pataskar (2013) have discussed the importance of efficient material procurement since it often represents the most significant cost factor (appr. 60%).

Nevertheless, this project addresses the inefficiencies within the material procurement processes, which is considered a sub-process. This process is about ensuring the required resource is available at the right time in the right place. It includes activities such as planning, purchasing, and delivering goods and services. As complexity and size increase, materials will be purchased from material suppliers, who will submit their offers beforehand. Hence, a coordinator is responsible for ensuring that all specifications are met and kept within the defined budget (Tunji-Olayeni et al. 2017).

These facts suggest that it would be beneficial to simplify and accelerate the recurring procurement process with digital solutions. Interestingly, for small projects that SMEs perform, material procurement still occasionally occurs at the local hardware store (Schwab 2020). Inefficiencies in terms of availability, plannability and logistics are the result. Given the importance of efficient material procurement and its current shortcomings, it would be interesting to investigate the possibility to design a digital solution for the material procurement process of small SMEs in the construction industry. Since few researchers have addressed this proposal in the past, and demand from the field became visible, it is part of the concept of this project.

2.4 Communication practices

Since communicating between employees and managers is essential for the construction project's success, it might entail factors relevant to consider for any digital solution for the industry. As established by Parker (1980), the efficiency and effectiveness of manufacturing activities are linked to high-quality levels of communication. Given the complexity and variety of projects, necessary information exchange needs to take place to ensure on-time completion. Specifically, Aiyewalehinmi (2013) formulated several different purposes that communication

assumes on a construction site: to exchange feedback on the quality of completed tasks, to receive information about the current condition of the workforce (i.e. efficiency, the status of progress, well-being), to submit on-site data for decision-making and allocation of subsequent tasks. All this information can be transmitted either through a verbal or non-verbal (written) way (Perumal and Bakar 2011). Of course, the question arises as to how communication takes place on the construction site nowadays. Modern tools include, most importantly, among others, instant messaging (e.g. WhatsApp or Telegram) and email. These can replace high-quality face-to-face conversations, improve understanding between employees and the entire communication process (Ou, Sia, and Hui 2013). Pozin and Nawi’s (2018) study mentioned a range of benefits (speediness, simplicity and clarity) derived from using an instant messaging tool like Whatsapp on a construction site. These apps are top-rated and used by many primarily due to a quicker decision-making process. Nevertheless, an instant messaging app has not explicitly been designed for the use case of a construction site. However, due to their popularity, the benefits of these applications should be considered when developing a new digital solution. Therefore, they are relevant for this project and are listed in this section.

2.5 Design Thinking Method

First mentioned already in 1987 by Rowe (1987) was the idea of the methodology “*design thinking*” as an approach to create, engineer or design products (Razzouk and Shute 2012). According to Plattner (2013), *design thinking* is made to find a solution for problems. It can be understood as an iterative process (see Figure 1) until a satisfying version of the product is found.

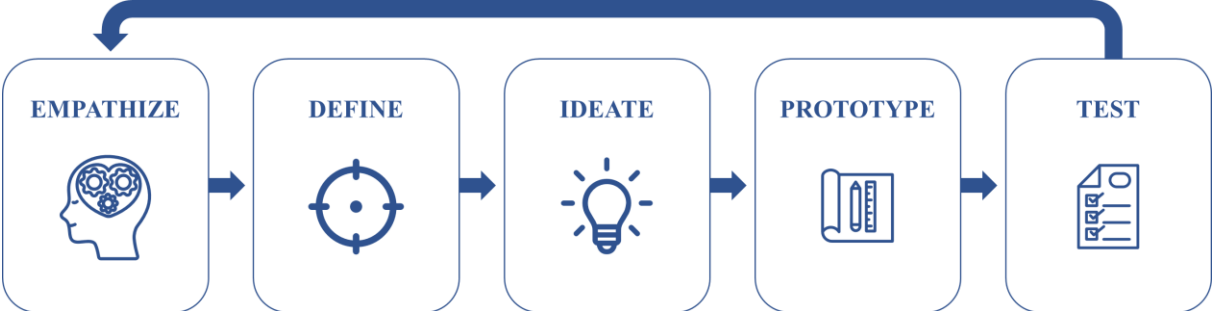


Figure 1: Design Thinking loop

The first step, “Empathize”, discovers real problems in the area (industry, market, country) of interest. By retrieving direct information, one may put himself in the stakeholders’ shoes to get a complete picture of their challenges. This phase also aims to determine why existing solutions (i.e. products, services, processes) are insufficient. All collected information is processed in the “Definition” step and combined to define the current problems/challenges. By doing that, the goal of this project is set. Step three, “Ideate”, aims to generate ideas on how to solve the defined problems. It can describe not only the way to get there but also a final product. Emphasis is placed on doing things differently than previous solutions. Often, a pre-selection is made, with the most preferred solutions becoming the first focus of the next phase. That is the “Prototype” phase; it turns the solutions into a version where the required functions/design/process features become visible/imaginable. Care is taken to keep the version as lean as possible in a resource-saving manner. During the last step, “Test”, prototypes are handed over to the end-user in order to receive valuable feedback, serving as an input for the “Empathize” phase as new information became clear and the “Definition” phase since new problems appeared that need to be solved (Plattner 2013). Great advantages of the *design thinking method* are that solutions are built around customer problems right from the start whilst relying on actual field testing. Further, problem solvers are encouraged to think innovatively and beyond boundaries. Since the starting point is unclear in the initial stages of this project, this method could prove helpful as the pre-defined steps and iterations can serve as a guideline.

3. Research Question

As previously noted, this project aims at guiding the design, functionality, and process of digital solution development. Thereby, it utilises use-cases of building trade businesses, while the results should also be understood as a framework for other developments. The following question will be investigated and answered by means of hypotheses to achieve these goals.

Thus, the research question is:

1) Which digital solution can ensure higher reliability and improve the efficiency of the procurement process of building trade businesses in the construction industry?

This question will provide answers for the procurement process and, as the *design thinking* process revealed, also communication processes within small SMEs operating in the construction industry. The research consists of three loops that build on each other and are complementary, meaning that one loop feeds into the subsequent. First, this project investigated current industry practices in the field of research. It started with conducting interviews of business owners to receive first-hand information and get acquainted with the industry. Second, this basic information got validated with another set of industry stakeholders based on visualisations. While many assumptions of those have not got confirmed by experts, other demands emerged during this process. This aggregated information gave answers to the hypotheses below. Lastly, application features got further validated during the third loop.

3.1 Hypothesis development

Both hypotheses are formulated in a way to cover the most common digital solutions used in the industry. Now that digitisation has slowly taken hold even in building trade businesses, many digital solutions are either web or mobile applications. It is, therefore, a question of the type of application. Since this is the first important question that needs to be answered, they are divided into two hypotheses (see Table 1). In order to conclude, solely the perspective of the end-user has been assumed. First, the option of a web application will be evaluated based on stakeholder opinions (H1). It is expected that the majority of information systems will run on web-based applications, mainly due to greater accessibility across different operating systems. Irrespective of the web browser type, data may be available for all users at the same time. Another benefit is that software updates are seamless and happen for everyone simultaneously (Tarud 2021). Even theoretical literature has highlighted the advantages of web applications in

construction projects and their enabling role for efficient communication (Chassiakos and Sakellaropoulos 2008).

In contrast, a digital solution running as a mobile application represents another possible outcome of this project (H2). Mobile applications are downloaded onto the user’s smartphone device and provide advantages in terms of functions. The full extent of the native functionality can ensure better integration of the features in the ecosystem compared to web applications, and customisable designs are possible.

Furthermore, the usage of certain functions in a repetitive manner also points towards a mobile application, as also performance tends to be quicker (Tarud 2021). Especially workers on a construction site, regardless of the size, need to retrieve essential information quickly and easily. Precisely those are the strengths of mobile applications. Given the widespread usage of smartphones of construction workers, a major prerequisite for rapid implementation would already be met. In general, it can be said that both solutions have the potential to improve the procurement process of SMEs in the construction industry in various ways.

RQ1	H1	A web application would positively impact the reliability and improve the efficiency of the procurement process of building trade businesses in the construction industry
RQ1	H2	A mobile application would positively impact the reliability and improve the efficiency of the procurement process of building trade businesses in the construction industry

Table 1: Hypotheses

4. Methodology

This project constantly validated customer needs derived from construction industry problems by iteratively exposing assumptions/prototypes to experts. Mainly due to insufficient digitisation, which many studies have confirmed, the construction industry was chosen. Furthermore, small SMEs (i.e. building trade businesses) were targeted due to easier accessibility and more direct communication. Collecting expert feedback was conducted in

three sequential loops according to the logic of the *design thinking method*. The initial assumption was based on processes in the procurement of supplies and materials of small SMEs operating as a building trade company (belonging to the construction industry). As described in the literature review, potential for improvement through a digital solution became apparent when reading through previous studies. Moreover, preliminary internet research and two conversations with business owners helped to identify crucial procurement processes and practices.

4.1 Initial use-case assumption

During one of the initial conversations, the managing director of *PilarCampos*, located in Sacavém, Portugal, provided most insights about the company's material procurement activities. The business offers craft services for construction projects and employs around 20 people, while their expertise lies in renovation projects. The procurement process, though, is still characterised by inefficiency and redundancy. While each head worker at the construction site is responsible for material planning, the company's purchaser, the managing director, gathers this information and ensures the supplies. However, many points along this process are insufficiently organised and miss the necessary routine. Firstly, on-site workers tend to forget material planning for the next day. Secondly, if missing supplies is noticed during the day, on-site workers send the material request whenever it occurs. Hence, the purchaser might be urged to purchase supplies several times a day. Thirdly, each head worker places the material request by a WhatsApp message for the sake of convenience. However, that hampers the availability of an aggregated overview of the required materials. Provided these unsatisfying gaps in the process, the company is willing to adopt a digital solution supporting re-organising and professionalising procurement. Given the small size of the entity, new measures may be implemented timely and with significant impact. Hence, the company's procurement process was chosen as the initial concept of this project to develop a digital solution.

The gathered assumptions were subsequently cross-checked with other market participants in three loops which revealed diverging implications compared to the initial concept. In the following sections, each loop's sample and tools and methods will be explained.

4.2 Loop #1: Samples, Tools and Methods

The goal of the first loop was to validate initial assumptions about the type of digital solutions derived from the procurement process at *PilarCampos*, by going through each step of the *design thinking* process. One of the primary resources of information was internet research about existing application types and their functions. Here, application comparison lists were screened (Sandage 2020; Rodriguez 2019) for solutions aiming at the procurement process of SMEs in the construction industry. Both renowned application stores, App Store and Google Play Store, were thoroughly checked for similar mobile applications. To guarantee to compare to current, relevant digital solutions, the internet was the preferred information source. It became apparent that existing solutions have different functionalities than required. However, much importance was paid to finding solutions with features similar to what the research on the procurement process required.

After the type of application was determined, low-fidelity wireframes were created with the aid of the design tool *Figma*, in which mockup screens for applications and their functions can be developed. This tool was selected due to its high user-friendliness and quick onboarding process. Additionally, it was preferred over simple sketches since the visualisations should be precise, eliminating room for false interpretation.

4.3 Loop #2: Samples, Tools and Methods

Subsequently, more feedback about the initial feature assumptions of the application was necessary. That was achieved through two telephone interview rounds with a total of 13 interviews of 15 minutes each. Interviewees were carefully identified via industry websites or through LinkedIn and filtered based on their business models and company size. Requirements were that the former revolves around building trade activities as described in the literature

review and be considered an SME (fewer than 250 employees). Approximately 30 companies were contacted, while all of them are in Germany. To avoid language barriers, only German-speaking companies were included as it is the mother tongue of the researcher. In the first round, firms with a similar business model as *PillarCampos* were contacted, and specific questions concerning the procurement process were asked. Seven full interviews were completed. The interview questions for this round are listed in Appendix 1. Once enough information was retrieved, other business models, including roofers, painters, plasterers, staircase constructors, and electricians, were approached, contributing to another six interviews. Similarly, the interview guide for round two is available in Appendix 2. The questions of both types of interviews were in line with the principles of “The Mom Test” published by Fitzpatrick (2013), which guided formulating questions. Common biases that mislead respondents to agree on propositions or to withhold relevant information were thereby avoided. Hence, it was possible to receive objective information about industry practices. Another close feedback provider of this project is the stair construction company *Pillitteri Treppen- u. Metallbau GmbH* (in short: *Pillitteri Treppenbau*) was adopted after they expressed strong interest and need for a digital solution during the interview.

In the next step, the application prototype was designed in *Figma* in the same fashion as in loop #1 but with more detail and sophistication. Design inspirations were retrieved from the social media and design collaboration platform *Dribbble* to align the basic designs of the application with modern and up-to-date examples.

4.4 Loop #3: Samples, Tools and Methods

In the last loop, the prototype was reviewed by potential users, which was performed in the online tool *Maze*, in which reviewers completed pre-defined tasks. These tasks, also called missions, collected data about the time to completion, feedback about design and functionality. Also, misclicks, points for improvement and common errors were recorded. Usability-testing was carried out by the managing directors of *PillarCampos* and *Pillitteri Treppenbau*, and other

employees, allowing for six reviewers. The two firms were chosen due to their high interest in implementing a digital solution and willingness to support it. Afterwards, the feedback was incorporated in the prototypes with the help of Figma.

5. Results

As mentioned earlier, this project aimed to develop a digital solution for the procurement process, while the answer to the research question is the following. The digital solution should, in the form of a hybrid application, offer two visually similar versions for web and mobile access. The features of both versions include an aggregated project overview with categorisation, project-specific chat function, document storage, material list, to-do list and notes section. Further, a material order function, create task function and create project function is integrated. Thus, both hypotheses (H1 and H2) regarding the application type got rejected since a combination of both has proven to be the best option. This result is different from what has been expected since the proposed solution can also be implemented in other use-cases than procurement. The following sections will describe the results of each iterative *design thinking* loop that led to this decision.

5.1 Loop #1: Getting acquainted

After completing the first loop, it was apparent that the correct type of digital solution suitable to ensure higher reliability and improve the efficiency of the procurement process would be a hybrid application. Since the answer to the hypotheses made up only a part of the insights that loop #1 revealed, the rest will also be explained in the following paragraphs.

Empathize: As described in the Methodology, the first step was to stock up on as much information as possible about the industry, software solutions and their features. First, the initial interview with the managing director of *PillarCampos* helped to understand the business processes. Second, market research showed that digital solutions for procurement in the construction industry exist in the form of web applications (e.g. *cathago* or *inpera*), mobile applications (e.g. *Schüttflix*, *Truckast* or *pds*) and hybrid applications (*capmo*, *craftboxx* or

craftnote), which is a mix of the two former. The latter often had functions similar to those requested by *PillarCampos*. Research showed that another point favouring hybrid applications is that both office and on-site workers need to access software, as procurement is an interplay. Furthermore, it became clear that building-trade business's IT infrastructure mainly consists of office computers and on-site smartphones while other tasks are still completed on paper.

Define: After building a knowledge base of other procurement processes and suitable digital applications, the next step was to define the problems and weaknesses of the procurement process at *PilarCampos*. That is necessary in order to determine requirements for application features later. The company's procurement process faced the following problems:

- 1) Material planning often forgotten: It is supposed to be done by on-site workers who fail to remember at the end of the workday.
- 2) Information exchange does not take place at regular intervals: Given the first problem, the material is ordered throughout the day at any time when supplies are just needed.
- 3) Little overview of the required materials: As material orders are sent via the messenger platform *WhatsApp*, an aggregated overview providing helpful information is missing.

Ideate: Due to what market research has revealed and after brainstorming about the correct type of application, it was decided to develop a hybrid application, accessible from the web browser and smartphone. Most importantly, the web browser version will not be visually different from the mobile one but simply larger in scale. Hence, it will be available on more giant screens without having to develop two separate versions. It seemed like an elegant way to avoid long prototyping phases testing but still offer a hybrid application. Then, the actual idea generation took place where 30 user stories were created, which helped define each user type's application requirement (office staff, purchaser or on-site worker). These are used to describe application features by expressing the intentions to reach an outcome of each user when using the application. One user story always follows the same pattern, for example: "As a purchaser, I want to have a complete list of required materials sorted by construction site so

that I do not need to scroll through WhatsApp chats” or “As an on-site worker, I want to quickly select materials and send my order so that I do not lose more time than when sending a simple message”. The complete list of user stories can be found in Appendix 3.

In summary, the purchaser needs to gain a better overview of the required materials while ensuring that orders arrive on time. On the contrary, on-site workers need to submit their order efficiently. The corresponding user stories then served as the starting point for the subsequent step that merges all these requirements into application features.

Prototype: During the prototype phase, two separate front-ends were designed as requirements for the purchaser and on-site worker seemed to differ significantly. Thus, the purchaser-version included (1) notification message when the material list is ready. (2) It offered a list of ordered materials including the category of supply, name, amount, unit, order date. (3) The possibility to check a box when purchased and (4) detailed view of each order including the responsible on-site worker and site address was available. On the other hand, the on-site-worker-version was more comprehensive and contained (1) a reminder for material planning as a screen notification and (2) a multi-step order process: choosing the construction site, selecting the category of material, typing in the name, defining quantity and unit. Moreover, (4) a list of requested materials by the user on this day and (5) a history of ordered materials grouped by construction sites was integrated. The prototype was built as a low-fidelity black and white wireframe with a total of 12 screens. The on-site worker version is available in Appendix 4, and the purchaser version displayed in Appendix 5.

Test: The prototype was handed over to *PillarCampos*, which revealed that the version already covered the demands and features were considered appropriate. The company’s most urgent problems would have been solved by implementing this version. Nevertheless, other experts and potential users were needed to validate the features to create a relevant product. Hence, it makes it the purpose of loop #2.

5.2 Loop #2: Turning the concept

Validation of the current solution with more stakeholders revealed that the assumption of developing a solution solely for the procurement process of building trade businesses was too narrow. Instead, as suggested by opinions from business owners and workers, the market indicated demand for an application that digitises and simplifies communication in general. Use-cases like the procurement process or task planning, which got discovered in this loop, would then count as sub-categories of communication. Furthermore, specifics about the design of proposed new functions were determined with user feedback. The subsequent paragraphs will describe the path to reach these findings.

Empathize: It was the aim to present the proposed solution found in loop #1 to a broader audience, thereby either validating the assumptions or identifying other inefficient processes. Through the first round of interviews, the procurement process of other construction firms seemed to be different to what was assumed before. In fact, (1) supplies and materials are usually ordered directly at the supplier, (2) through email or phone contact. (3) At the beginning of a project, the material will be planned and ordered by the supplier beforehand. (4) If unexpected demand arises, the responsible site engineer places an order at the supplier. At *PillarCampos*, though, materials are purchased at a physical hardware store at any given time throughout the project. Given these contradictions, it was reasonable to examine whether the value proposition of the current version of the application would be too restricted to procurement. The second round of interviews with seven different business models confirmed this assumption and revealed the following. (1) Widespread use of *Microsoft Office* and *WhatsApp* as project information sharing tool for site information, to-do lists, material planning, pictures and videos. (2) Ordering of new supplies happens via phone call with the office. (3) Demand for mobile to-do lists of tasks assigned to certain workers got identified. (4) Projects cannot be put into sections based on status/progress. Lastly, (5) missing mobile overview of files/documents relevant at the construction site.

Define: Based on the new findings, the problem set needed to be updated. This set provided an overview of needs that later serves as input for new application features. Most importantly, (1) the current integration of project information, to-do lists, material planning, and employee communication is insufficient. Further, (2) the information transfer between office and construction site is confusing and inefficient. Lastly, (3) information supply outside the office is complicated or non-existent.

Ideate: Now, other ways were sought to solve the new set of problems and also address other customer groups with the application. Of course, it was essential to cover as many use cases as possible. The interviews showed that no matter what type of building trade business, there is a need for a solution that can be used in various ways. Thus, the idea was born to create a digital solution covering the purchasing process and simplifying communication between the office and construction site (O2CS) and between the construction site and construction site (CS2CS). Thus, the existing functions from Loop #1 were to be integrated and supplemented by new ones. Just like in loop #1, 25 user stories were created: for example, “As a worker, I want to have communication separated for each project so that I gain a better overview and find information quicker.”. Appendix 6 lists the remaining entries.

Prototype: Using user stories as the starting point for the features, another prototype (low-fidelity wireframe) with 17 essential screens was created. As opposed to the first wireframe, it was only one universal version for all user types. The version contained the following features: (1) A project overview in which projects are listed based on project status. Each project has its chat, (2) document folder structure, (3) material list, (4) to-do list and (5) notes function. The chat function notifies about messages, documents, changes in the material list/to-do list. (6) For each user, a personal material list shows the material requests assigned to the user as a responsible person. Further, (7) a personal to-do list contained the assigned tasks for the user. All screens and their descriptions are available in Appendix 7.

Test: Feature validation took place with the help of the three respondents, namely the managing director of *PillarCampos* and two employees of *Pillitteri Treppenbau*. The feedback was generally positive. Functions were all considered valuable, and the logical flow of functions was felt to be logical. Nevertheless, some points for improvement were noted. (1) The project overview missed information regarding project type, start date and site address. Also, (2) the document list missed the name of the sender. (3) Further, the possibility to categorise material requests based on intended use (e.g. water pipes belongs to plumbing.) would be helpful. Further, (4) material requests should be assigned with a supplier code.

5.3 Loop #3: Further elaboration with functions

Subsequent usability testing identified shortcomings of the current design and functionality, which still manifested its good impression from the last iteration. Users were very enthusiastic about the application if the problems were fixed in the subsequent version.

Empathize: In the final loop #3, it was the goal to measure the usability of the implemented functions of the application while also observing how the testers cope with the design. As the functions are multi-step paths, common errors or misunderstandings would need to be discovered early on in the process. Further, whether all screen areas are used by the user as intended and if changes to the layout or logical flow would be necessary was observed. To receive this valuable feedback, it was necessary to simulate different scenarios.

Define: Beforehand, these scenarios had to be defined based on tasks of the user journey that are crucial to a satisfying experience with the application. Essentially, the questions had to be answered: “In any case, which crucial points throughout the user journey are essential for a smooth user experience and important to investigate?” As such, the following points were identified. (1) The project needs to be selectable based on its status to gain an efficient overview. (2) Ordering new materials and (3) creating new tasks should happen close to their respective overview screen to avoid duplicate entries.

Ideate: Iterating on these, it became clear that these features would need to be prioritized and part of the usability testing to observe shortcomings of these essential functions.

Prototype: Using those features, a sophisticated prototype with detailed screens, including colours, buttons with functionalities and native gestures, was developed. This so-called high-fidelity wireframe had a total of 17 screens. As an advancement from the version of loop #2, the new development had a more smooth and seamless appearance, while a (1) dark-blue colour scheme underlined the logical flow of the functionalities. (2) The project overview screen showed more specifics about the project, and changes were made visible by small, coloured numbers. (3) Material order and task create screen were implemented as lay-overs of the lists. Furthermore, (5) personal material and to-do lists were now visually identical to their corresponding project-based list. On top, suggestions of loop #2, as mentioned in “Test”, were also incorporated. The screens, including the detailed description of changes, can be found in Appendix 8.

Test: Usability testing was conducted with five separate missions, covering the crucial tasks as defined under “define” and included: “Sign In and check the details of the first project”, “Find the material list of project P-01”, “Check the details of the first material request”, “Create a new material order”, “Find your personal material list”, “Find the to-do list of project P-01”, “Check the details of the first task”, “Create a new task” and “Find your personal to-do list”. Exemplary screens of the usability testing can be found in Appendix 9. Based on the observed data, the testing revealed the following shortcomings of the version. (1) The colour scheme is not optimal for outdoor usage. (2) Archived projects are not available. (3) Material list icon is not recognisable. (4) The form of the tab bar seems ambiguous. (5) Adding new materials out of the personal material screen seems unclear. (6) Notifications about each project are not visible. (7) Unclear navigation path to personal material list.

Afterwards, these problems would be resolved for the next version #4. The observed usability problems and their corresponding solutions that make up version #4 are summarised in

Appendix 10. The updated version #4 and the changes are presented in Appendix 11. The browser version is displayed in Appendix 12.

6. Discussion

In this project, a hybrid application suitable for web or mobile usage was developed. By utilising a widely recognised methodology, the “*Design Thinking Method*”, it was possible to develop a digital solution for small building trade businesses. Thanks to that, this solution already incorporated feedback from potential customers, which makes it so valuable. Especially in an industry as under-digitised as the construction industry and their building trade businesses, there is little reference to suitable solutions, so early customer contact is imperative. In addition, small businesses, which have less purchasing power, are often overlooked by large software development firms. However, it is precisely in this area, with 99% of all EU enterprises considered as SMEs (European Investment Bank 2019), that there are great opportunities for solutions that have the potential to make everyday work more efficient. The outcome of this project, the application, serves as an example of a digital solution that drives the digitisation of building trade businesses and thus the construction industry. Further, it shows that, as opposed to the highly complex software (e.g. BIM) integration, applications for specific processes (i.e. procurement, task-planning) may already satisfy the very different needs of small SMEs. Furthermore, this project provided an illustrated framework for similar software development projects and may therefore serve as a guide. As such, this lean and probably cost-effective digital solution has many advantages for the users. (1) Most importantly, this solution is based on old routines, namely Whatsapp for communication. Therefore, the familiarisation period should be low for employees and willingness to switch high. (2) Thanks to project-based communication, all stakeholders have the same information level and independently of the location since it can be accessed on the move. (3) Moreover, noteworthy information for the user (e.g. material purchases or tasks that the user has been assigned to) is prepared in personal

cross-project lists. (4) The chat function serves as the centre of information distribution and informs not only about messages but also about changes in material planning and task list. (5) Project details are now retrievable outside the office. (6) On top, a visually improved folder structure with keyword tagging makes document search (photos, videos, PDFs, word, excel, csv) clearer and more straightforward.

In sum, the great advantage of this application derives from its multi-purpose character aiming to improve communication in many use-cases (e.g. material procurement and task planning). Hence, it can be used in various types of building trade businesses in the construction industry. A complete list of suitable business types can be found in Appendix 13.

Even though suitable other digital solutions have not been found throughout the process, it is important to compare the validated features with others in the market. A detailed list of other applications close to version #4 is available in Appendix 14. The most pressing competitive solution, as confirmed by industry experts, is said to be WhatsApp. However, this project expanded on WhatsApp's features by tailoring for building trade. A fact that potential users would appreciate quickly. Furthermore, several hybrid applications targeted at building trade offer very similar features (e.g. craftboxx, HERO, BauBuddy). However, these either miss the task planning or the chat function. Also, a couple of mobile applications for construction site documentation are essentially different in their functionality but should be considered indirect competition since the purpose of these are comparable (e.g. Renewa, Memomeister, pro-report 3). Moreover, many software solutions exist for construction companies, which partly cover the requirements of this developed solution (e.g. capmo or planradar) and are therefore also marked as indirect competition.

Nevertheless, the risk of them serving as an alternative seems low. Firstly, these solutions are comprehensive and complicated to implement. Secondly, the mobile versions of the hybrid application only offer certain features. That limits small business with no permanent office worker in their flexibility. Besides those, other cloud service platforms, such as slack, could be

a potential substitute. Although these might be sufficient for pure communication, they lack building trade specific functions and an efficient mobile overview of information. Therefore, the presented application can distinguish itself from other offers in the market thanks to the unique combination of features, also grouped per project. Furthermore, since the application will also offer a Portuguese version, the language may be another differentiating factor.

The target user group of this application would be any business providing craft services that perform their work on-site. Given the extensive contact with industry experts during the feedback loops, potential users (leads) have already been identified. That includes the two firms *PillarCampos* and *Pillitteri Treppenbau*, accounting for a total of +20 users. They would be already familiar with the idea of the application and would still serve as close feedback providers for further development.

However, to deliver a working application, several steps are still to be taken beyond the scope of this master thesis. The decision about the type of actual software development has to be taken: no-code application development (e.g. via Appy Pie, Airtable, Bubble) or conventional code development. While the former would be faster and cheaper, it is not as flexible as a newly written application. On the contrary, the latter would be conducted by extracting the Figma file, to serve as the basis for front-end development. Once the front-end source code exists, the back-end, namely the infrastructure, database, storage methods, and security processes, would be developed. Without that, the developed front-end would be useless since the functionality would be missing. Nevertheless, the final decision regarding this crucial point will be made after no-code tools are tested and pricing compared to external software development.

7. Limitations & Future Projects

Even though extensive care was taken to collect feedback from a large sample of businesses, future projects could increase the number of respondents to further back the results of the *design thinking* loops. However, given the missing experience and few contacts within the construction

industry of the researcher, it was difficult to get in touch with businesses and hence, a limitation. Further, cold calling proved to be the most effective method to meet the target group. Nevertheless, many respondents were highly sceptical and refused to provide answers. It would therefore be beneficial for upcoming projects if an industry expert could forward high-quality contacts. Another limitation was the time constraint of this master thesis, as more functionalities could have been implemented and even a beta version of the application coded. That would also simplify approaching unknown businesses since a proper product shows higher credibility than wireframes.

8. Conclusion

The goal of this project was to find the design and functionality of a digital solution suitable for building trade businesses in the construction industry. The outcome of this undertaking was a hybrid application, accessible through the web browser and mobile smartphone. As opposed to initial planning, this application may be deployed not only for material procurement/planning but also for task planning and information exchange (i.e. communication) in general. Since this paper should also be considered a framework for similar projects, a major finding remains that the *design thinking* method requires high flexibility of the researcher. Contradicting field feedback should be embraced and seen as a valid foundation for the work while pivoting is a normal phenomenon. Given this steep learning curve throughout this project, this form of work can only be recommended to others. It has not only introduced the researcher to practical new methodologies/approaches (i.e. *design thinking*, cold calling) but also to new tools (i.e. *Figma*, *Maze*) and could serve as a starting point for any entrepreneur. As this work project has reinforced the researcher's entrepreneurial spirit, the development of the application will be pursued so it can be launched as an actual product.

9. References

- Aiyewalehinmi, E O. 2013. "Factor Analysis of Communication in the Construction Industry." *The International Journal of Engineering and Science* 2 (10): 49–57.
- Alaloul, Wesam S, Mohd Shahir Liew, Noor Amila Wan Abdullah Zawawi, and Bashar S Mohammed. 2018. "Industry Revolution IR 4.0: Future Opportunities and Challenges in Construction Industry." In *MATEC Web of Conferences*, 203:02010. EDP Sciences.
- Bloomberg, Jason. 2018. "Digitization, Digitalization, And Digital Transformation: Confuse Them At Your Peril." *Forbes*. April 29, 2018. <https://www.forbes.com/sites/jasonbloomberg/2018/04/29/digitization-digitalization-and-digital-transformation-confuse-them-at-your-peril/?sh=7f4dca472f2c>.
- Chassiakos, Athanasios, and S P Sakellariopoulos. 2008. "A Web-Based System for Managing Construction Information." *Advances in Engineering Software* 39 (November): 865–76. <https://doi.org/10.1016/j.advengsoft.2008.05.006>.
- Chitkara, K K. 1998. *Construction Project Management*. Tata McGraw-Hill Education.
- Daniotti, Bruno, Marco Gianinetta, and Stefano della Torre. 2020. *Digital Transformation of the Design, Construction and Management Processes of the Built Environment*. Springer Nature.
- Davenport, Thomas H., and Thomas C. Redman. 2020. "Digital Transformation Comes Down to Talent in 4 Key Areas." *Harvard Business Review*. May 21, 2020.
- DMCC. 2020. "Future of Trade 2020."
- EURACTIV. 2019. "Digitising the EU's Construction Industry."
- European Commission. 2020. "Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions." Brussels.
- European Investment Bank. 2019. "Financing the Digitalisation of Small and Mediumsized Enterprises."

- f:data GmbH. 2016. "Purchasing in Construction." February 13, 2016.
<https://www.bauprofessor.de/einkauf/>.
- Fitzpatrick, Rob. 2013. *The Mom Test: How to Talk to Customers & Learn If Your Business Is a Good Idea When Everyone Is Lying to You*. 1st ed. CreateSpace Independent Publishing Platform.
- Foulkes, A, and L Ruddock. 2007. "Defining the Scope of the Construction Sector." In *Proceedings of the 8th IPGR Conference, Salford*, 89–98.
- Gartner. 2021a. "Digitalization." Gartner Dictionary. 2021.
<https://www.gartner.com/en/information-technology/glossary/digitalization>.
- . 2021b. "Digitization." Gartner Dictionary. 2021.
<https://www.gartner.com/en/information-technology/glossary/digitization>.
- Gulghane, A A, and P v Khandve. 2015. "Management for Construction Materials and Control of Construction Waste in Construction Industry: A Review." *International Journal of Engineering Research and Applications* 5 (4): 59–64.
- Hosseini, M Reza, Saeed Banihashemi, Nicholas Chileshe, Mehran Oraee Namzadi, C E Udeaja, Raufdeen Rameezdeen, and Tammy McCuen. 2016. "BIM Adoption within Australian Small and Medium-Sized Enterprises (SMEs): An Innovation Diffusion Model." *Construction Economics and Building* 16 (3): 71–86.
- Khosrowshahi, Farzad, and Yusuf Arayici. 2012. "Roadmap for Implementation of BIM in the UK Construction Industry." *Engineering, Construction and Architectural Management*.
- Lance Taylor. 2018. "Market Power, Low Productivity, and Lagging Wages: The Real Drivers." Institute for New Economic Thinking. August 2018.
- Marchese, Lorenzo. 2020. "The DigitaliseSME Final Conference Frames the Positive Impact of the Project in Helping European Companies Digitalise." February 26, 2020.
<https://digitalisesme.eu/the-digitalisesme-final-conference-frames-the-real-positive-impact-of-the-projects-in-helping-companies-in-europe-digitalise/>.

- Ou, Carol Xiaojuan, Choon Ling Sia, and Chun Kit Hui. 2013. "Computer-mediated Communication and Social Networking Tools at Work." *Information Technology & People*.
- Parker, Henry W. 1980. "Communication: Key to Productive Construction." *Issues in Engineering: Journal of Professional Activities* 106 (3): 173–80.
- Patel, Pankaj. 2019. "Difference between Software and Application." GeeksforGeeks. May 30, 2019. <https://www.geeksforgeeks.org/difference-between-software-and-application/>.
- Patil, Ashwini R, and Smita v Pataskar. 2013. "Analyzing Material Management Techniques on Construction Project." *International Journal of Engineering and Innovative Technology* 3 (4): 96–100.
- Perumal, Vasanthi R, and Abu Hassan Abu Bakar. 2011. "The Needs for Standardization of Document towards an Efficient Communication in the Construction Industry." *Acta Technica Corviniensis-Bulletin of Engineering* 4 (1): 23.
- Pesämaa, Ossi, Per Erik Eriksson, and Joseph F Hair. 2009. "Validating a Model of Cooperative Procurement in the Construction Industry." *International Journal of Project Management* 27 (6): 552–59. <https://doi.org/https://doi.org/10.1016/j.ijproman.2008.10.007>.
- Plattner, Hasso. 2013. "An Introduction to Design Thinking." *Institute of Design at Stanford*, 1–15.
- Razzouk, Rim, and Valerie Shute. 2012. "What Is Design Thinking and Why Is It Important?" *Review of Educational Research* 82 (3): 330–48.
- Rodriguez, Juan. 2019. "Top 10 Must-Have Smartphone Apps for Construction Work." November 20, 2019. <https://www.thebalancesmb.com/construction-apps-for-builders-844901>.
- Rowe, Peter G. 1987. *Design Thinking*. MIT press.
- Sandage, Erin. 2020. "The 10 Best Apps for Construction Companies." ExakTime. December 29, 2020. <https://www.exaktime.com/blog/best-apps-for-construction-companies/>.

- Sarker, Bhaba R, Pius J Egbelu, T Warren Liao, and Junfang Yu. 2012. "Planning and Design Models for Construction Industry: A Critical Survey." *Automation in Construction* 22: 123–34.
- Schwab, Irmela. 2020. "Digital Shopping: How Profishop Is Restructuring the Procurement Process in the Skilled Trades Sector." July 25, 2020. <https://www.handwerk-magazin.de/digital-einkaufen-wie-profishop-den-beschaffungsprozess-im-handwerk-neustrukturiert/150/23108/404535>.
- Stevens, Emily. 2018. "What Is The Difference Between A Mobile App And A Web App?" *Careerfoundry*, April. <https://careerfoundry.com/en/blog/web-development/what-is-the-difference-between-a-mobile-app-and-a-web-app/#:~:text=Web%20apps%20need%20an%20active,Web%20apps%20will%20update%20themselves>.
- Tarud, Jonathan. 2021. "Mobile Apps vs Web Apps: What's The Difference?" Koombea. April 19, 2021. <https://www.koombea.com/blog/difference-between-mobile-apps-and-web-apps/>.
- Tezel, Algan, Lauri Koskela, and Zeeshan Aziz. 2018. "Current Condition and Future Directions for Lean Construction in Highways Projects: A Small and Medium-Sized Enterprises (SMEs) Perspective." *International Journal of Project Management* 36 (2): 267–86.
- Tezel, Algan, Martin Taggart, Lauri Koskela, Patricia Tzortzopoulos, John Hanahoe, and Mark Kelly. 2020. "Lean Construction and BIM in Small and Medium-Sized Enterprises (SMEs) in Construction: A Systematic Literature Review." *Canadian Journal of Civil Engineering* 47 (2): 186–201.
- The Chartered Institute of Building. 2010. "A Report Exploring Procurement in the Construction Industry."

Tunji-Olayeni, Patience F, Adedeji O Afolabi, Rapheal A Ojelabi, and Beatrice A Ayim. 2017.

“Impact of Logistics Factors on Material Procurement for Construction Projects.”

International Journal of Civil Engineering and Technology (IJCET 8 (12): 1142–48.

Vodafone Group Plc. 2020. “SME Digitalisation – Charting a Course towards Resilience and Recovery.”

10. Appendix

Appendix 1: Interview questions round 1

#	QUESTIONS
1	Could you describe the process of material procurement?
2	Who is responsible for it (also on-site)?
3	Who is responsible for re-orders?
4	What details are important for the order (e.g. item number, description, quantity, delivery date)?
5	What problems occur during the process?
6	Which analogue or digital tools are used?
7	Why don't you use digital solutions?
8	Have you ever wished there was a software/app to assist you in procurement?

Appendix 2: Interview questions round 2

#	QUESTIONS
1	How do you communicate between the construction site and the office?
2	What information is communicated?
3	Do you use mainstream communication tools?
4	Which other digital solutions are used in your company?
5	What are they used for?
6	Do any problems arise in the process?
7	Why don't you use digital solutions?

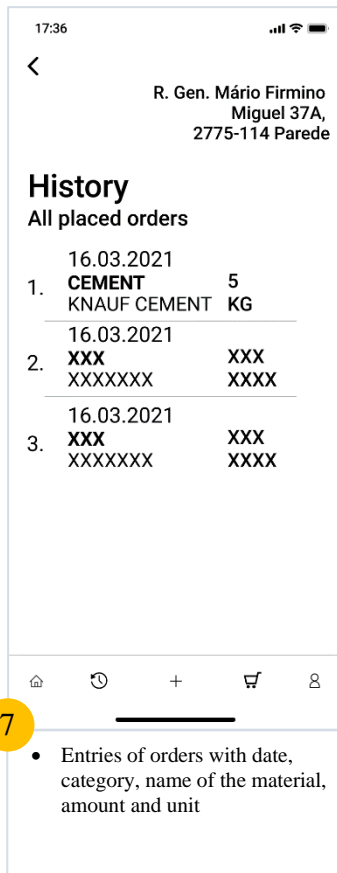
Appendix 3: User stories loop #1

#	AS A (ROLE)	I WANT (GOAL)	SO THAT (OUTCOME)
1	Managing director	To have efficient construction sites	No time and money is wasted for waiting
2	Managing director	To reduce the time of the material purchasing process	Workers have time for other work
3	Managing director	To use the history of orders	To perform cost controlling
4	Managing director	To know the number of consumed materials	I can estimate the project stage
5	Purchaser	To purchase materials only once per day	I do not need to go several times
6	Purchaser	To have an overview of a complete list of materials	I do not need to scroll through WhatsApp chats anymore
7	Purchaser	To have an aggregated list available every morning	I can go purchase without another task
8	Purchaser	A complete list with entries from each work site each morning	No communication is needed before purchasing
9	Purchaser	That the orders arrive without extra communication	I do not have to remind the worker's to plan and order for their site
10	Purchaser	That the workers plan and send an order every evening	The process is automated
11	Purchaser	To know the name of the worker who ordered	Orders are traceable

12	Purchaser	To know the name and location of the construction site corresponding to the order	I am fast in dropping off the right materials
13	Purchaser	That only one head worker of each site orders materials	No double orders take place
14	Purchaser	That if the head workers is absent, another worker of the site plans and orders	Planning and purchasing takes place in any case
15	Purchaser	That the head worker gets automatically notified	I do not need to take care of that anymore
16	Purchaser	That each site either places an order or indicates no demand	The purchased volume is correct
17	Purchaser	To have a history of orders	I can compare orders
18	Head worker	To quickly find the right materials and order	I do not waste time
19	Head worker	To be able to select the required materials	I do not have to type it in by hand
20	Head worker	To type in the quantity	The right amount is on-site
21	Head worker	To get notified each afternoon to plan and order for tomorrow	I do not have to remember myself
22	Head worker	To order as fast as possible	I do not have to spend extra time
23	Head worker	To be able to copy previous orders	I do not have to type it in again

24	Head worker	To be able to place ongoing, repetitive orders	I do not have to order every single day the same
25	Head worker	To know if materials could not have been purchased	I know what I have available
26	Head worker	To understand the value of the APP	I am motivated to use it
27	Head worker	The App to have big buttons and bright colors	The screen is always clearly visible
28	Head worker	To know when the material is going to arrive	I can plan the work on site
29	Head worker	To leave extra comments related to my order	I can make sure the purchaser has all information
30	Head worker	To be able to attach a picture related to my order	I can also order material without knowing the name
31	Worker	To make sure that the Head Worker planned for my materials	I can work properly
32	Purchaser	To have an overview of the current construction sites	I can quickly find orders
33	Purchaser	To have site-specific information	I can comprehend orders

Appendix 4: Wireframes loop #1: Version on-site worker 2/2



17:36

R. Gen. Mário Firmino
Miguel 37A,
2775-114 Parede

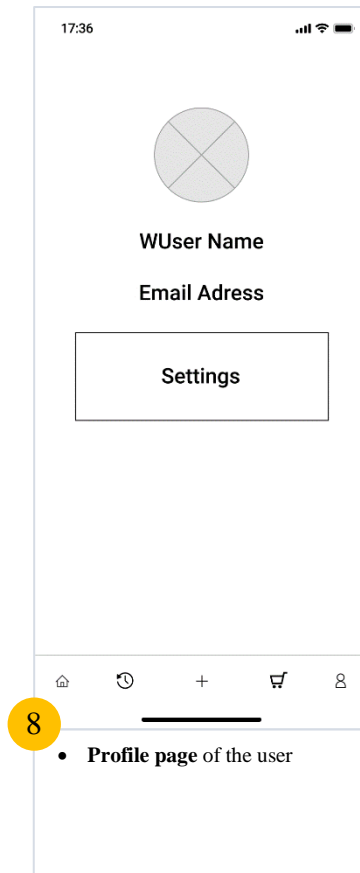
History

All placed orders

16.03.2021		
1. CEMENT	5	
KNAUF CEMENT	KG	
16.03.2021		
2. XXX	XXX	
XXXXXXXX	XXXX	
16.03.2021		
3. XXX	XXX	
XXXXXXXX	XXXX	

7

- Entries of orders with date, category, name of the material, amount and unit



17:36

WUser Name

Email Adress

Settings

8

- **Profile page** of the user



17:33

COPLAN 3m ago

Daily planning 📅

Take a moment to plan for tomorrow and order the materials you need for your team!

9

- **Notification:** Reminder for material planning at the end of workday

Appendix 5: Wireframes loop #1: Version purchaser

08:04

Hi PUuser

Your shopping list
dd.mm.yy

Sort by

MATERIAL	SITE	DATE	
1. CEMENT KNAUF CEMENT	5 KG	16.03.21	<input checked="" type="checkbox"/>
2. XXX XXXXXXXXXXXX	XXX XXX	16.03.21	<input checked="" type="checkbox"/>
3. XXX XXXXXXXXXXXX	XXX XXX	16.03.21	<input type="checkbox"/>

Navigation bar: Home, +, Profile

1

- **List of ordered materials**
- Can be sorted by category of material, site or date
- Navigation bar only with home, list of materials and profile

08:05

<

Order

All details

CEMENT 5
KNAUF CEMENT KG

WUSER 16.03.2021

R. Gen. Mário Firmino
Miguel 37A,
2775-114 Parede

Navigation bar: Home, +, Profile

2

- **Details** of each order when clicking on the list entry

08:03

COPLAN 3m ago

Ready to get started 🗓️

Your workers have requested material.
Check out your shopping list for today!

Notification icon

3

- **Notification** as a reminder of the new shopping list of materials for the day

Appendix 6: User stories loop #2

#	AS A (ROLE)	I WANT (GOAL)	SO THAT (OUTCOME)
1	Manager	To have efficient construction sites	No time and money is wasted for waiting
2	Manager	To reduce the time of the material purchasing process	Workers have time for other work
3	Manager	To be in direct contact with my team	Efficient communication is possible
4	Manager	To share all communication	Everyone is on the same page
5	Manager	To use the history of orders	To perform cost controlling
6	Manager	To know the amount of consumed materials	I can estimate the project stage
7	Purchaser	To purchase materials only once per day	I do not need to go several times
8	Purchaser	To have an overview of a complete list of materials	I do not need to scroll through WhatsApp chats anymore
9	Purchaser	To have the materials sorted by project and categories	I can see where to deliver and buy them in aggregation
10	Purchaser	To have an aggregated list available every morning	I can go purchase without another task
11	Purchaser	a complete list with entries from each work site each morning	No communication is needed before purchasing
12	Purchaser	That the orders arrive without extra communication	I do not have to remind the worker's to plan and order for their site

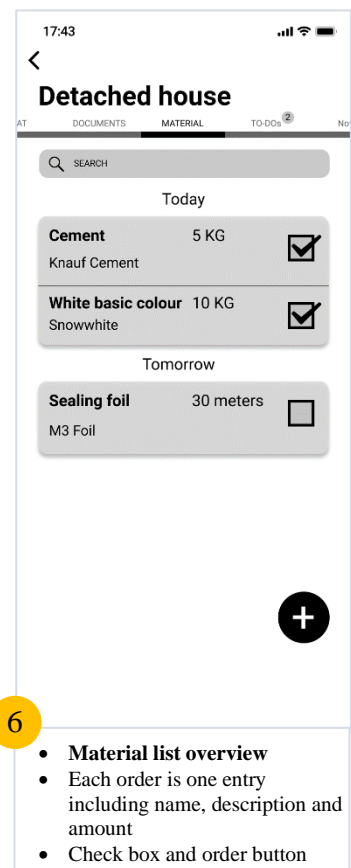
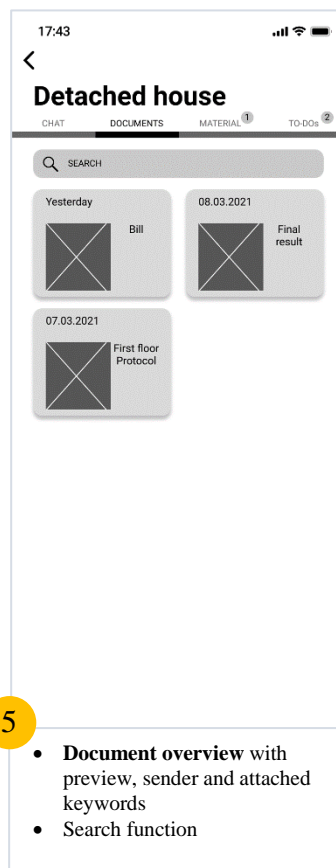
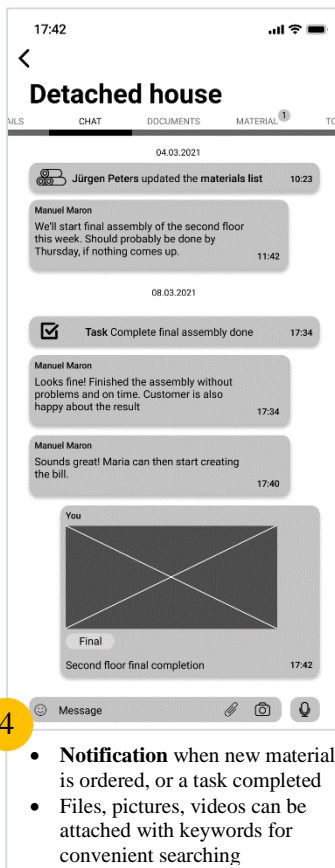
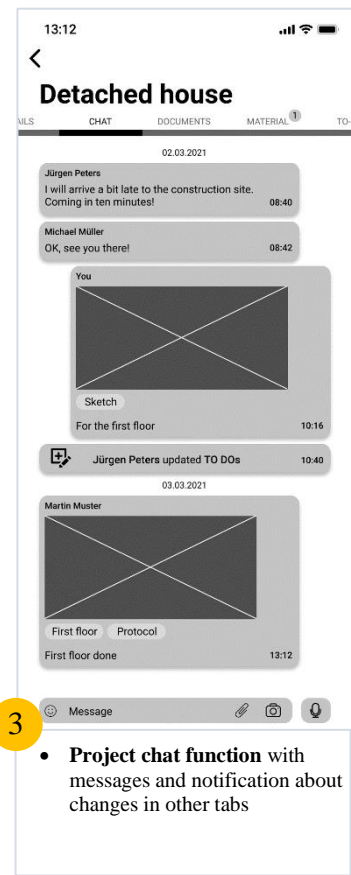
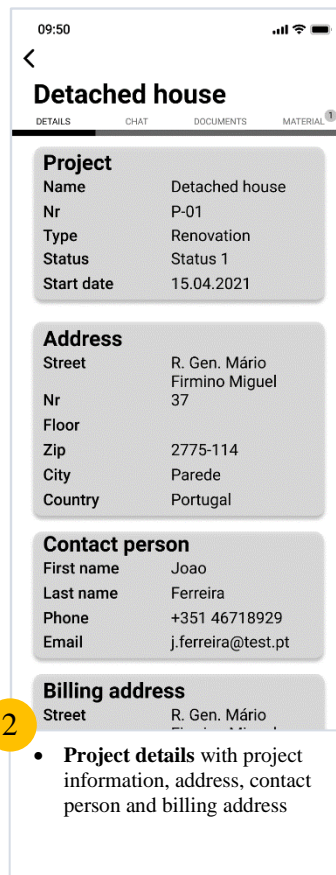
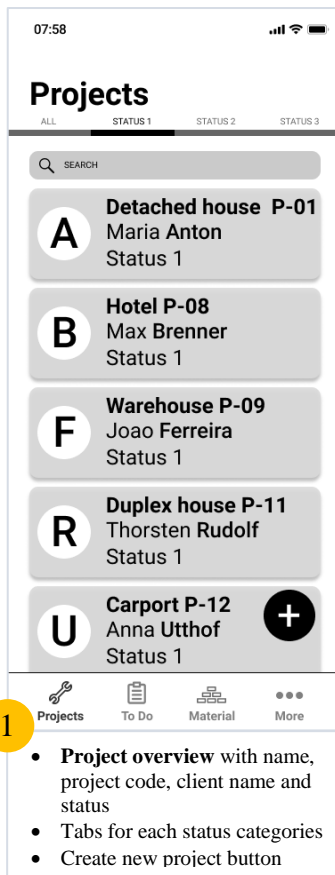
13	Purchaser	That the workers plan and send an order every evening	The process is automated
14	Purchaser	To know the name of the worker who ordered	Orders are traceable
15	Purchaser	To know the name and location of the construction site corresponding to the order	I am fast in dropping off the right materials
16	Purchaser	That only one head worker of each site orders materials	No double orders take place
17	Purchaser	That if the head workers is absent, another worker of the site plans and orders	Planning and purchasing takes place in any case
18	Purchaser	That the head worker gets automatically notified	I do not need to take care of that anymore
19	Purchaser	That each site either places an order or indicates no demand	The purchased volume is correct
20	Purchaser	To have an overview of the current construction sites	I can quickly find orders
21	Purchaser	To have construction-specific information	I can comprehend orders
22	Purchaser	To have the materials sorted in categories	I can accelerate the purchasing process
23	Purchaser	That each order is shared with everyone	No double orders take place
24	Purchaser	To have a history of orders	I can compare orders

25	Worker	To quickly find the right materials and order	I do not waste time
26	Worker	To be able to select the required materials	I do not have to type it in by hand
27	Worker	To type in the quantity	The right amount is on-site
28	Worker	To get notified each afternoon to plan and order for tomorrow	I do not have to remember myself
29	Worker	To order as fast as possible	I do not have to spend extra time
30	Worker	To be able to copy previous orders	I do not have to type it in again
31	Worker	To be able to place ongoing, repetitive orders	I do not have to order every single day the same
32	Worker	To know if materials could not have been purchased	I know what I have available
33	Worker	To understand the value of the APP	I am motivated to use it
34	Worker	The App to have big buttons and bright colours	The screen is always clearly visible
35	Worker	To know when the material is going to arrive	I can plan the work on site
36	Worker	To leave extra comments related to my order	I can make sure the purchaser has all information
37	Worker	To be able to attach a picture related to my order	I can also order material without knowing the name
38	Worker	I want separate communication for each project	To keep things apart

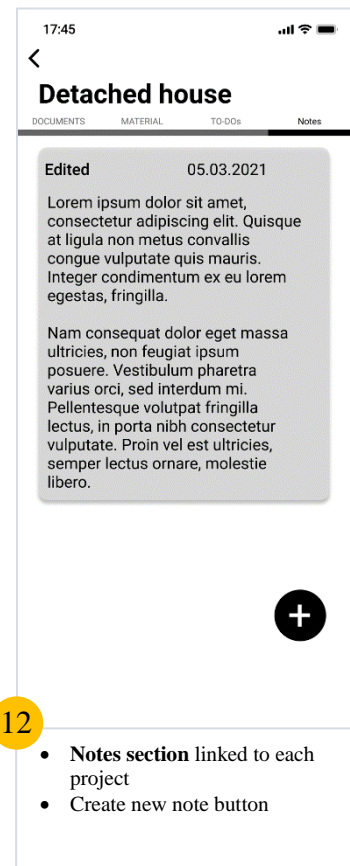
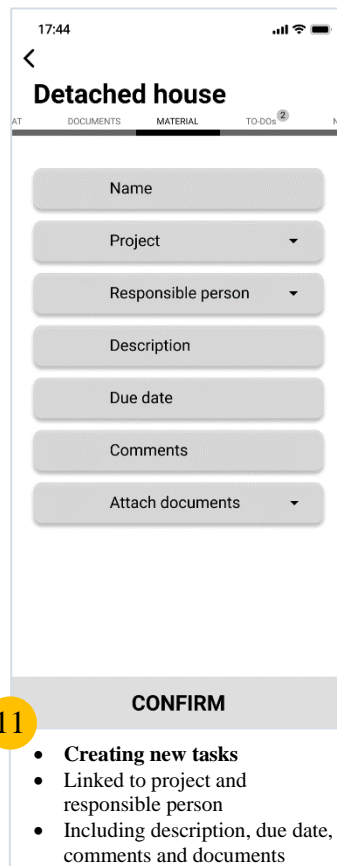
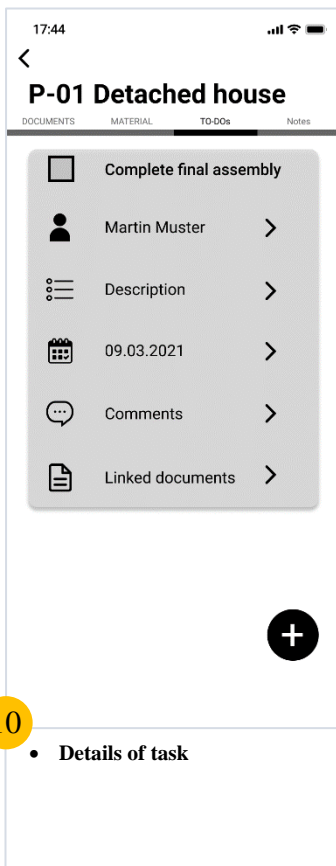
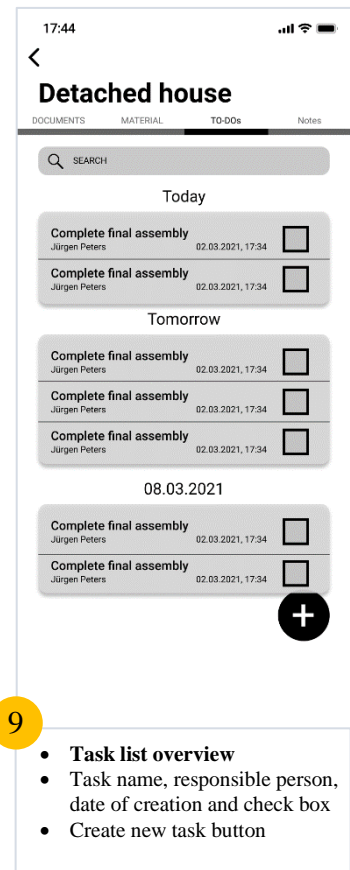
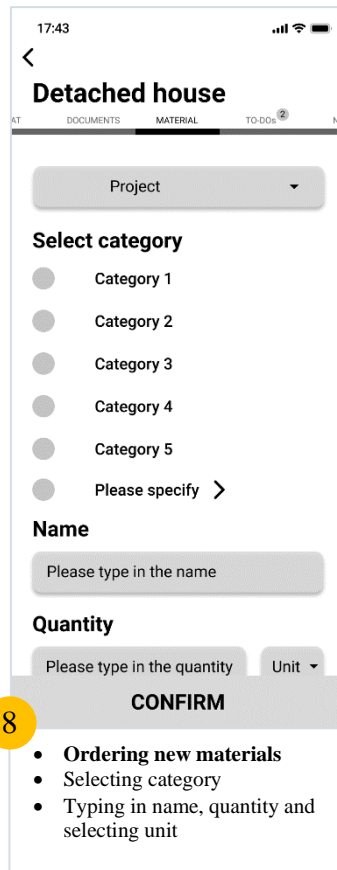
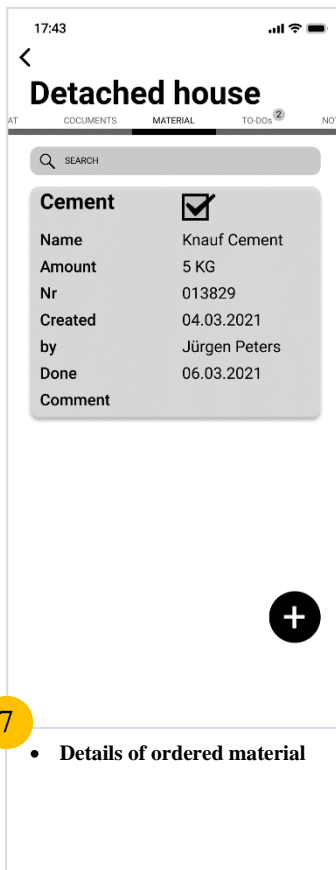
39	Worker	I want separate materials & to-do lists for each project	To be organised better
40	Worker	I want to have personal materials & to-do lists	To have a quick overview
41	Worker	To make sure that the Head Worker planned for my materials	I can work properly
42	Worker	To communicate with my team in a known fashion	I can easily orient myself
43	Worker	To share documents, pictures, videos with my team	I can share more info about the project
44	Worker	To use keyword tagging for files	I can easily find files again
45	Worker	To have projects placed in different stages	I can have an ordered overview
46	Worker	To have a list of my upcoming tasks	I can plan myself
47	Worker	To see all the tasks related to one project	I know what my colleagues are doing
48	Worker	To see completed tasks related to a project	I can understand what happened
49	Worker	To search for tasks	I can find tasks quicker
50	Worker	To have my personal tasks sorted by project and date	I know where and when
51	Worker	To see the name, status and address of the task-related project in the personal to-do list	I can immediately recognise

52	Worker	To attach documents, comments related to my task	I have more information
53	Worker	To see the responsible person, name of the task and date of the task	I can have a quick overview
54	Worker	I would like to tick a box as soon as the task is completed	That they move into completed section

Appendix 7: Wireframes loop #2 1/3



Appendix 7: Wireframes loop #2 2/3



Appendix 7: Wireframes loop #2 3/3

17:46

Upcoming To Dos

Today

Project: P-01 >

Complete final assembly
Status 1
04.03.2021

Tomorrow

Project: P-08 >

Lorem ipsum dolor sit amet
Status 2
05.03.2021

06.03.2021

Project: P-11 >

Lorem ipsum dolor sit amet
Status 4
06.03.2021

Projects To Do Material More

- **Personal To-Do list**
- Sorted by project with name, status and due date
- Create new task button

17:46

Material list

Heute

Project: P-01 >

Cement 5 KG
Knauf Cement

Silicone 20 pcs.
Pattex Silicone

Silicone 20 pcs.
Pattex Silicone

Morgen

Project: P-11 >

Cement 5 KG
Knauf Cement

Silicone 20 pcs.
Pattex Silicone

Projects To Do Material More

- **Personal material list**
- Only visible if assigned to the user
- Sorted by project, with name, description, amount

17:47

More

Settings

Profile

Logout

Projects To Do Material More

- **More**
- Settings
- Profile
- Logout

17:50

New Project

General information

Name

Type

Order number

State Date

Status

Description

Address

Street

Nr Floor

ZIP City

Country

Projects To Do Material More

- **Creating new project**
- General information and address information

17:50

New Project

Name

First Name

Last Name

Phone

Email

Other

Attach documents

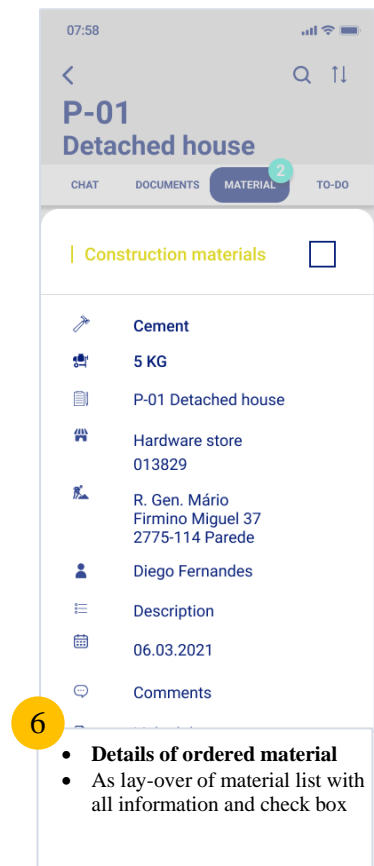
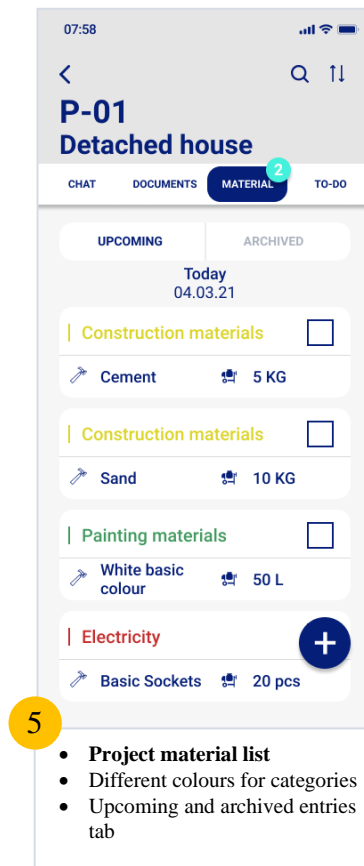
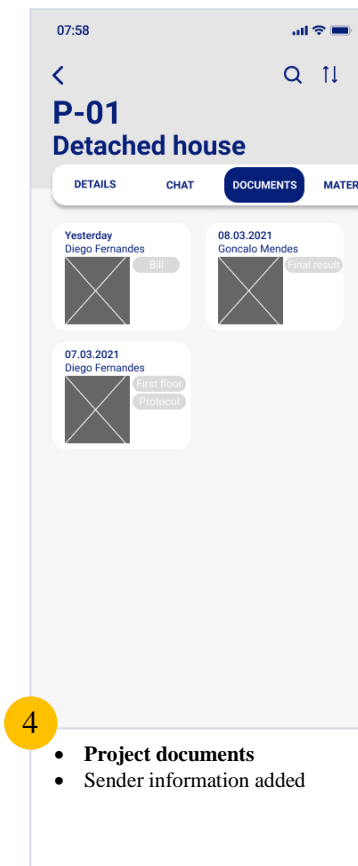
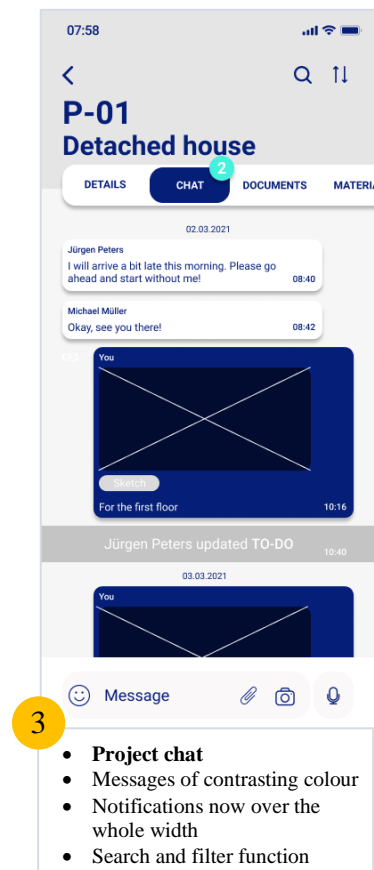
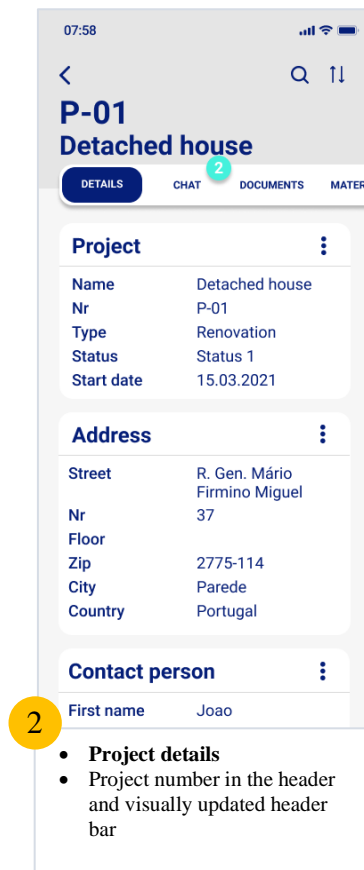
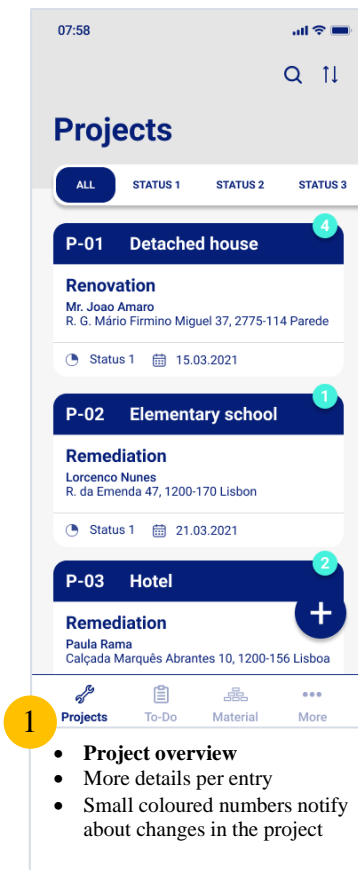
Notes

CONFIRM

Projects To Do Material More

- **Creating new project**
- Name information and documents and notes

Appendix 8: Prototype loop #3 1/3



Appendix 8: Prototype loop #3 2/3

7

- Ordering new materials
- As lay-over of material list with drop down menus and manual type-in field
- Deleted button added

8

- Ordering new materials
- Project is selected

9

- Ordering new materials
- Material category is selected

10

- Ordering of new materials
- Selecting responsible person for the purchase
- This user will have material order in personal material list

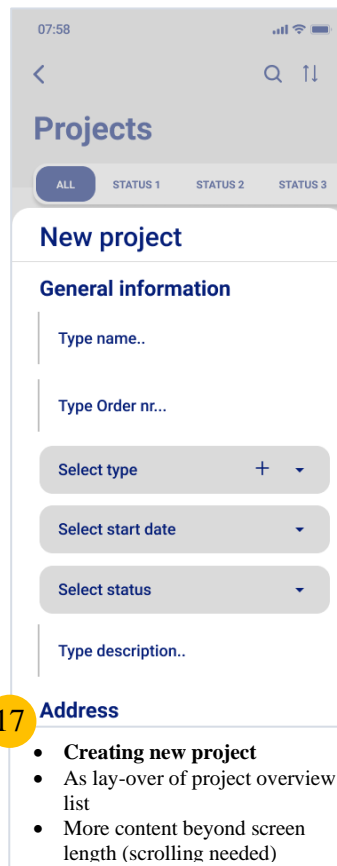
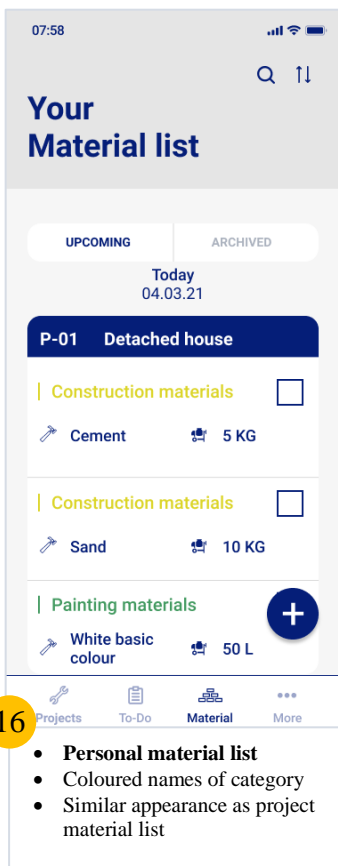
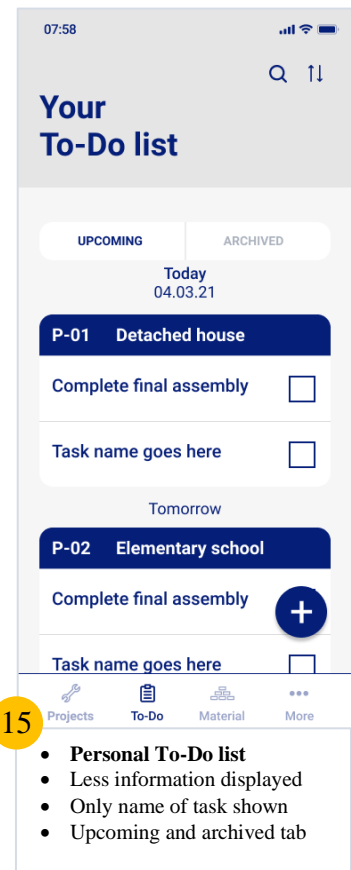
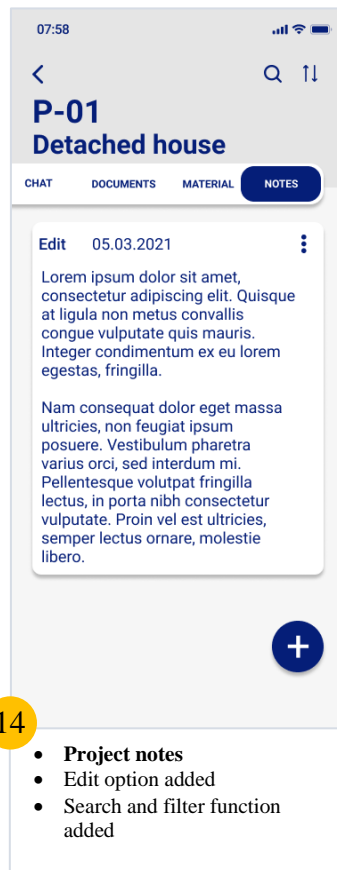
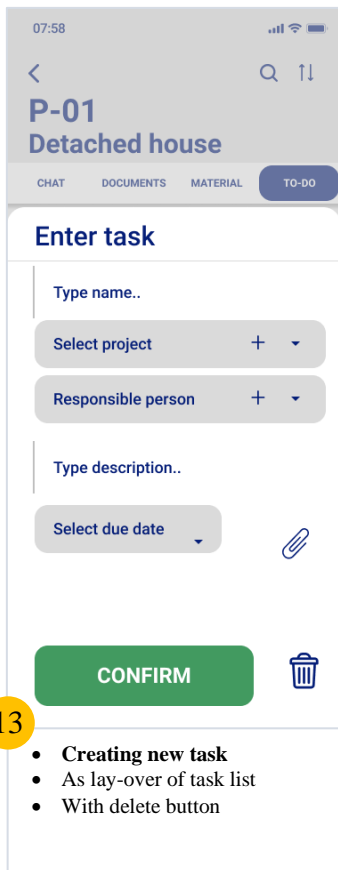
11

- Project To-Do list
- Upcoming and archived entries tab

12

- Details of task
- As lay-over of task list with all information and check box

Appendix 8: Prototype loop #3 3/3

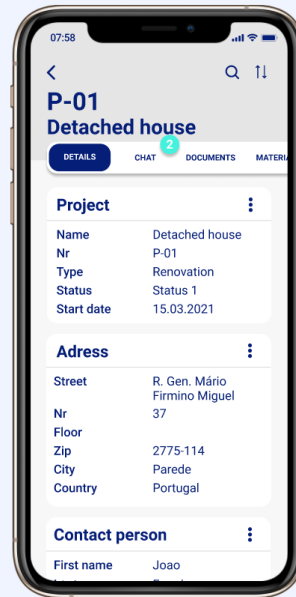


Appendix 9: Extracts of usability testing in Maze

MISSION

- Find the material list of project P-01

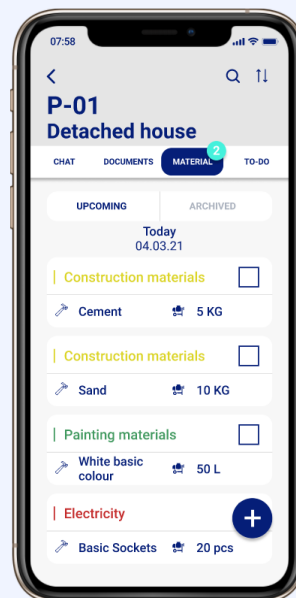
Each project has its own material list



MISSION

- Check the details of the first material request

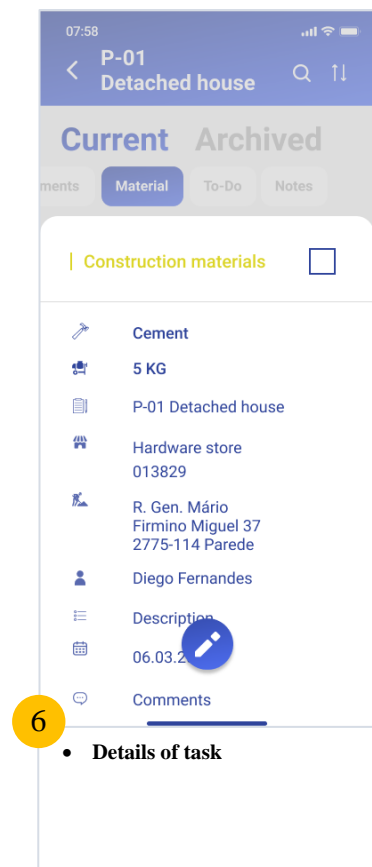
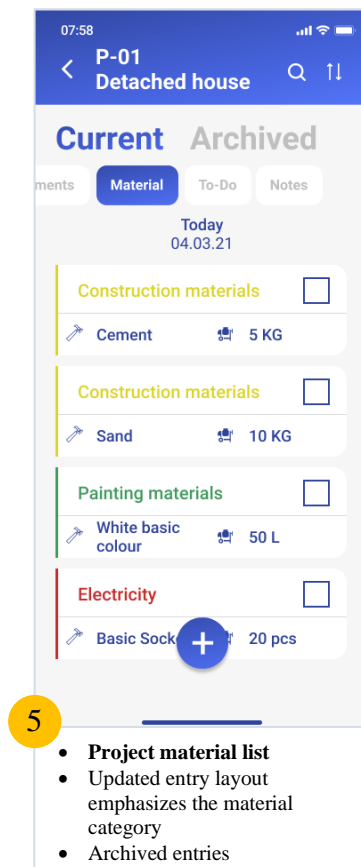
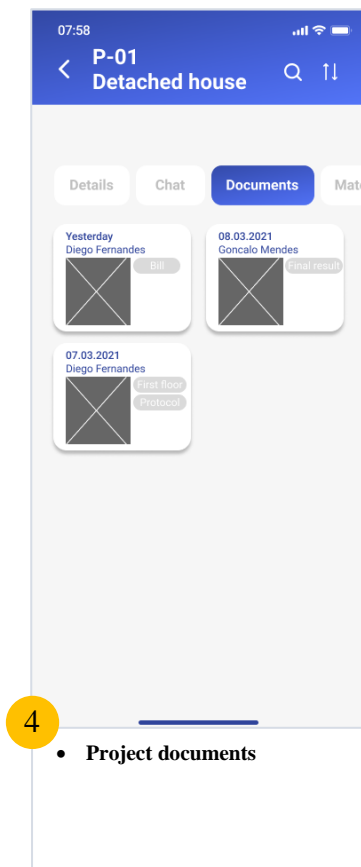
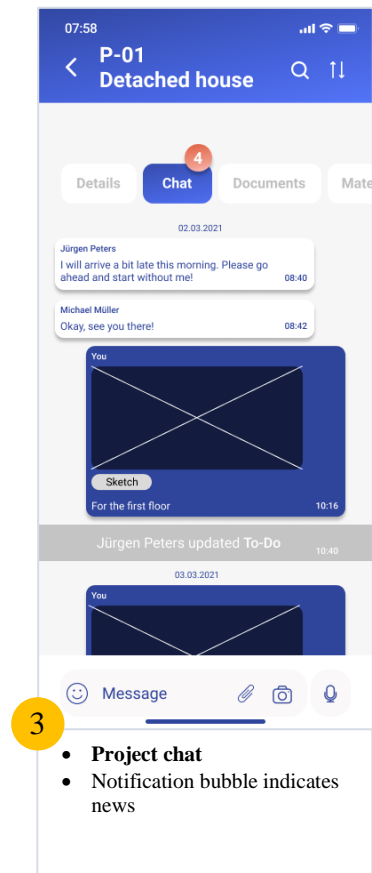
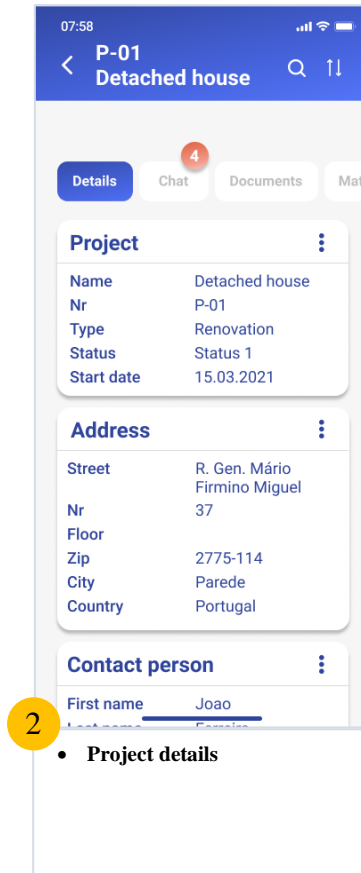
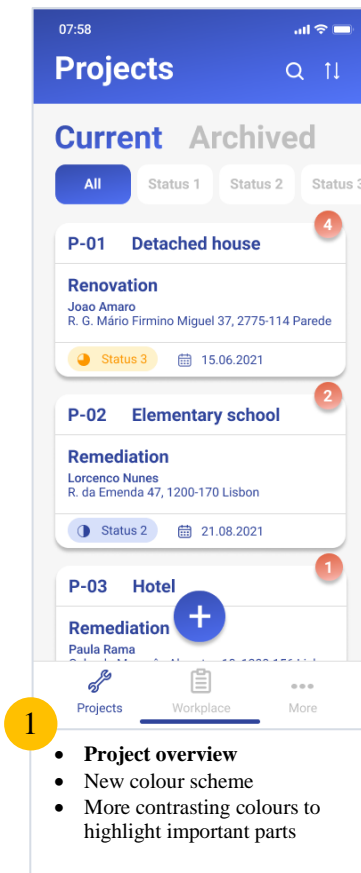
Each material order has more information linked to it



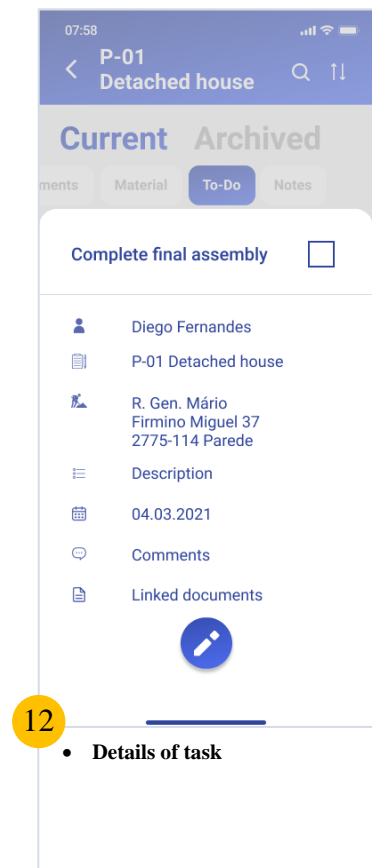
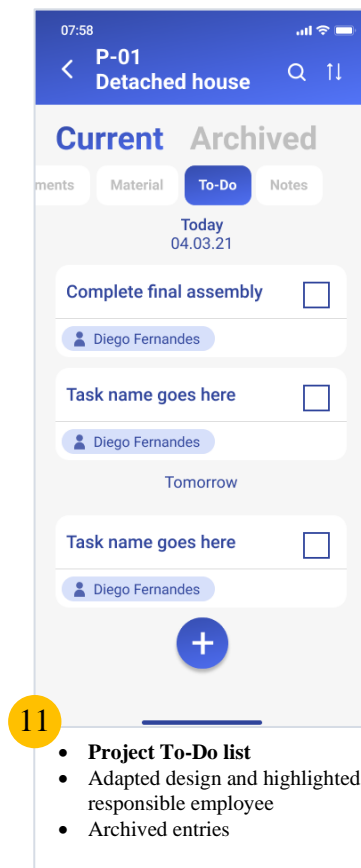
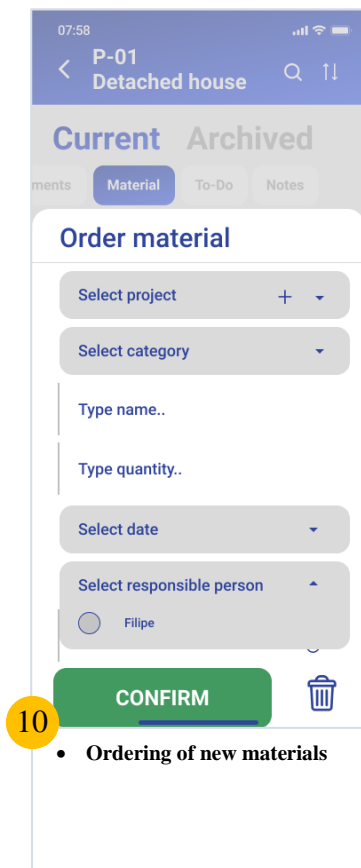
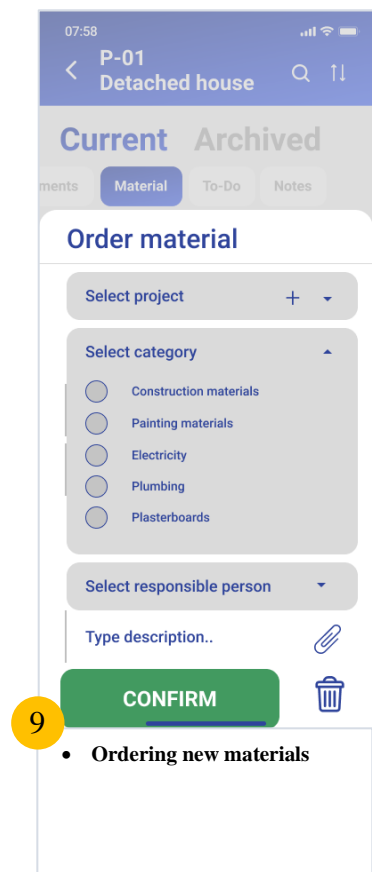
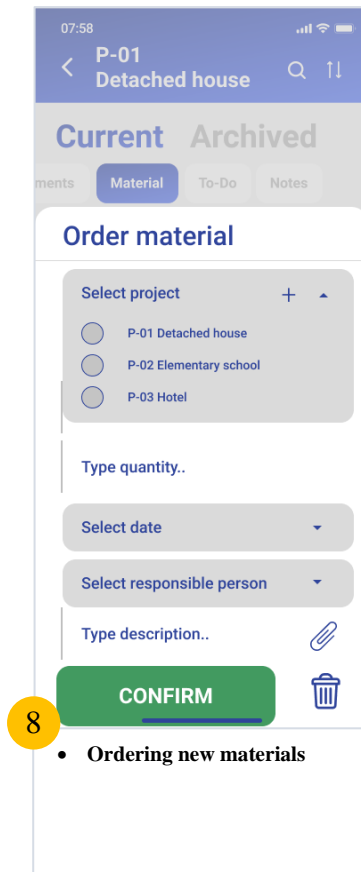
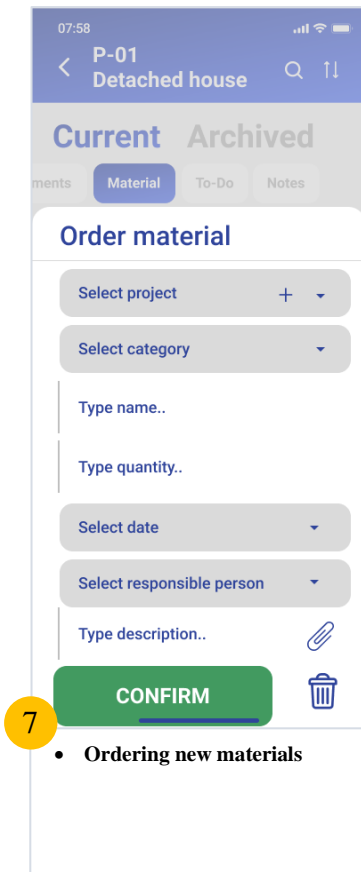
Appendix 10: Usability testing: problem-solution overview

#	KEY ISSUES	FIX
1	Unable to distinguish between different tabs under sunshine	Change colour scheme to a more visible one
2	Tried in vain to find completed projects	Implement an archived/completed projects tab
3	Material list-icon unclear	Find more precise icon related to construction material
4	Unclear that more tabs are one after another	Change design of tab bar to a more explicit version
5	Unable to navigate to add more materials from personal material list	Visibly differentiate adding button from rest of the screen
6	Unable to read notification bubbles in project overview screen	Change colour selection to a more visible one
7	Unable to navigate to personal material list	Adapt design of bottom navigation bar

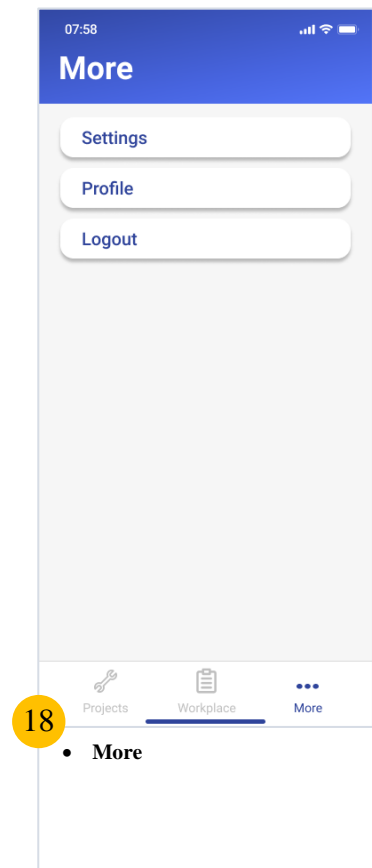
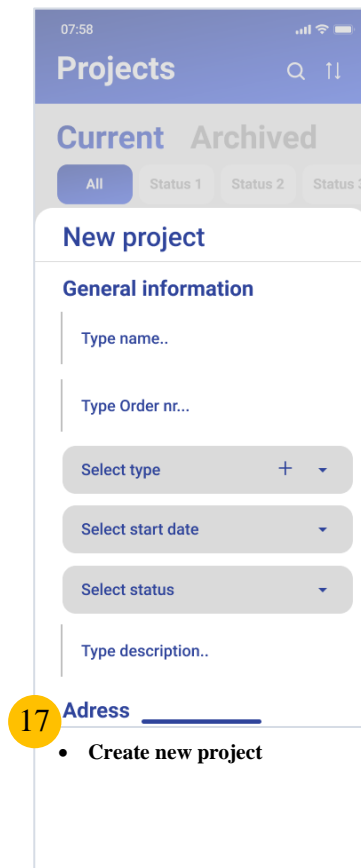
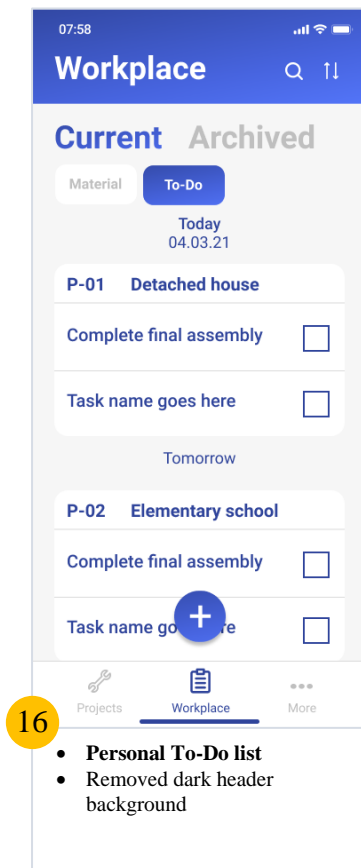
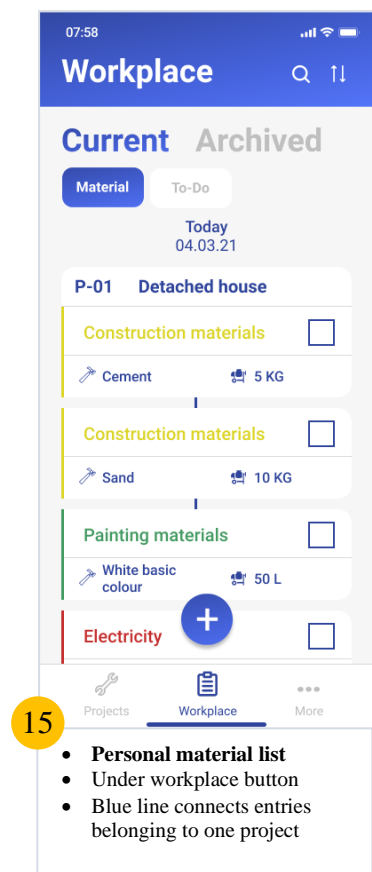
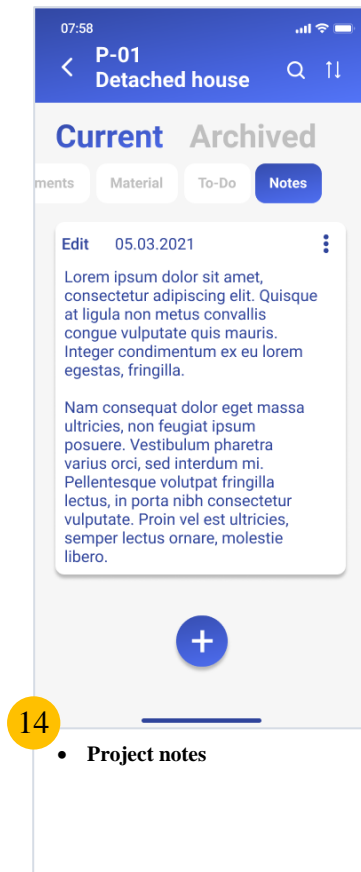
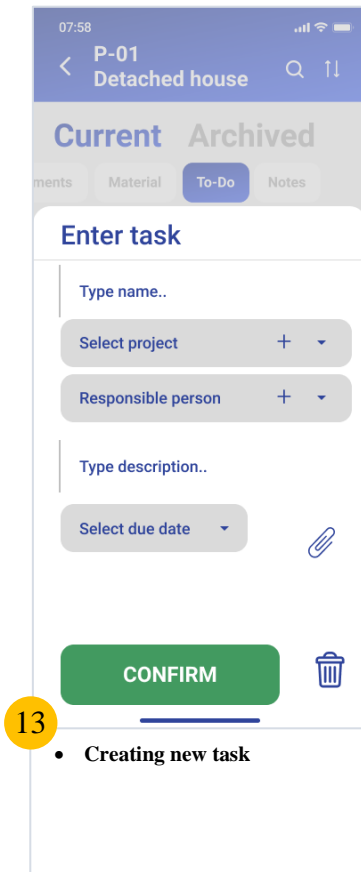
Appendix 11: Prototype version #4 1/3



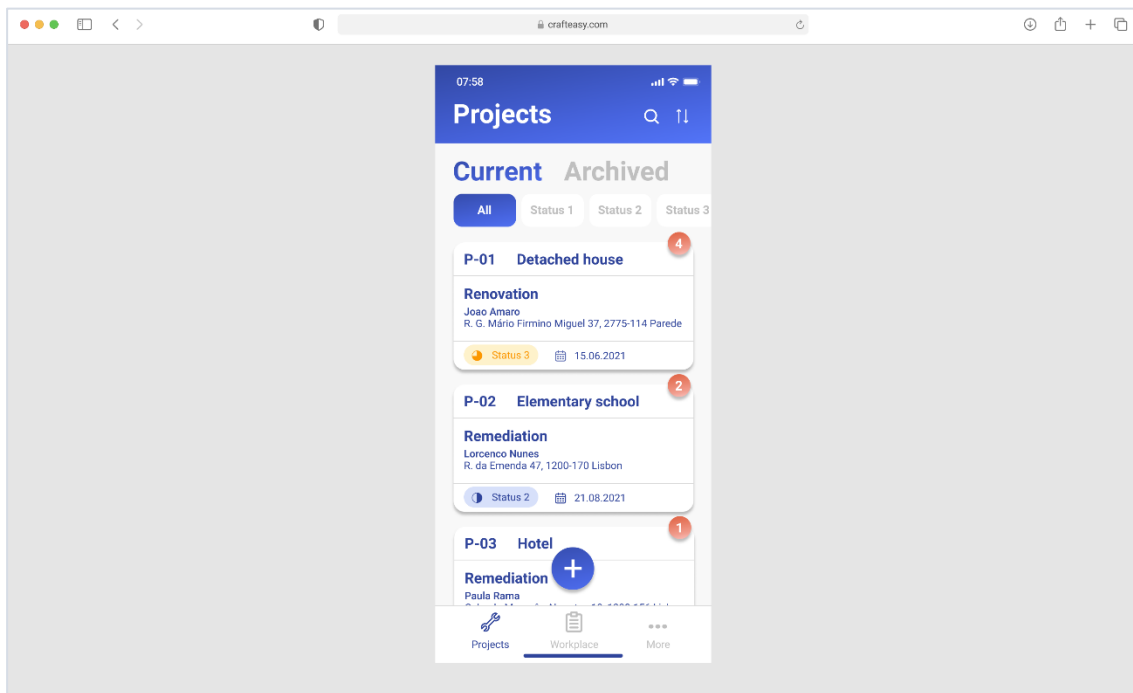
Appendix 11: Prototype version #4 2/3



Appendix 11: Prototype version #4 3/3



Appendix 12: Project overview screen of web browser version #4



Appendix 13: business models of target user group

#	TYPE
1	Construction firms
2	Concrete builders
3	Plant constructors
4	Roofers
5	Facade builders
6	Window constructors
7	Tilers
8	Staircase builders
9	Plumbers
10	Refrigeration plant assemblers
11	House painter and varnisher
12	Bricklayers
13	Drywall constructors
14	Carpenter
15	Plasterer
16	Electricians

Appendix 14: Similar digital solutions

Name	Type	Competition	Features	Shortcomings
Craftboxx	Hybrid application	Direct	<ul style="list-style-type: none"> - Web application: project management, employee & resource planning, route planning, calendar, job tickets - Mobile application: time tracking, documentation (photos, videos), final inspection incl. signature, offline mode, site address 	Not all features are usable on the move, which restricts small businesses if they have no office worker
HERO	Hybrid application	Direct	<ul style="list-style-type: none"> - Web application: maintenance orders, checklists, communication, job lists, project pipeline, document management, invoices, accounting - Mobile application: time tracking, documents, communication 	Complex for simple use-cases, missing material planning feature
BauBuddy	Hybrid application	Direct	<ul style="list-style-type: none"> - Web application: planning board, work hours report - Mobile application: job overview, documentation, time tracking, project overview 	Complex for simple use-cases, missing material planning feature

WhatsApp	Mobile Application	Direct	Communication including the exchange of files, documents, pictures, videos	Missing material and task planning feature, unclear document folder
Renewa	Mobile application	Indirect	Corporate feed, project overview, document management, calendar, tasks, time tracking	Rudimentary and without material planning
Memo-meister	Hybrid application	Indirect	Project structure, recording with: pictures, videos or documents, notes, checklists, digital signature	Only for documentation of status of craftwork
pro-report 3	Hybrid application	Indirect	- Mobile application: project documents, site journal/diary, stakeholder tracking, appointment - Web application: accessing open reports	Old-fashioned design and missing material and task planning feature, rather for construction companies that need to coordinate construction sites

planradar	Hybrid application	Indirect	- Web application: document management, project management, employee management, planning tools - Mobile application: Tracking of errors, acceptance reports	Complex software for construction companies not for simple use-cases, web application misses material and task planning
capmo	Hybrid application	Indirect	- Web application: project management, planning, calendar, employee management, construction timetable, quality management, dashboard - Web application: tracking of errors, documentation	Complex software for construction companies not for simple use-cases, web application misses material and task planning
slack	Hybrid application	Substitutes	Communication of staff within functional groups, including the exchange of files, documents, pictures, videos etc.	Missing material and task planning feature, unclear document storage