The Design of a Machine Status Management Tool

Creative Technology

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ABSTRACT

A lot of advancements are happening at the moment in the manufacturing industry, one of which being that data-driven applications are on a rise. This report describes the development of an interface design made to show the status of machines on a shopfloor, and to provide an insight into their performance for Fraunhofer Project Center (FPC). Additionally, maintenance information and product information are displayed. The users for this interface are clients and visitors, management, and engineers. The research question for this report is "How can an interface be designed such that it shows the status of the various machines around the shopfloor?" with sub-questions relating to what information to display, how to display this information, and how the user should get to this information.

This interface is realized using an iterative design process and the Moscow method to prioritize tasks and is designed in Adobe XD. This resulted in a visualization of the machines using 3D-models, which had coloured roofs according to their status. Selecting a machine would allow the user to inspect parameters of the machine, including historical data, past failures, maintenance information, as well as its capabilities. The final design was evaluated using both a questionnaire and a semi-structured interview. The result of this evaluation is that the participants found the interface very self-explanatory and found the visualizations clear. The iconography used throughout the design was also understood well according to the questionnaire. Though, it was lacking in user experience due to the development taking place during the coronavirus pandemic. Further research and development of this interface should be focussed on developing the user experience. Research should be done towards whether it would not be better to develop separate interfaces for the separate users. Development of the back end that would support this interface is also recommended.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

Fraunhofer Project Center (FPC) has a central task of transferring current research in advanced manufacturing directly into industrial practise. Together with the manufacturing industry, FPC builds synergies to achieve high-tech excellence within the fourth industrial revolution. FPC, together with regional partners, will develop the Advanced Manufacturing Center (AMC). The AMC facilitate multi-disciplinary interlinking technologies through demonstrators and testbeds for advancing manufacturing technologies. One of these technologies will be a shopfloor. This shopfloor will be centred around the fourth industrial revolution, by collecting and processing data to create all kinds of purposeful insights into the manufacturing environment.

As a part of industry 4.0 where manufacturing data is increasingly available and data-driven applications are increasingly common, equipment maintenance has also grown to be a data-driven task [1]. The collection, evaluation, and comprehension of large data sets is seen as one of the nine pillars of industry 4.0 [2]. These large data sets contain fairly complex data and thus have to be visualized in such a way that it is made understandable. Performance and utilization of a machine is one of the things that needs to be visualized out of large data sets. Machine utilization is of particular importance for the production technique used.

Equipment maintenance is a part of that manufacturing environment, which is of a vital role in manufacturing. Inappropriate maintenance of equipment can lead to a shorter lifespan, inefficiencies and even safety issues. However, the majority of manufacturers are still practising calendar based preventative maintenance [3]. This strategy often leads to either over-maintaining the equipment, as to make sure the equipment does not fail; or undermaintaining the equipment, as it is almost impossible to cater to the exact needs of a machine. For this reason, a data-driven condition monitoring system is in demand, as to be able to service a machine whenever there is a need for it.

The challenge that will be tackled in this report will be in the area of displaying information about a typical shopfloor. Specifically, how the various machines on the shopfloor are performing. The main research question is therefore: “How can an interface be designed such that it shows the status of the various machines around the shopfloor?”. In order to answer this question, sub-questions have been formulated, all departing from the assumption that an interface can be displayed on a large display:

1. What information should the dashboard display?
2. How should the information on the dashboard be displayed?
3. How should the user obtain the information that is present within the dashboard?

In this report the design and the development process of a shopfloor status manager is described and will have the following structure. First, chapter 2 describes the background research, consisting of a literature review and products that provide a similar function. Chapter 3 describes the ideation phase, during which broad ideas are developed and worked out. In chapter 4, requirements for building the prototype are captured. Chapter 5 describes the realization phase, during which the prototype is developed. Chapter 6 is about the evaluation of the final product using a questionnaire and discusses the limitations of the project. Chapter 7 states the conclusion, and chapter 8 states recommendations for future work. The report ends with the appendices and references used in the report.

2. BACKGROUND

2.1 DASHBOARDS

Dashboards are intended to convey and communicate information to users through graphical means, enabling users of the dashboard to understand the meaning behind all of the data. In an organisation, a dashboard is often used for decision making [4]. Effective data visualisations can help the user of a dashboard to interpret and extract important values from complex and multi-dimensional data [5]. To start designing a dashboard, the designer has to have a clear goal in mind for as what they want to visualize. However, choosing a good visualisation goal can be a difficult task, and therefore a guideline can be followed, as can be seen in Figure 1 [6].

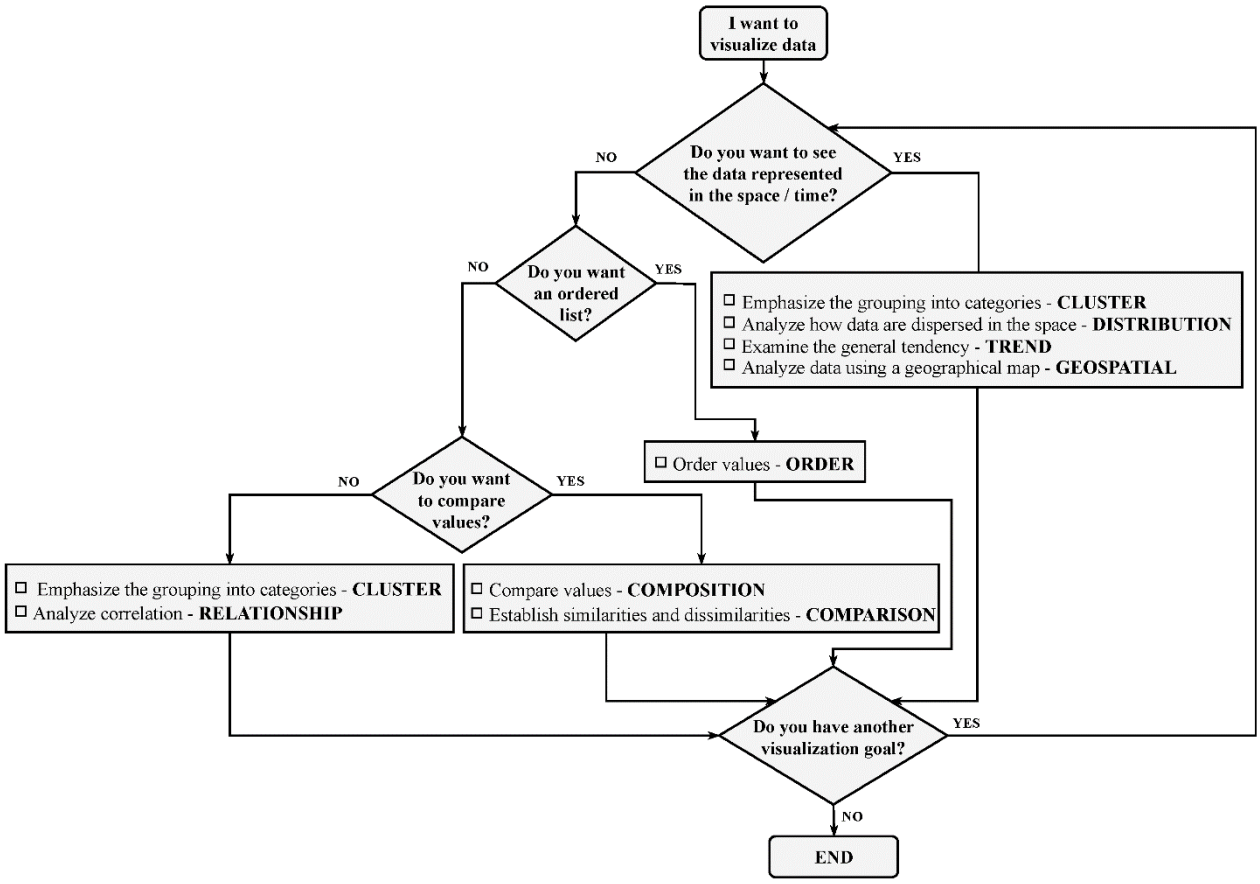


Figure 1. Guidelines to help a non-expert user to define visualization goals according to [6].

Another way to lay a foundation for a dashboard is using Goal-Question-Measurement (GQM) models [7]. A GQM model is defined on three different levels. The goal is defined as to what we want to study and why. The questions define what information is relevant, and what parts of this information are used to characterize what we are trying to achieve the related goal. The measures define which data has to be collected to be able to objectively answer the questions [4].

Once a visualization goal has been selected, the designer can start thinking about the implementation of the dashboard. There are two scenarios for a dashboard, being “pull” and “push” [8]. In the scenario of a pull dashboard, the user wants to get specific information, and uses the dashboard to obtain this information. In the pull scenario, the user actively uses the dashboard to seek out information, and actively looks for this information. In the push scenario, the dashboard is designed such that it captures the user’s attention when

important information is available to the user. In this case, the dashboard is used passively, and the attention of the user needs to be captured or brought to a specific element within the dashboard. The difference between the two scenarios can thus be found in how the dashboard is designed to be used.

A method for capturing the user's attention is through a technique called pre-attentive processing. This is a technique that allows people to process information before they start paying conscious attention to it [9]. Pre-attentive process is the process of fading out other elements, or highlighting the element(s) in question, such that it the relevant elements in the design stand out more than others. This can for example be done through the usage of colour, size, texture, opacity, or even by making certain elements glow.

When the status of an object has to be conveyed to the user, it is advised to use colour coding based upon the colours red, yellow, and green, respectfully meaning that there is a serious problem, action is required, and that everything is fine [4].

2.2 Performance Analyzer

Performance analysis is an important feature in production planning software [10, 11]. This performance analyser should be able to give managers, as well as operators on the shopfloor itself, an insight into how well the shop floor is performing. This analysis should then be visualized in such a way that it is clear to the user what the conclusion of the analysis is.

There are multiple ways in which performance can be measured. How the performance is measured is entirely dependent on the nature of the shopfloor. For example, the number of products produced can be a good indicator if that is the goal. However, if the shopfloor produces various types of products, the workload of a production cell could be a good indicator [12]. However, the most important key performance indicator for a company is whether a profit is being made, though for this project this is not the case. For this project, the most important KPIs are the ones that indicate the status of the machine. Other KPIs which can be considered are number of products produced, hours of cutting time, or number of linear feats performed [12]. The most important KPI that is specific for the use case of FPC is machine utilisation, with cycle time being another relevant KPI. [11, 13, 14].

There are also KPIs to consider that are more specific to the machine itself. These machine KPIs includes machining time, operation costs, availability, and performance [15, 16, 17]. However, Koren et al. [18] is the only one mentioning that reliability and finish quality are important factors to consider.

2.3 Data Formatting

Simulation is seen as one of the nine technologies that form the foundation of industry 4.0 [2]. However, for a simulation to work and run, data is required to feed into that simulation and will have to be formatted such that it is both legible for a human as well as the computer. Choosing a good data format is important, as a good data format can house all of the relevant information and relations. Terkaj and Urgo [19] state that to create a successful simulation explicit modelling of possible states of a resource, as well as hierarchical nesting is required. Additionally, historical data and characteristics of the machine are also relevant [20].

Laemmle and Gust [21] did research regarding what the correct data format is for manufacturing system simulation and evaluation. They consider multiple types of data formats; Text-based, table-based, XML-based,

geometry based, and graphic-basic. XML-based data formats are deemed the best and specifically AutomationML. A correct data format is not only important for a visualisation of the data, but also as a basis for creating a data model, and as a solid foundation for simulation software [19, 20].

2.4 State of the Art

Well-known simulation tools for industrial production planning include Tecnomatrix by Siemens [22], IMK EMA [23], and Visual Components by KUKA [24]. However, these are all largely companies which focus on simulation of a digital system, rather than evaluation of the physical system. Katana [25] is a product that is focussed on the evaluation of a system that is already in place. The most notable things about Katana are that they have a very friendly looking interface, which is easy to understand and is intuitive, as is visible in Figure 2. Inventory control and shopfloor control for workshop users are interesting features found within Katana. These features allow users of Katana to see the progress of their orders, as well as view and control the shopfloor from an online environment.

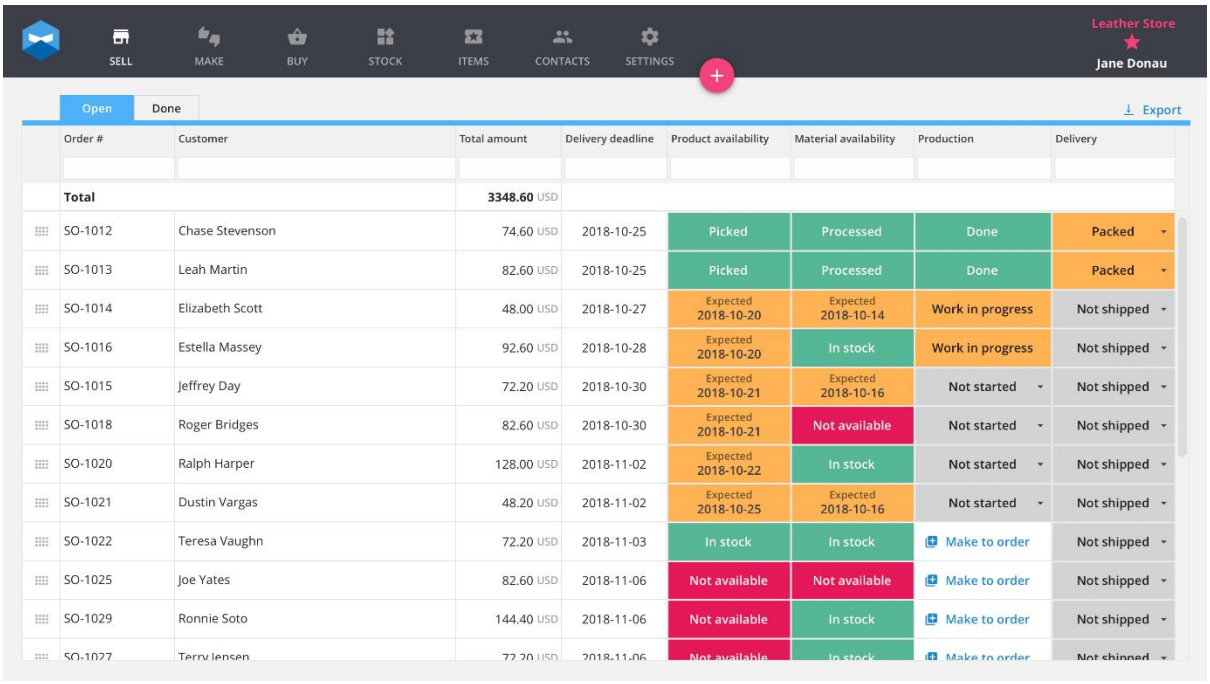


Figure 2. the interface of Katana

Seiki Systems also produces a software solution for performance analytics [26]. The notable things about Seiki are that their interface design is a lot less friendly to look at, but still provides a clear overview of relevant data. A notable feature they have is one that allows for inspection of products which are linked to production batches.

Another company which produces performance analytics software for shopfloor is MachineMetrics [27]. What is noticeable about MachineMetrics is that their software solution is a cloud-based solution, as well as that this software is capable of machine monitoring and condition monitoring. Machine monitoring means that an overview is created that allows the identification of bottlenecks and inefficiencies. Condition monitoring allows for the monitoring of the health of the equipment on the shopfloor, and thus allows for preventative maintenance. MachineMetrics also gives actionable feedback to the users of their platform.

FreedomIoT [28], TeamViewer [29], and Evocon [30], MaintainX [31], The Asset Guardian [32], UpKeep [33], and Wats [34] also produce production analytics software, but do not have any interesting features that are important to this research. Evocon, Katana, MaintainX, and UpKeep do have a clear looking design of their interface.

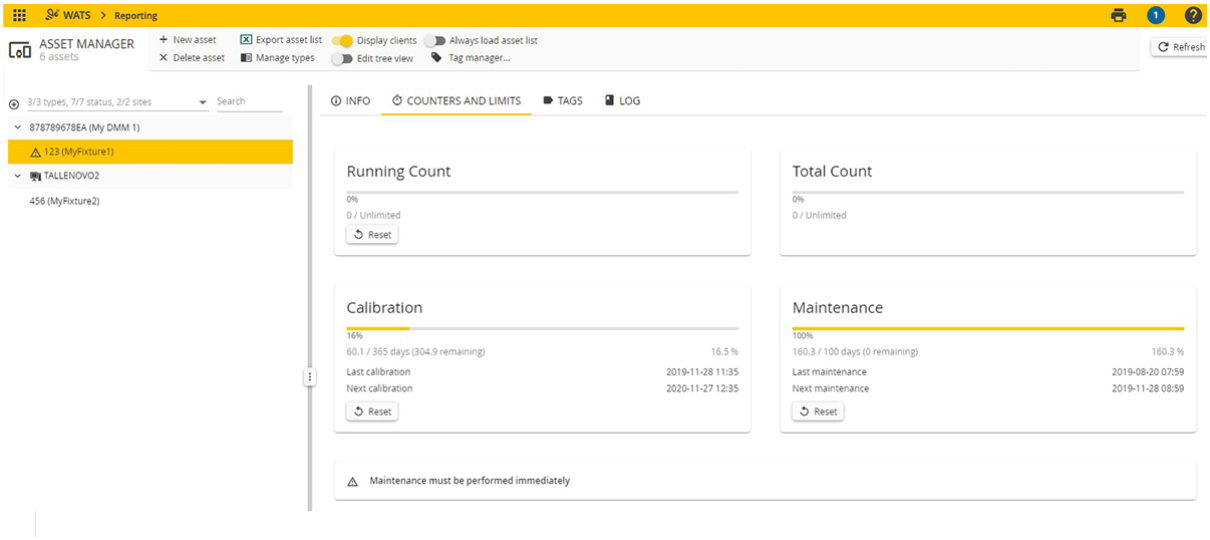


Figure 3. The interface of Wats

As to provide a summary of what design highlights that are common across asset performance management systems, a simple coloured background with brightly coloured highlights is a common design feature, as is seen in Figure 2. In terms of design style, there seems to be a great divide. It would seem that most systems look either very modern with rounded edges, friendly looking shapes, and minimalist design elements, as can be seen in Figure 4. The other style that systems go for seems to be an older style, one that is reminiscent of the ages of windows XP, as is visible Figure 3. These systems tend to have more blocky design features, with sharp edges and simpler data visualisations. Additionally, it is common practise to use a lot of tables as data visualisations.

Figure 4. The interface of Evocon

Common features that are found within asset performance management systems are being able to send a repair work-order from within the same interface as the status overview interface. Another feature that is commonly found is being able to customize the dashboard however the user wants. The customization of the dashboard can range from re-organizing the location of dashboard components to only being able to filter data the data in the dashboard. The last, and also most noticeable feature is being able to see whether spare parts are available for a machine. This would mean that the inventory management system is also tied into the same system.

2.5 Conclusion from State of the Art

To conclude this chapter, there are multiple requirements for the project that should be considered during the ideation phase. Firstly, what design elements should be considered. Most of the state of the art uses brightly coloured highlights as to either indicate a problem with an element in the system, or as a design feature. These highlights are to be implemented with a colour that differs enough from the background colour in both hue and saturation, such that it becomes an element that stands out. Besides this, a consistent style is to be used throughout the product. Style consistency not only looks more appealing, but also makes the interactions for the user clearer. By using the same elements to go back to a previous menu or close a menu for example, the interface becomes much easier to use. Styles that are commonly used within the state of the art are either a modern style with rounded design elements, or a style with more blocky design elements. Lastly, since the project is about displaying the status of a machine, it is advised to use the colours red, orange, and green to indicate the status of the object. This respectively means needs immediate attention, warning, and operational.

Secondly, an analysis is done to find features that are found to be important. These features are being able to change the data displayed on the dashboard, all the while keeping the dashboard looking the same or similar looking as it did before. Filtering data that is available on the dashboard is also a common feature among dashboards. This feature enables the user to only view the data they are interested in. Additionally, being able to view historical data is also a very common, as well as prized feature in dashboards. Historical data can allow the user to gain an insight into why and how things might have developed as they did. Furthermore, being able to view characteristics of a machine is also an appreciated feature. This feature would allow the user to see what a machine is capable of, as well as what process it enables. The conclusions drawn from this chapter can be used in developing the project.

3. Ideation

This chapter describes the ideation phase, during which broad ideas are developed for the project. The development of broad ideas was developed in phases. At the end of every phase, the ideas was pitched to FPC and feedback was received about ideas, as well as that more information was obtained about the project in the shape of requirements and insights into the bigger picture in which this project can take place.

3.1 PHASE ONE

At the very start of the project, the project was presented in a very different light than it is now. The most important requirement that was set then was to lower the human error and time spent on production planning, and to show off what the client is capable of doing with their showcase production floor. A brainstorm was held to come up with ideas for the project, this brainstorm can be seen in Appendix A. The outcome of this brainstorm was rather inconclusive, and a lot of questions arose from the brainstorm about the requirements and about the project. Reading up about layout problems, process planning, and layout optimization was done to be able draw up a correct reference frame. Thereafter, two ideas were worked out in more detail.

The first idea that was worked out was called “Providing a Clear Overview”. This idea was to provide an overview of what machines are present on the shopfloor, where they are positioned, and produce an interface which allows you to interact with the overview and see details about machines. This would be visualized using a two-dimensional view of the shopfloor, an impression of which can be seen in Figure 5. For this idea, a lot of inspiration was drawn from the top-down factory building simulator game Factorio [35].

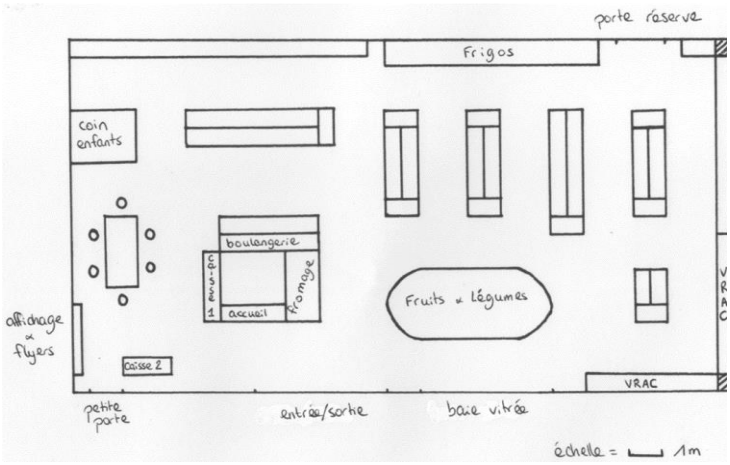


Figure 5. An impression of how the first idea would look like.

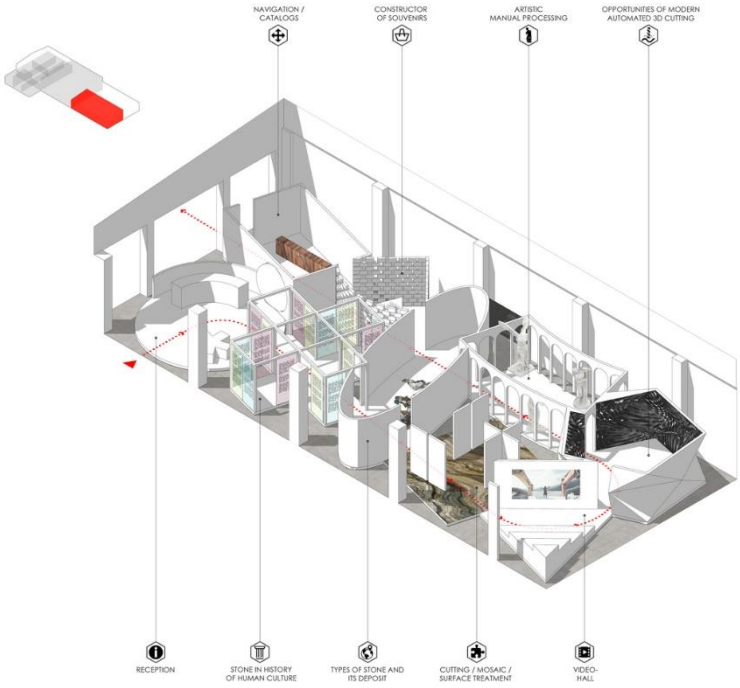


Figure 6. An impression of how the second idea would look like.

The second idea that was thought of was called “Looks of the Building”. This idea had a very strong look on how the building and shopfloor looks. This was supposed to especially appeal to the requirement that it was supposed to show off what the client is capable of doing through presenting this through very high-quality 3D models and visualisations. This would bring across the feeling of how the shopfloor looks and feels. This would be visualized with a 3D animated rendering of the shopfloor, an impression of which can be seen in Figure 6.

3.2 PHASE TWO

The second phase of ideation started after the first phase was presented to the client, and with that feedback and more specific information about the project. It turned out that the ideas that were presented were not relevant enough to the project, and thus different ideas needed to be produced. The ideas of phase one were not relevant

enough due to the fact that they did not see any interaction with the production technique that is being used. The most important thing in this phase was coming up with an idea that is in line with process optimization. The idea that was produced in this phase was a program with two main features.

The first feature is called a “production line manager”. This would allow the user to specify how a product is made, which is done by linking up a series of machines which would define the order of production. Estimates are put in regarding how long an operation would take on every machine. After the user has put in all of the products that are to be produced, the shopfloor can be simulated, and bottlenecks can be identified and correctly dealt with in the simulation before anything would be physically produced.

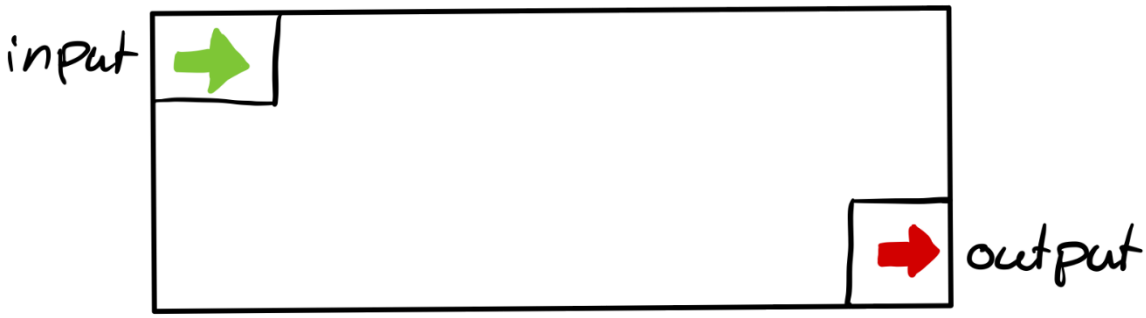


Figure 7. A sketch of how a single machine would look like in the second ideation phase.

The second feature is called the “Floor planner”. This would allow the user to simulate an optimal layout for the products that are being produced. This would then determine the physical location of every machine, and what an optimal layout would be in terms of machine placement. This feature is intertwined with the production line manager. This feature would produce a map where a machine would look like the sketch made in Figure 7, in which an identifier is placed such that the layout can be physically reproduced.

3.3 Phase Three

After presenting the idea of phase two, feedback was received that this idea would be too complicated for a bachelor graduation project, as this is an idea that goes more towards applied mathematics, with a specialisation in Operations Research. Therefore, we switched to a less demanding and more realistic idea that allows the user to assess how well the shopfloor is performing, instead of optimizing the production process. This would allow the user to see how well the shopfloor is performing and would be done from serious gaming perspective. This would mean that an interface would be created which has gaming elements in it. This would make the interface more fun to use, and thus encourage the user to use the interface to further optimize the layout. Additionally, a list of features will be created that is required to make process optimization happen and find out what kind of data is required per feature.

This was however found to be too much for the project, and a preference for only working out a single feature was preferred. It was quickly decided upon that the project was now going to be in the direction of creating an interface which would show the capabilities and limitations of the machines on the shopfloor.

3.4 Ideation Phase Conclusion

The ideation phase was concluded with that the third phase of ideation left a lot of questions unanswered about what exactly the requirements were for the project, as well as that the design goal of the project was not

quite satisfactory. Although, there was already a clear direction the project was going in, which is displaying information about a shopfloor. This would be different than the initial perspective on the project, where this project would be about providing feedback to the shopfloor managers, rather than attempting to optimize the production process itself. Thus, a discussion was had with the client to talk about the details of the project, and what exactly this project would entail, what the new design goal is, and what the new requirements will be are discussed in chapter 4.

4. REQUIREMENTS CAPTURE

The requirements which form the basis for this project are described in this chapter. The requirements are captured through a semi-structured interview. The chapter describes the use cases for this interface, as well as further details about the project.

4.1 USE CASES

It became clear that the users of this product will be created are not yet present, as the factory in which this product will be used is not yet built. However, the stakeholders for the project could be identified in more general terms, FPC, a theoretical production manager, management, as well as visitors of the AMC. Of which the production manager, management, and the visitors of the AMC will be users, and where FPC is invested in this as a company.

During the interview it also became clear that this is a project that is meant to show off to outsiders what the AMC is capable of doing, as well as what they do. Though the combination of users this interface will have, the most important requirements being that the interface should look appealing and convey a high-tech feeling towards customers but should also be ready for daily use by a production manager and management. The fact that this interface will be used by such a wide variety of users poses a challenge for the designer and will most likely mean that some compromises have to be made to be able to satisfy all users as much as possible.

4.2 PROJECT DETAILS

When asked what the exact purpose of the project is, it was made clear that this would need to become an interactive tool that can be used to show to people what AMC is capable of doing towards customers, as well as showing that AMC is working on the cutting edge of manufacturing technology. Besides this, it should also be used by a production manager to give an overview of the statuses of the machines on the shopfloor, of which there will be 16. The tool will also be used by engineers and management of FPC, meaning that this tool will be used in the top and the bottom of the business. The tool should also provide an insight into why a machine is performing the way it is, whether that be good or bad performance. Besides providing an insight into the machine's performance, it should also be a tool that allows for predictive maintenance. Predictive maintenance is being able to perform maintenance based upon sensor data of the machine, such that a machine is neither over-maintained nor under-maintained.

5. REALIZATION

Now that the direction of the project has been specified in Chapter 4, it is time to realize ideas within the constraints of the requirements. This chapter will explain the methodology, as well as all the iterations that have taken place.

5.1 METHODOLOGY

The development of the tool will be done using an iterative method called iterative design. It has been recognized that that user interfaces should be designed iteratively, because designing a user interface without usability problems from the start is virtually impossible [36]. Iterative development involves improvements of a design based on user testing and other evaluation methods. These improvements are specifically aimed at the problems and suggestions encountered in the previous iteration. The evaluation methods used in this iterative design will be user testing, as well as semi-structured interviews.

When an iteration has concluded, a series of problems and suggestions are defined, which in turn will be prioritized using the MoSCoW method [37]. This prioritization method is used as to make sure that the most important tasks get done, and since there will always be more tasks to do than can possibly get done. This is a prioritization technique that lists items in various categories, depending on their respective priority. The categories are “must have”, “should have”, “could have”, and “won’t have”, all of which have self-explanatory names.

5.2 FIRST ITERATION

The first iteration of this project was intentionally meant to give the client a very broad selection of prototypes, which all have their own strong points. The requirements at the start of this iteration were the requirements that were specified in chapter 4. The prototypes in this iteration were produced with the purpose of trying to extract more information about the use case, as well as trying to find elements which the client would like and appreciate in this design.

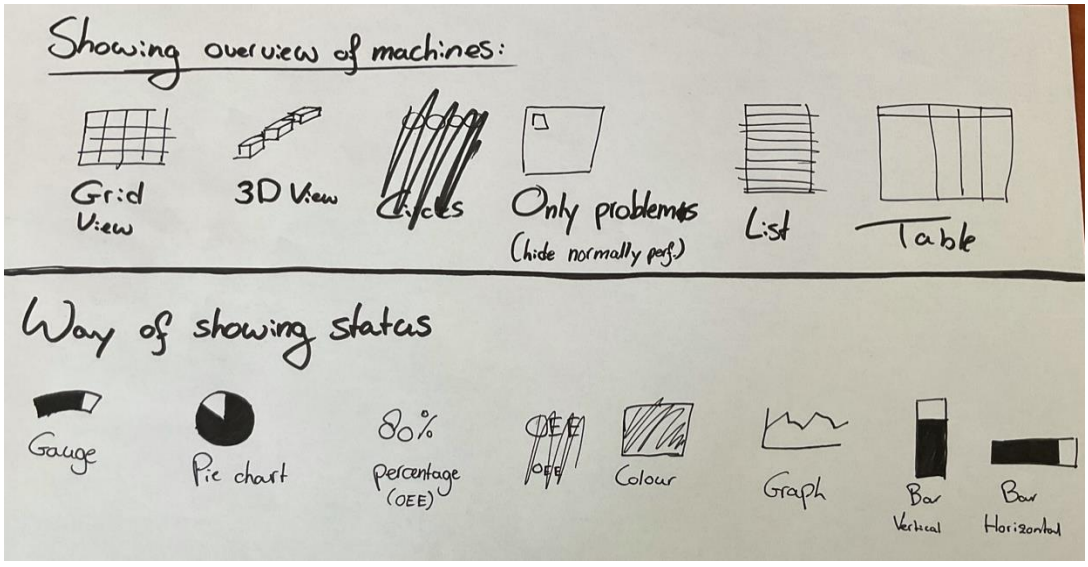


Figure 8. Morphological overview of the project

To come up with a broad range of designs, a brainstorm was held to come up with different kinds of ways to show an overview of the machines, as well as different ways of showing the status of the machines. After the brainstorm, this was combined into a morphological analysis that can be seen in Figure 8. These different elements were combined to create four different prototypes. All of the prototypes in this iteration use the colours red, orange, and green, as is found to be the best colours of displaying status according to Janes et al. [4]. This would respectively mean that a machine is broken down, has a warning, or is operating well.

To produce the prototypes, it was chosen for to develop these prototypes using the Apple iPad application ProCreate. This application was chosen as presenting the prototypes would all have to be done online, due to the Corona pandemic. Using this application was found to be the best way to mimic the usage of paper prototypes that would normally be used to change things during the presentation of the prototypes. To present the prototypes to the client, another application would be used to mirror the screen of the iPad to the computer to be able to present the prototypes, as well as edit the prototypes on the fly.

5.2.1 First Prototype

The first combination that was used was the Grid View, together with the various ways of showing the status of the machine. This would be done by dividing the screen up into 16 equally sized rectangles, which would then house the information of the relevant machine. As one of the requirements was that a production floor manager should be able to get an insight into why a machine is performing the way it is, an interaction needed to be thought of as well that would change the screen and provide more information to the user somehow. This would be done by selecting one of the machine tiles, and having it expand, where it overlaps other machine tiles. This prototype was envisioned to look like Figure 9.

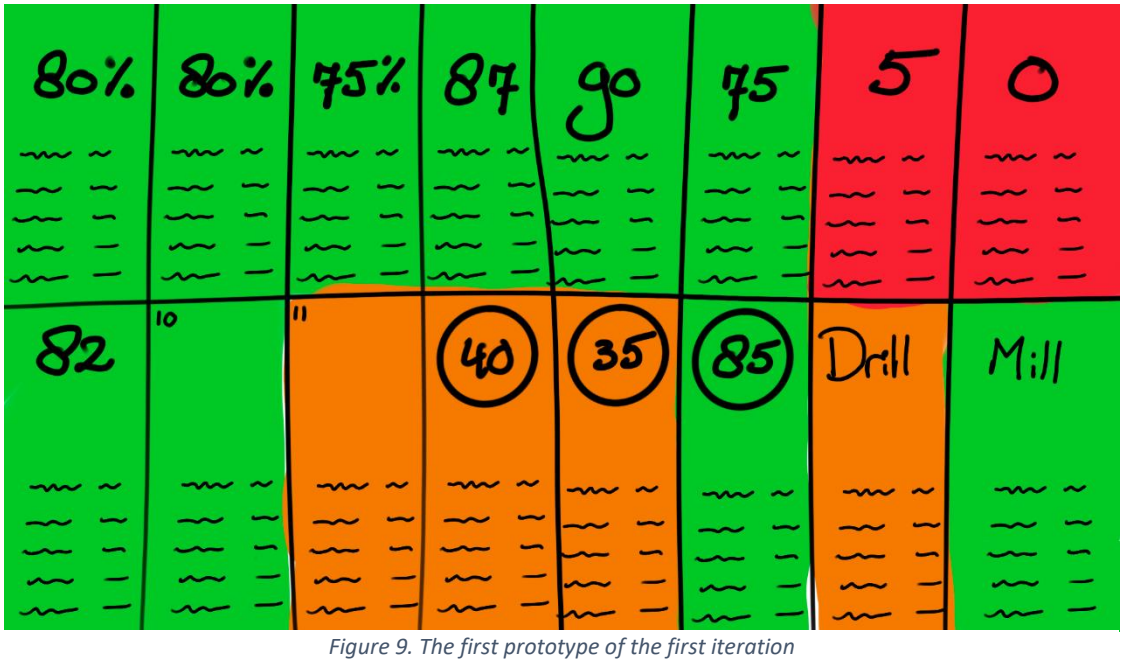


Figure 9. The first prototype of the first iteration

This prototype has a number of advantages and disadvantages. The first of which is that it is good that the user can, immediately see all kinds of parameters of the machine. However, this does mean that the user will have a lot of information on the screen, and therefore the screen will be quite cluttered. Another benefit of this prototype is that is a very scalable design and would therefor allow for the creation of mobile applications that

look very similar to the desktop application. This would create great uniformity amongst the different applications AMC could be using for shopfloor status management. However, a big disadvantage of this design is that once one of the machines is selected, as can be seen in Figure 10, not all of the 16 machines are visible anymore. When one of the machines is selected, as can be seen in Figure 10, the other machines have a less vibrant colour, and thus pre-attentive processing is applied in this prototype, which focusses the attention of the user on what is important on the screen.

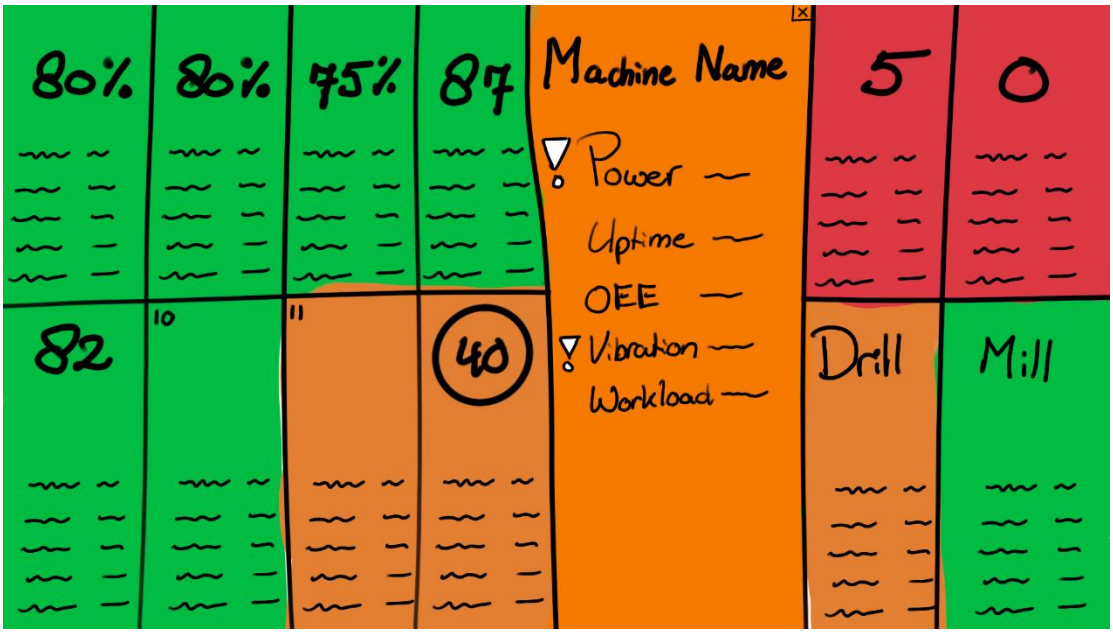


Figure 10. The first protype of the first iteration, after clicking on one of the machine tiles

5.2.2 Second Prototype

The second prototype combined a three-dimensional view, together with showing using a colour to display the status of the machines. In this prototype, a 2-point perspective is used to show the machines on the shopfloor, and having the machines also be positioned as they would be on the shopfloor. This would not only visually appeal to customers and visitors of AMC by looking attractive, but also it would also provide a good overview to the production floor manager about what machine might have broken down or needs attention. However, this

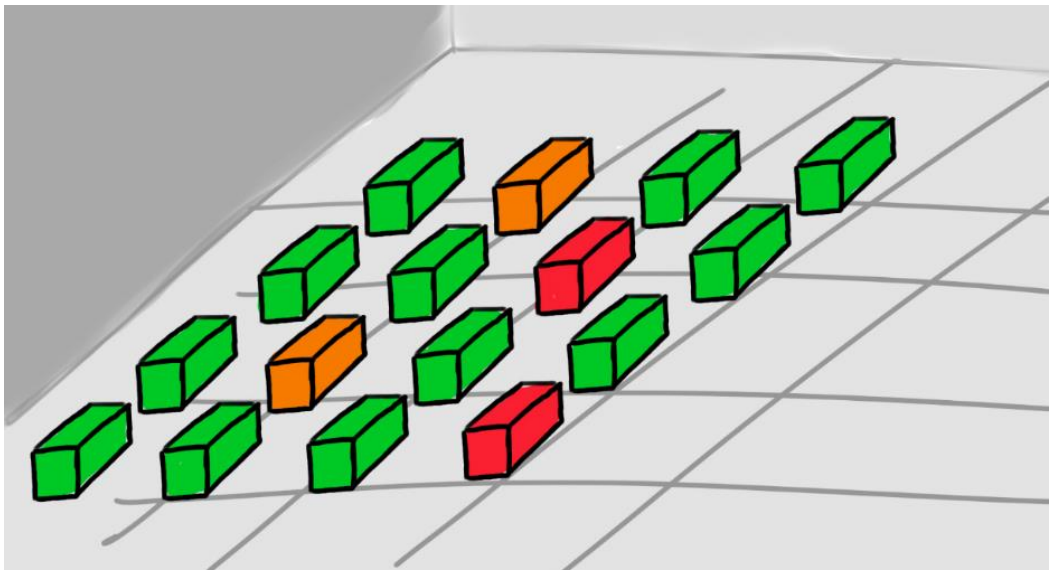


Figure 11. Second prototype of the first iteration

would be a very space-inefficient way of showing multiple machines and is not very flexible for adding on more machines than the current 16. The visualisation of the machines can be seen in Figure 11.

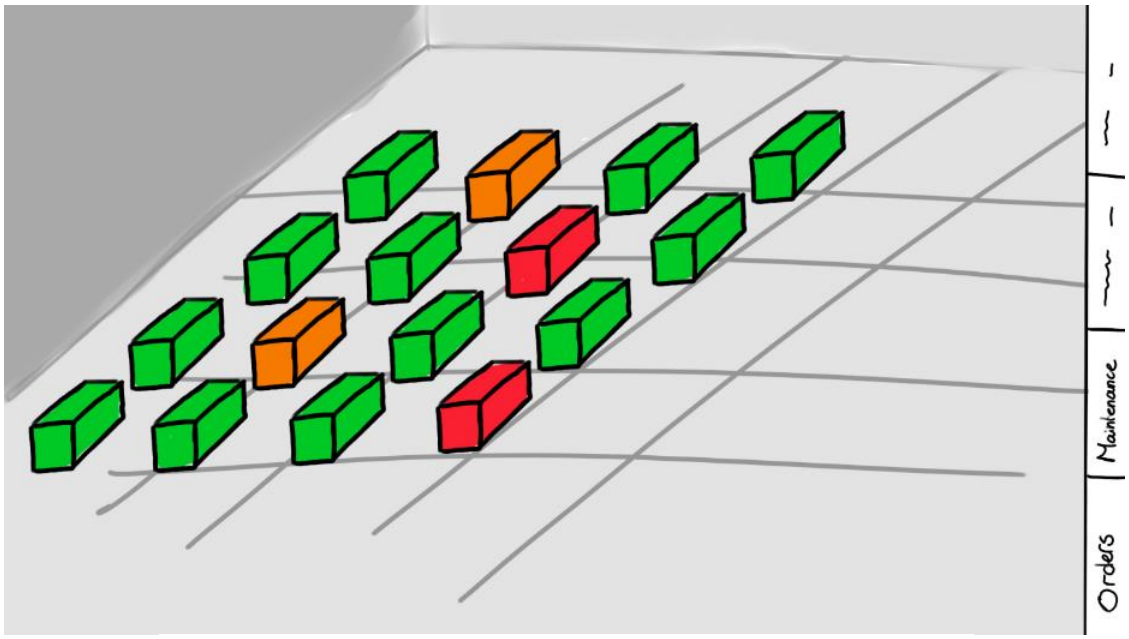


Figure 12. Second prototype of the first iteration, with the side menu showing

This visualisation, as is pictured like this would leave a lot of space to the right side of the screen. This space is thought of to be used for information about the machine. However, this side could also be used for more things than just the machines information. This side menu could also offer up much more functionality, such as maintenance information or order information. The worked-out idea can be seen in Figure 12.

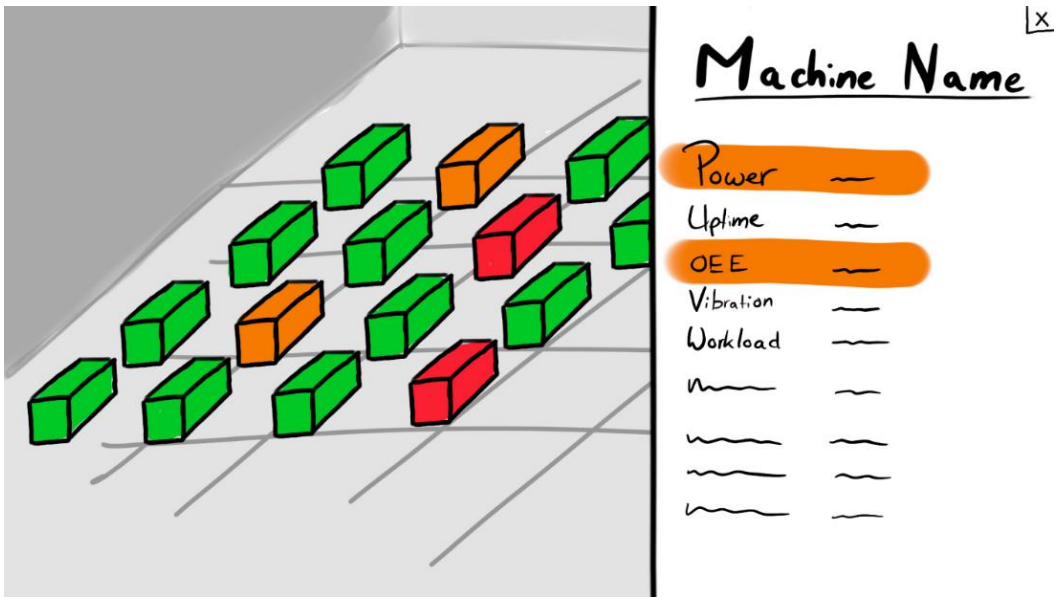
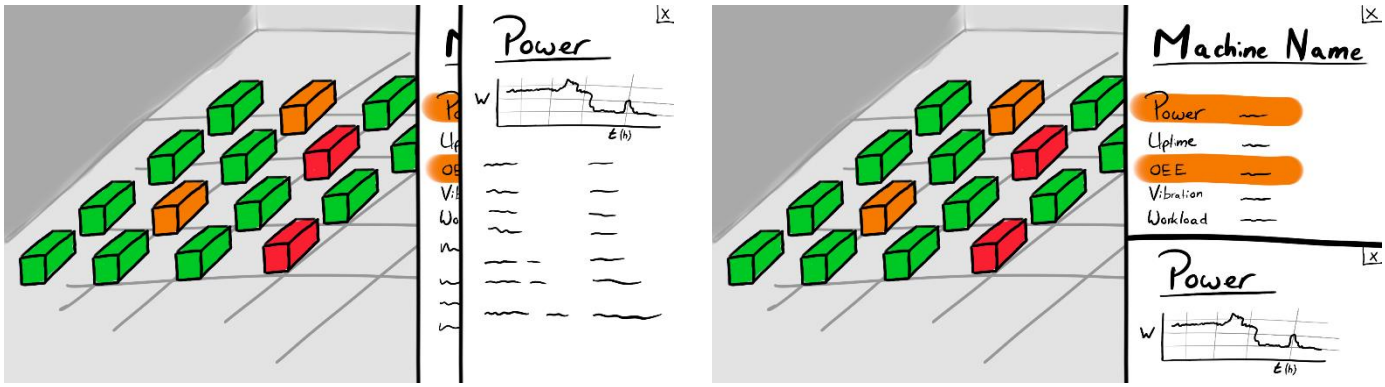


Figure 13. Second prototype of the first iteration, with the machine information screen showing

Once a machine is selected, information about the machine should be displayed as well. This information will also appeal over to the right side of the screen. It is displayed on the right side of the screen, as the user will expect more information to be displayed there, because of the presence of the side-menu. This side-menu therefore also helps to create an expectation of where information is going to appear, thus making the interaction smoother. This idea can be seen in Figure 13.

Once the user is on this screen, a production floor manager might want to find out why a machine has failed, and when this machine started to fail. This can be done through analysing the historical data of a variable.

This was envisioned to be displayed in a graph, which can be displayed once a user has selected a variable of the machine. This graph would then be displayed either overlapping the variables, or on the bottom of the side-menu, as can be seen in Figure 14.



(a) *(b)*

Figure 14. Second prototype of the first iteration with historical data where (a) is overlapping and (b) is on the bottom of the side-menu

5.2.3 Third Prototype

The third prototype combines the grid view, as well as various ways of showing the status of the machines. In terms of choices from the morphological analysis this prototype is very similar to the first prototype. However, this differs much in thought behind this design. This prototype did not compromise upon the fact that a user will not be able to see all the different machines once one is selected. This prototype used much of a similar side-menu style idea as the first prototype. This design however was thought of to be well usable on mobile devices such as tablets and mobile phones. With this design, as can be seen in Figure 15, allows for great

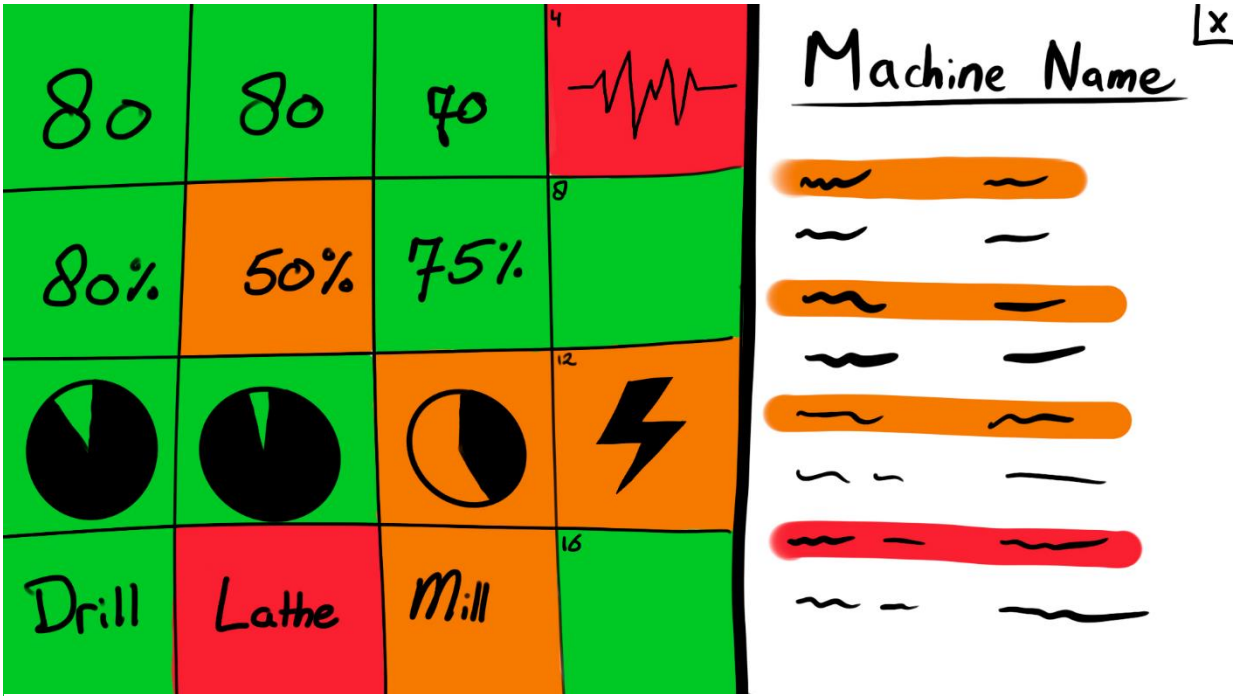


Figure 15. Third prototype of the first iteration

scalability between devices because of the square machine tiles. Various ways of showing status are used, which are colour, pie chart, OEE with percentage, and OEE without percentage. Additionally, what was thought of is that if a machine is performing as it should, nothing is displayed on the machine tile. However, when there is

an issue with the machine, this is displayed to the user by using icons. If the user decides that they do not want to see any statistic, but would rather see an identifier, the user can customize the dashboard such that the machine tile shows the name of the machine.

(a) (b)

Figure 16. Third prototype of the first iteration with other side information being displayed where (a) displays order information and (b) displays maintenance information

For when a user does not have a machine selected, the right-most side of the dashboard would not be visible. However, since showing no information on that side would be a waste of space, other information can be displayed there. This information can vary from maintenance, product, or order information, as can be seen in Figure 16.

5.2.4 Fourth Prototype

The fourth and last prototype created in this iteration was a combination of the showing the machines through a table and displaying the status both through colour and through percentages and numbers. This is very efficient in showing the user what is wrong with a machine, and where that problem lies. This is a prototype that scales the best of all prototypes in this iteration in the number of machines. However, due to the fact that this is displayed to the user with a table, it does not portray well that AMC is on the cutting edge of technology, as that would require a more advanced visualisation than a table. Neither does this prototype provide the overview that someone from management would be looking for. This prototype was both produced for completionism, as well as seeking to see what the reactions are to this prototype, as this can provoke some responses which the client might see as insignificant but can be very significant for the design process. This prototype can be seen in Figure 17.

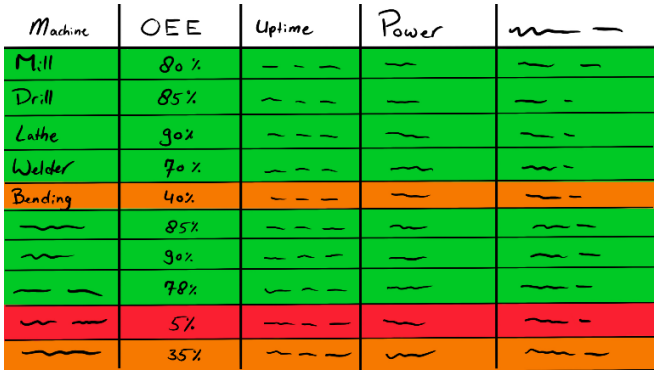


Figure 17. The fourth prototype of the first iteration

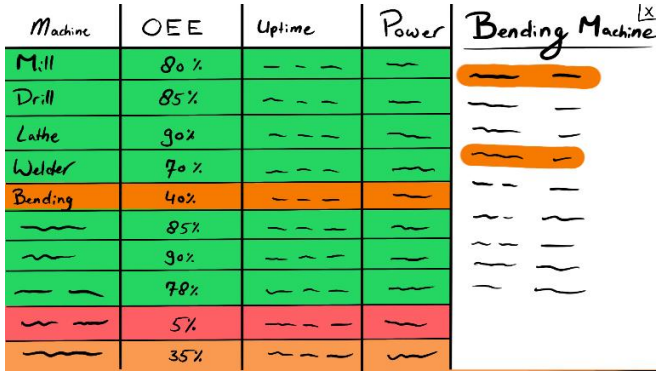


Figure 18. The fourth prototype of the first iteration, showing

A definite drawback of this prototype is the fact that a lot of information is shown on screen at the same time. To also imagine that this data is live, and therefore does change all the time, this can be imagined as very cluttered. However, this is a great tool for acquiring data as a user without having to click on anywhere, as the most common failing variables are shown directly on screen. However, if the user is curious about historical data, or wants to see more variables about this machine, the user would be able to interact with the tool and click on one of the rows. This will show the user Figure 18. On this screen, the user will be able to view more in-depth data about the machine.

5.2.5 Evaluation First Iteration

At the end of the first iteration, additional requirements were found out through a series of questions and discussions. All of the prototypes of the first iteration were also shown to the client, about which constructive feedback was given about every design.

The first prototype was presented, on which the feedback that was received was that this was not something that the client had envisioned. This was mostly because of that the requirement that this should show that AMC is on the cutting edge of technology was not met well enough with this concept. However, this was agreed upon that this would be a good basis for a design for a mobile application to review the status of the machines. It also became quite clear that the client sought out for not only something functional, but also something aesthetically pleasing.

The second prototype presented was received with a lot more positive feedback. This prototype was almost what the client had hoped for to be created. The side-menu that was introduced in this prototype was also very much liked, as this offered up a lot of potential for the future development of this project. During this presentation, a discussion arose about what the additional content of the side-menu should be, which indicated that this was a feature that was really liked by the client, and that this was something to be kept. Another point of feedback that was given about this prototype is that ideally the boxes would ideally be looking like the actual machines that are on the shopfloor.

The third prototype presented received very similar feedback to the first prototype but was liked more than the first prototype. This was found to be the better option for mobile devices, as this allows for good cross-compatibility if this were to be developed into a web application. However, this was not liked for the purpose of this project, as this is prototype is also looking too basic, and was specifically said that this prototype is not showy enough. If this were to be developed further into a mobile application, it was mentioned that names of the machines are desired in the tiles, as being able to identify the machines is most important.

The fourth concept presented was met not met with a lot of positive feedback, as it had become clear that being visually pleasing as well as functional was what the client was looking for. Though, this was found to be very practical in the use case that a maintenance engineer is performing maintenance on a machine and is thus quickly able to look at the different parameters of the machines. This was also found to possibly be a good alternative view for engineers as this provides a clear overview of the parameters of the machines on the shopfloor.

Next to the prototypes being shown, additional requirements were found out through a series of questions, discussions, and responses to the prototypes. The first of which is that the use case of this project became clearer

for the client and visitor stakeholder. The use case of the tool being developed is that it will be used as a main display piece for the shopfloor. This tool will create both an overview of the shopfloor, as well as to provide insightful information to the user of the interface. This will be displayed on a very large touch-screen television in the welcome hall of AMC. This screen will be, as described by the client, the eye catcher when you enter the building. This screen will be located next to a glass wall overlooking the shopfloor. As the second prototype would satisfy all of the users the best, this was chosen as the basis of the design for future iterations. This overview allows for the insight that the engineer is looking for, the overview that management would like to see, as well as that it looks high-tech and is representable enough to show a customer or client.

5.3 Second Iteration

The second iteration started with deciding on which software product would be used to develop the further prototypes. It was quickly upon that Adobe XD would be used to develop the interface for this tool. Adobe XD was chosen as it allows for tremendous amounts of freedom in the design, as well as that it has a lot of handy plugins which allow can serve a multitude of features. Besides this, Adobe XD allows for the re-usability of design elements, such that only the parent element has to be edited to affect all child elements. Adobe XD also has very good integration with Adobe Illustrator and Adobe Photoshop, both of which have more extensive features for vector art creation and image editing, as well as being used previously by the designer. Two prototypes were developed for this iteration.

5.3.1 First Prototype

As the first prototype, a digitalization of the first iteration was made with some minor adjustments, such

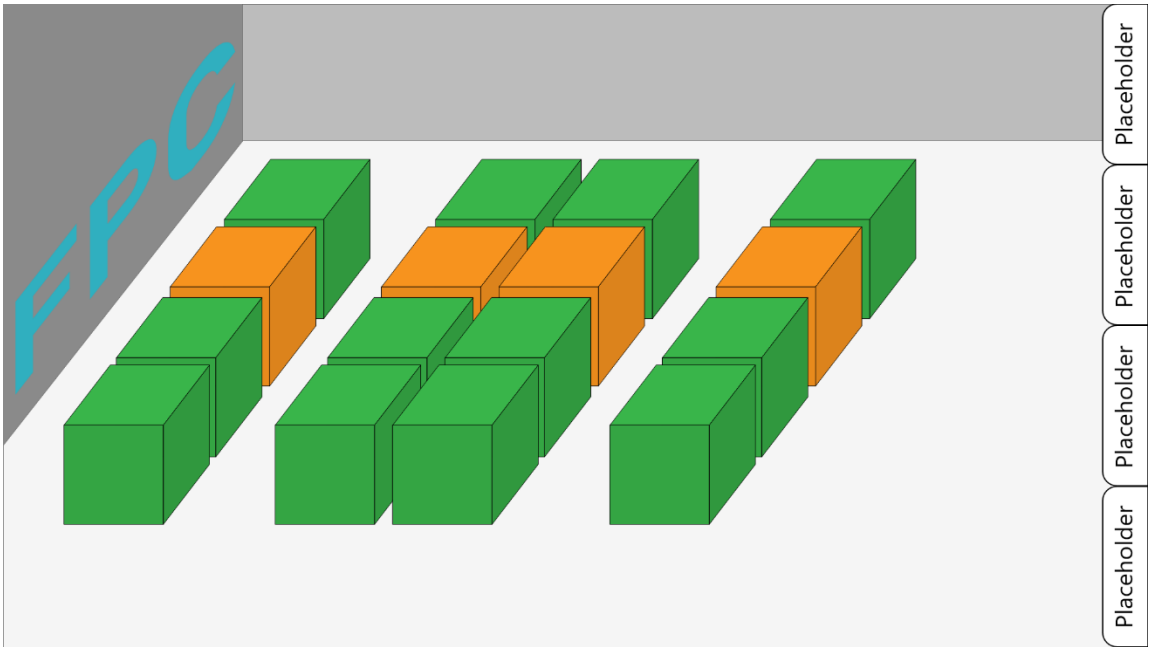


Figure 19. The first prototype of the second iteration

that the side-menu now consisted of rectangles with rounded edges, as to give a more friendly look, as well as that the letters PFC were put on one of the walls. These letters were put on the wall both to fill up the empty space on the wall and to make this design something that is clearly targeted to FPC. The colour of the FPC letters was extracted from the backdrop of one of the individuals with which meetings were held from the client.

On this backdrop there would be huge letters, saying “FPC” in this colour blue in the office of FPC. Furthermore, it was chosen for this perspective, to be able to see the right side of the machine as this feels most natural to people that have a native language that reads from left to right [38]. In Figure 19 the starting screen of the interface can be seen.

Once a machine is selected by clicking on it, the user will be able see the screen as seen in Figure 20. In this screen, an overview of presented of all the parameters of the machine, with warning triangles next to the problematic parameters. The background colour of the parameter is also changed to an orange, as to give another

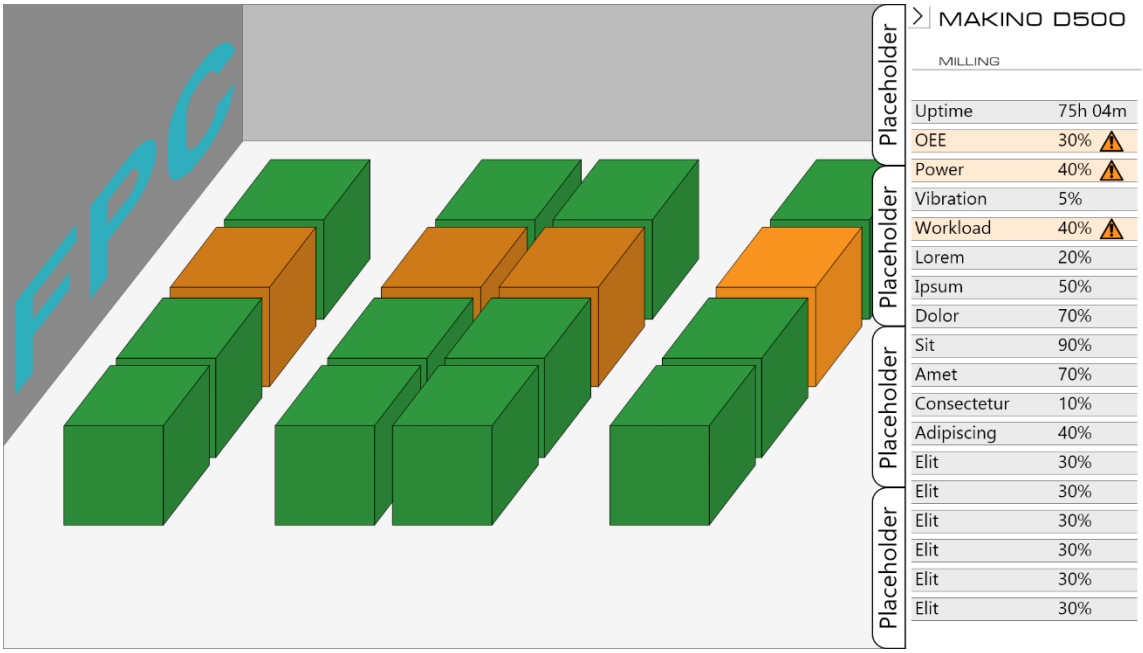


Figure 20. The first prototype of the second iteration when a machine is selected

visual cue to the user. Pre-attentive process is also applied, as the machine that is selected is also highlighted. On the top-left of the side-menu, the user is able to select the return button, which returns the user to the screen present in Figure 20**Error! Reference source not found.**. The design of this was intentionally chosen to be very minimalistic, as that would fit the font that is picked as the title of the side-menu, as this also constitutes as a modern design. The font of the title of the side-menu is chosen as an all-caps font with thin sharp lines, and big open areas inside of the letters. Additionally, the font exists out of a lot of straight lines, where curves are kept are there, but all have very small radii. These are all aspects of a modern looking font, which aligns well with the requirement set that this should look like AMC is on the cutting edge of technology. The same font is chosen for the sub-title, which describes the function of the machine. The colour of the sub-title is chosen to a grey at about 20% brightness, as this does not take the attention away from the title. By aligning the left sides of the title and sub-title, as well as putting a division line underneath of the sub-title, this indicated clearly that this is a part of the header of the side-menu, and that all information displayed below this line is details about what is inside of the header.

Regarding the design of the parameters displayed within the side-menu, rows are drawn. Within a single row there exists a parameter and a value, without any separating character, but rather using space between the parameter and the value to indicate they are separate entities. However, due to the colour of the row present, it is clear that they belong together. A decision was made to not implement a separating character, as this would

not align with the modern and minimalistic style that was chosen for both the font and the design of the return button.

When a user selects one of the parameters, a graph is presented to the user, as can be seen in Figure 21

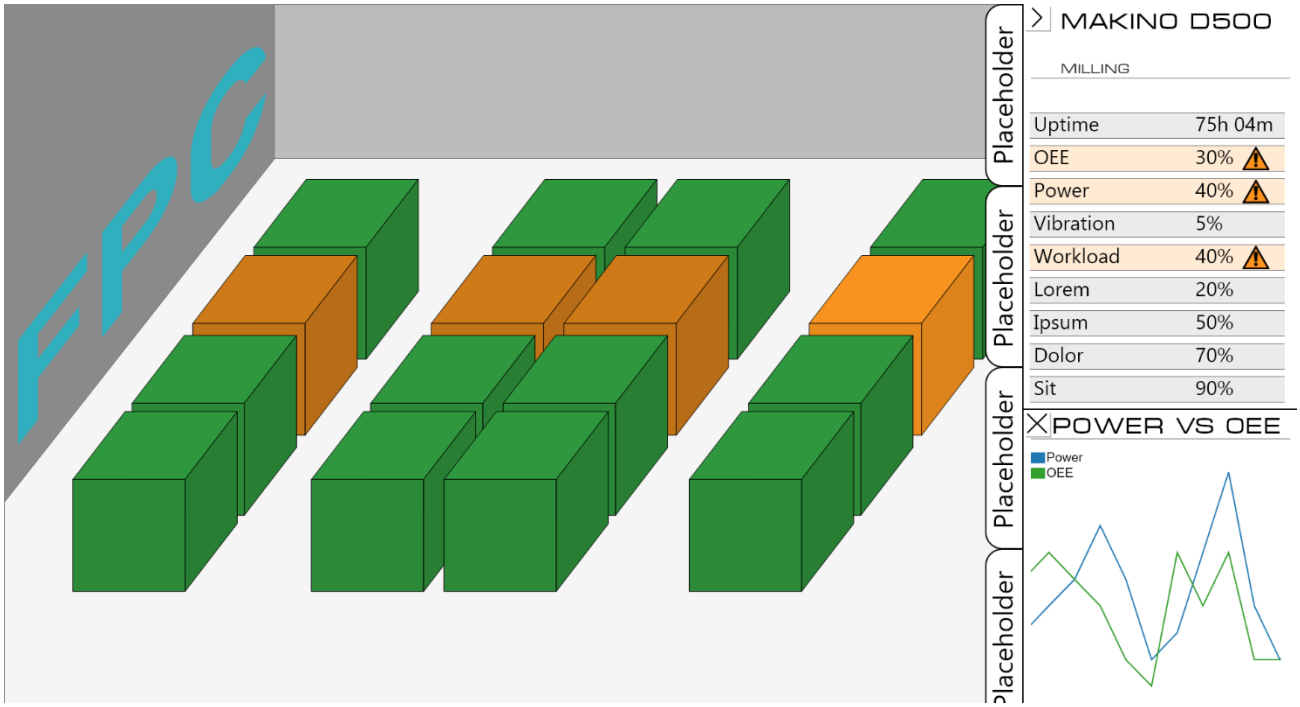


Figure 21. The first prototype of the second iteration when looking at historical data of a machine parameter

which presents the user with historical data about that parameter compared to the OEE at that time. For producing the graph, the plugin VizzyCharts is used. On the graph, there is an exit button present, that is within the same style as the previously described return button. A line is used to separate the chart area from the header area.

5.3.2 Second Prototype

The second prototype was designed much like the first prototype of this iteration, apart from that it used a two-and-a-half dimensional way of representing the machines. The functionality is the same as the first prototype, but the design elements are different. The two-and-a-half dimensional machines and the side menu design of this prototype can be seen in Figure 23. The design of the side-menu has been changed in this design, as this now has sharp edges. It was expected that the client would prefer the rounded edges over the sharp edges. However, as this is also a very viable option to go for, it should also be presented to the client. A zoomed-in image of a single side-menu tab can be seen in Appendix B.

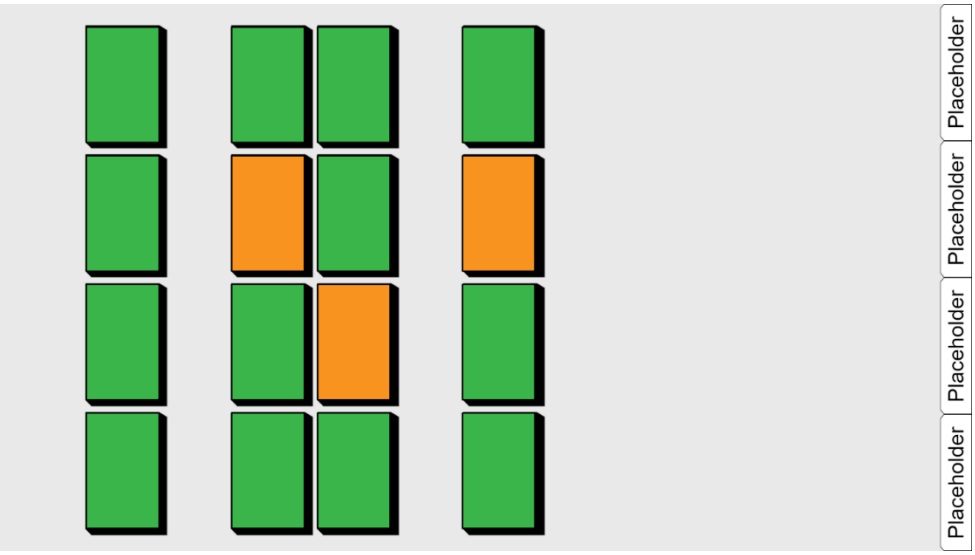


Figure 23. The second prototype of the second iteration on its starting screen

Once a machine is selected, pre-attentive processing is applied by highlighting the currently selected machine, as can be seen in Figure 22. This also displays various parameters about the machine on the right side of the screen. This design of the side-menu includes the manufacturer of the machine in a different location to a in a small font, to the right-hand side under the name of the machine. In this design another font is used that is also thought to be liked by the client and fits the same requirements as the header font chosen for the first prototype, apart from that this font is not an all-caps font.

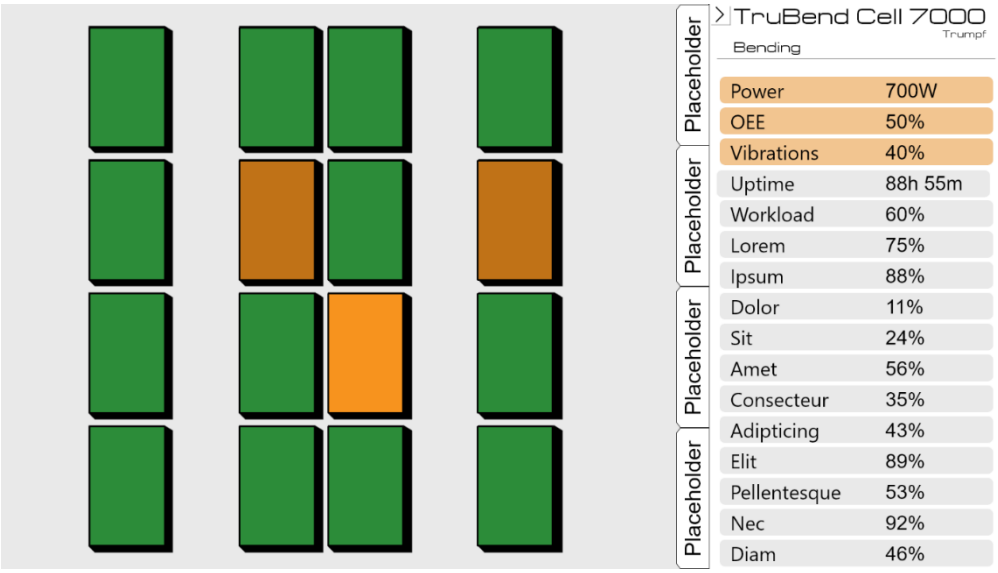


Figure 22. The second prototype of the second iteration with a machine selected and its parameters showing

Regarding how the parameters are displayed, the same font and spacing options were chosen as in the first prototype of this iteration. However, how the rows of the different parameters look are changed. For this prototype, rectangles with rounded corners are made. The decision to make the rows shaped like this was made to see whether the client would prefer this over the design used in the first prototype.

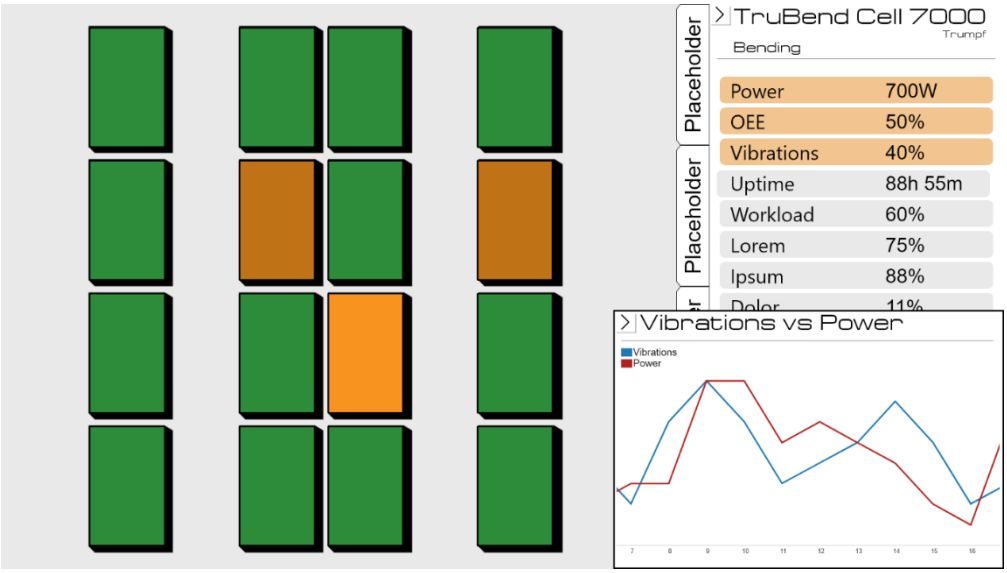


Figure 24. Second prototype of the second iteration with historical data showing of vibrations and power

When a machine has been selected, a parameter can be selected to show historical data of this parameter, as is shown in Figure 24. In this prototype only Power and Vibrations were able to show graphs. The user would also be able to show Power and Vibrations within one and the same graph, as such the user would be able to inspect multiple parameters within a singular plot. This would especially be helpful to see whether there are parameters that have a relation between them when it comes to problem detection within the machine itself.

5.3.3 Conclusion Second Iteration

At the end of this iteration, the product was shown to the client, after which more requirements were found out, preferences were expressed, and discussions were had about the development of the product. What was discussed are the way to visualize the machines, feature requests and changes, as well as generally applicable comments on the design.

The way to visualize the machines was done in two ways this iteration. The first of which is a three-dimensional, and the other is in a two-and-a-half dimensional way. A big preference was expressed for the three-dimensional visualisation. The three-dimensional representation of the machines conveys the same amount of information as the two-and-a-half dimensional way, but look better and more high-tech. This related back to the requirements set in Chapter 4, in which it was found to be important that the interface gives off a high-tech feeling towards the customers and clients.

The first of the features which requires attention is the graphs of the individual machines. Requested features are to be able to open more than one graph, and not to have multiple parameters in a single graph. It was also desired to drag the graphs across the screen, so that the user can position the graph in a location that works best for them.

The second of feature that requires mostly addition is the tabs on the side-menu. A discussion was held about what these tabs should be, as well as what information should be contained within these tabs. One tab would be dedicated to providing an overview of the entire shopfloor. Various parameters can be selected, such that for example the total power usage can be seen, or the average workload of the machines on the shopfloor. The second tab on the side-menu would be a tab dedicated to maintenance. This tab would contain information

about when the next maintenance is planned for the total shopfloor, providing chronologically ordered list of scheduled maintenances. This tab would also contain of past maintenance jobs that have been done on every machine. The third tab on the side-menu would a tab that would contain information about all the products that are currently being produced. However, as further design of this would be outside of the scope of this project, simply creating a placeholder is all that is required.

Another feature requested is simply a placeholder, but desired either way. This is a feature that would allow the user to toggle live data received on or off. Turning this toggle on would show the different machines working, as well as see robots driving around on the shopfloor. However, as implementation of this feature is far outside of the scope of this project, a simple placeholder button is all that is required.

The final feature to be changed is the models of the machines. At the moment only the problematic machines allow for an interaction, but in the end all of the machines would require to be clickable. There was also a discussion about whether there should be icons on top of the problematic machines, such that a user would be able to identify what is wrong with a machine without having to have further interaction with the tool. Additionally, it is desired to be able to also recognize the machines without having to interact with the tool. Another placeholder button is desired for the machine information screen, which is to have a button which shows the specifications of the machine. This would include the workable area, what materials it can process, and so on. However, designing this is outside of the scope of the project, and therefore will simply be implemented as a placeholder button.

As general comments about the design for this iteration, the first of which being that the triangle next to a problematic variable is liked a lot. It grabs the attention of the user very well. The FPC text is also very much liked on the wall, as this brands the tool very well. Another comment that was made is that some of the hitboxes of the machines were off, as you would be able to select a machine, while the user is not hovering over that machine.

5.4 Third Iteration

The third iteration of the project was an iteration which did not add a lot of features, but rather improved upon the already existing features. In this iteration, only a single prototype was produced, as there was a very clear preference expressed in the previous iteration on various designs. Thus, there was no need to produce multiple prototypes, as time would be better spent upon improving the chosen for prototype and design elements.

5.4.1 Prototype Development

The start screen of the third iteration can be seen in Figure 26, which houses a lot of new changes. The collapsed side-menu was improved to use icons instead of the usage of words. This change was made to both make the side-menu less prominently visible on the start screen, as well as to move in the direction of a sleek and modern design, which uses well-chosen icons to represent words. All of the symbols that are used were found within the Adobe XD plugin Auto Icon, after which some were edited to make them suit the design of the product. The three side-menu buttons can also be seen in Appendix C.

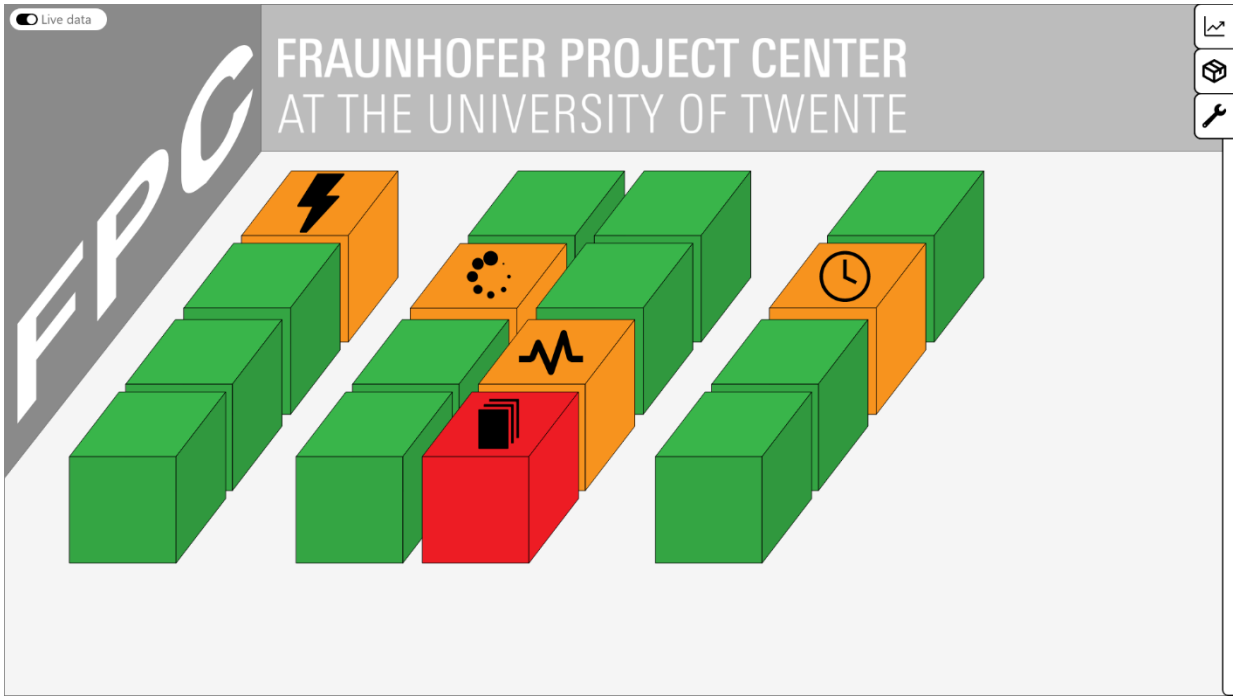


Figure 26. The start screen of the third iteration

A lot of placeholder buttons were designed and placed in this iteration. The live data button that was requested in the previous iteration was implemented, of which the two states can be seen in Appendix D. The blue selected for the on button was found on the Apple human interface guidelines page for colours, for which the dark cyan was chosen after experimenting with the various colours present on the web page [39]. A blue colour was chosen as to not conflict with the rest of the colours on the screen. This blue colour is used through various parts of the design.

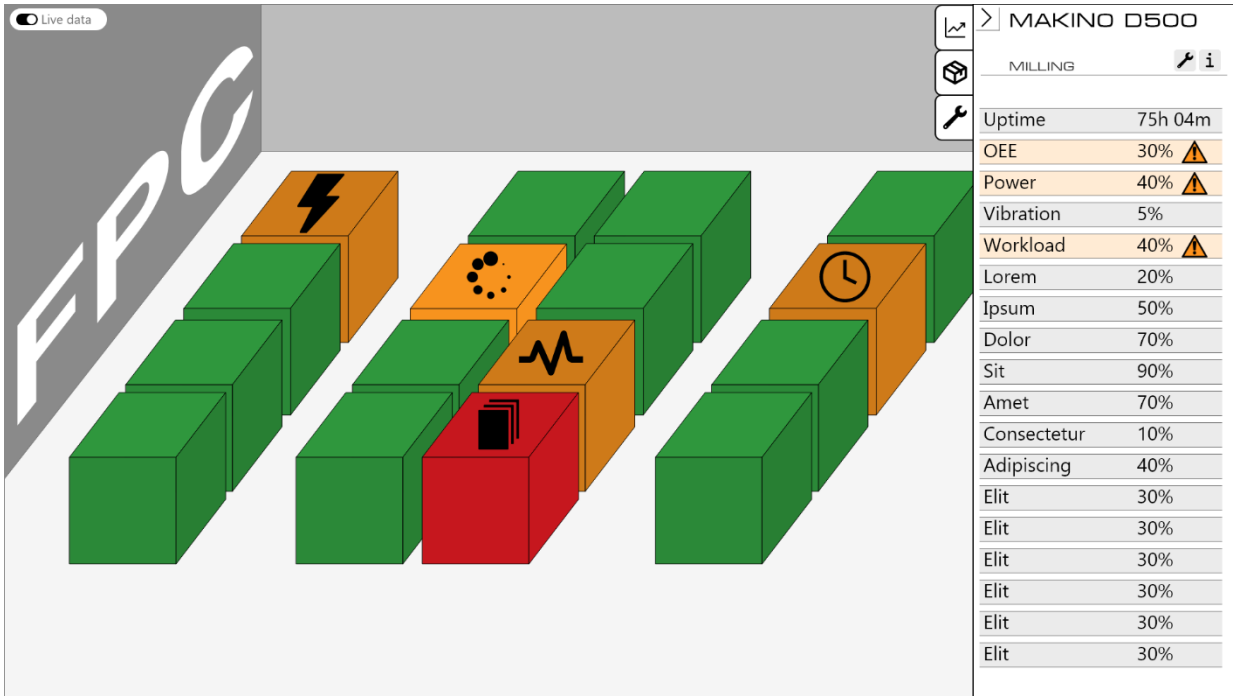


Figure 25. Once a machine has been selected in the third iteration

Furthermore, there was a request to be able to recognize what is wrong with a machine without interaction. This why there are symbols located on top of the machines. A series of icons were placed on top of the machines

to give the client an impression of how this would look like. If this idea is liked by the client at the end of the iteration, an entire series of icons would be designed to represent the various problems a machine could have.

Another change made is the logo of FPC on the back wall of the design. The client mentioned that they prefer to have this logo on the wall rather than just the FPC text. However, due to the fact that this logo is rather large, the logo disappears the moment that the side-menu is expanded, such as can be seen in Figure 25. Additionally, once a machine is selected two more buttons are presented to the user in the form of an information button and a spanner in the header of the side-meu. Both of these are placeholder buttons and are not to be implemented. However, when the user hovers over the buttons with their mouse, the button turns a darker grey, providing feedback to the user that they are in fact hovering over that button and conveying to the user that this is a clickable item.

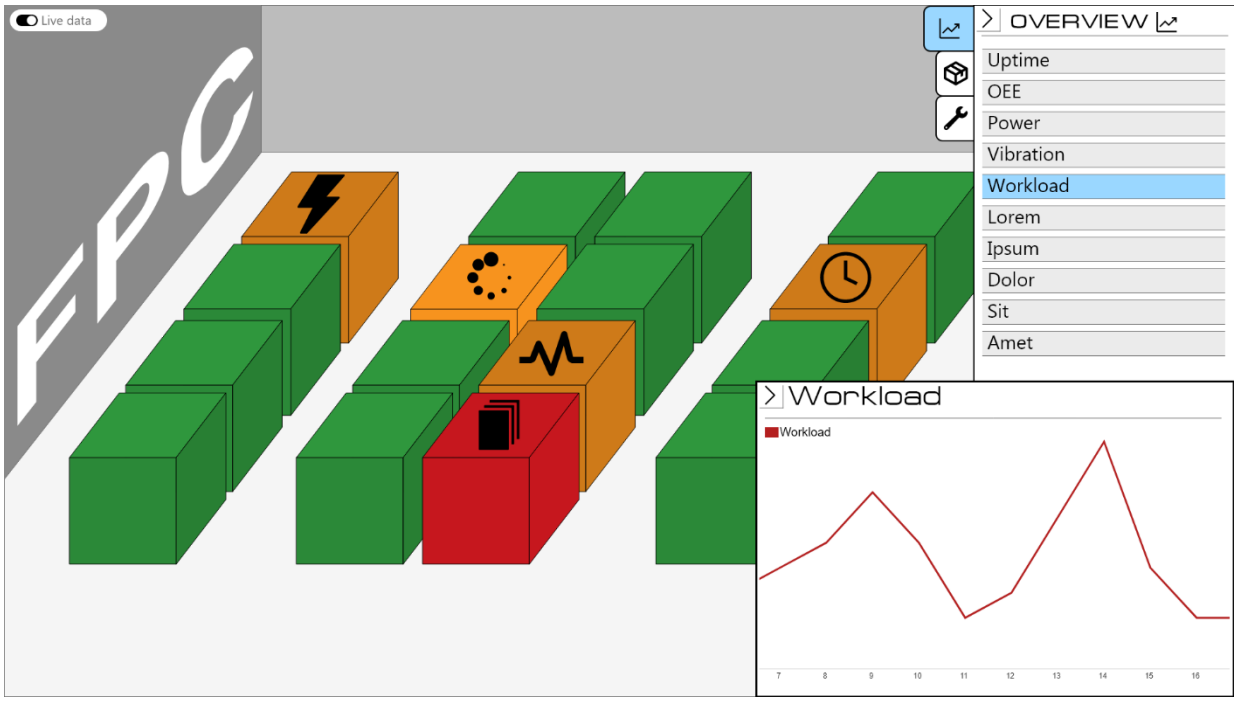


Figure 27. The overview tab as it is made in the third iteration

Furthermore, the side-menu tab which provides an overview of the entire shopfloor has also created, as can be seen in Figure 27. In this menu, a parameter can be selected, which provides an overview of the total parameter. For example, this would show a graph of the total power used, or average workload of the shopfloor. In this menu, the icon of the side-menu tab is added at the end of the title of the header as to help the user more quickly identify on which tab, they are by adding in an additional visual cue besides the highlighted side-menu tab and the title of the header. The graph that was implemented is the same design as was found in the second iteration. Both the product and maintenance tab were left empty, as it was unclear what exact information the client would want to see in these tabs.

5.4.2 Conclusion Third Iteration

At the end of this iteration, the product was shown to the client, after which various changes and additions were thought to be desirable for the end-product. What was discussed were all the new ways additions in this iteration, as well as the discussion of reworking of some components of the design.

The first of which was discussed was the visualisation of a machine, which at the moment is a very simple three-dimensional box. Ideally every machine would be modelled after the actual machine that is also located on the shopfloor. Here, new requirements were set for the visualisations of the machines, which is to make the machines look more high-tech, as well as really make it come across that AMC is on the cutting edge of technology.

Second thing discussed was the symbols on top of the machines to represent the reason of failure or warning of a machine. This idea was liked quite a lot, but after a short discussion it was thought to look too busy if the machines were to also be reworked. It was concluded that this should not be in the final product of this project, as this would most likely take away from the high-tech looking rework of the machines.

Thirdly, the reworked side-menu navigation bar was also very welcome. The reworked side-menu buttons can be seen in Appendix C. It was both clear what the meanings behind the icons were, as well as that the interaction was more satisfying according to the client.

As fourth, a discussion was held about what to include in the maintenance tab. The desired functionality of this tab would be to create an overview of when a machine would have to undergo maintenance. This would preferably be in a chronologically ordered list in which all of the machines are present. Specific information about the maintenance order would be desired to present to the user once a planned maintenance order is selected.

Furthermore, there were a handful of features that were to be changed or added. The first of which being that it is thought that the machines that are in red are thought to present different information in the machine details menu. This would come down to showing the user something that would make it clear that this machine is not functioning anymore.

Further features that requested for the machine information screen is presenting the user with a small image of the machine in the header. Additionally, a failure log per machine is also desired. This would show when a machine has failed and what the reason for the failure was.

5.5 Fourth Iteration

The fourth iteration of this project was much about applying refinements from the previous iterations. The largest part of this iteration was the rework of the machines and further development of the prototype within Adobe XD. As this iteration was, just like the third iteration, much about refining the current work that has already been done, no additional prototypes were created.

5.5.1 Machine Visualisation Rework

The visualisations of the machines were modelled after the actual machines that would be placed on the shopfloor. To start off with this, all of the potential machines that will be placed on the shopfloor were looked at and taken as inspiration for a series of prototype drawings, as an example with a bending cell, laser cutting cell and milling machine are used [40, 41, 42]. A list of potential equipment can be found in Appendix E. These were drawn on paper to be able to quickly make changes more quickly, as well as leaving some space for imagination. All of the drawings can be found in Appendix F, and the highlights of these can be seen in Figure

28. After the highlights were presented to the client, there was a strong liking towards the fourth drawing. However, the rest of them were liked a lot.

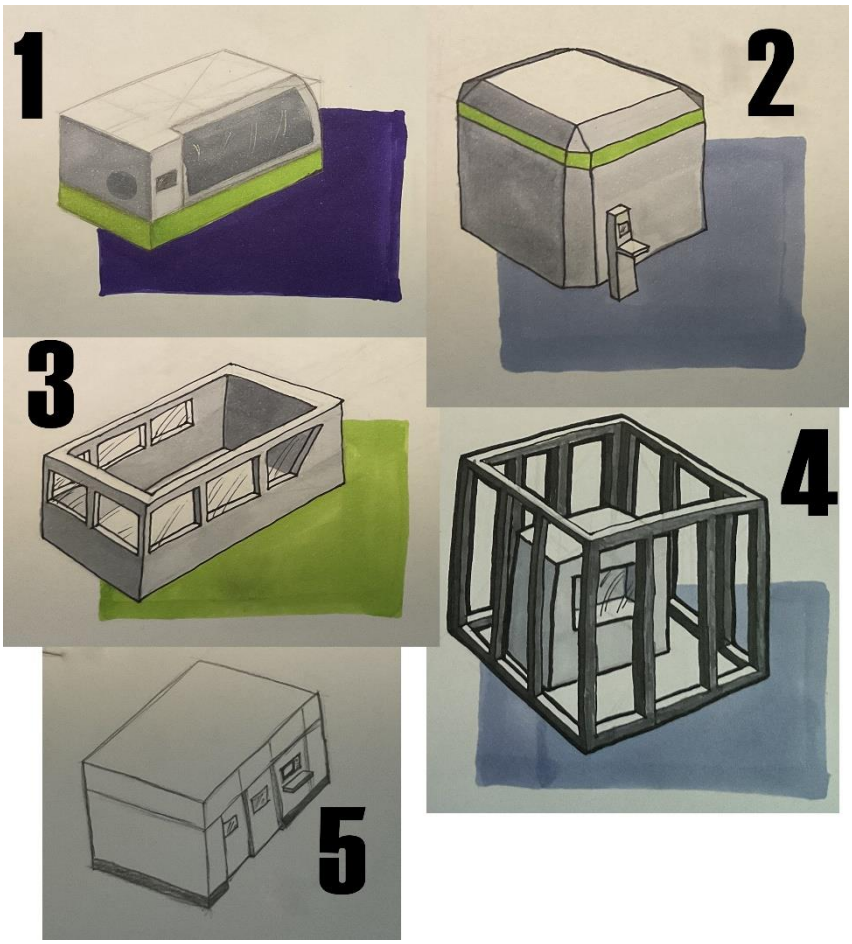


Figure 28. The highlights of the paper prototypes of the machine visualization rework

The next step would be to make a digital model of these drawings. It was decided to model the machines after the actual machines that would be placed on the shopfloor. The machines were modelled after the Trumpf TruLaser Cell 5030 [40], Makino D500 [41], and Trumpf TruBend Cell 7000 [42]. To not make the models too detailed and cluttered, the majorly defining components of the machines were selected and used in the model. To model the machines, Fusion 360 from AutoDesk was used [43]. This program was chosen as this it allows for rendering models in varying amounts of quality, the friendly usage of the program, as well as that I have previous experience with Fusion 360. While creating the models of the machines, an effort was made to make all the machines be similarly styled. This made is so that not all of the machines have realistic physical ratios but was kept to a minimum. Only for the model of the bending cell a non-existing feature was added, being a white strip. This was done to make it look similarly styled to the other models, as well as to make it look more high-tech, as was requested by the client. The models that were produced can be found in Appendix G.

In order to show the status of the machines, the top of the models are given a colour. In order to not make this look like it is part of the design of the machine, notches were created on the models of the bending cell and laser cutting cell. Due to the fact that this did not look natural on the model of the milling machine, another approach was taken. This was done by making a roof appear on top of the machines in a way that looked most natural. The thought behind this roof was to make it appear so that the part of the machine that is coloured is a part that was naturally formed due to the construction of the machine.

To create an image that could be used within Adobe XD, all of the machines would have to be put together to form a visualisation of the shopfloor. A semi-random order of the three models were put together to create the visualisation that can be seen in Figure 29.

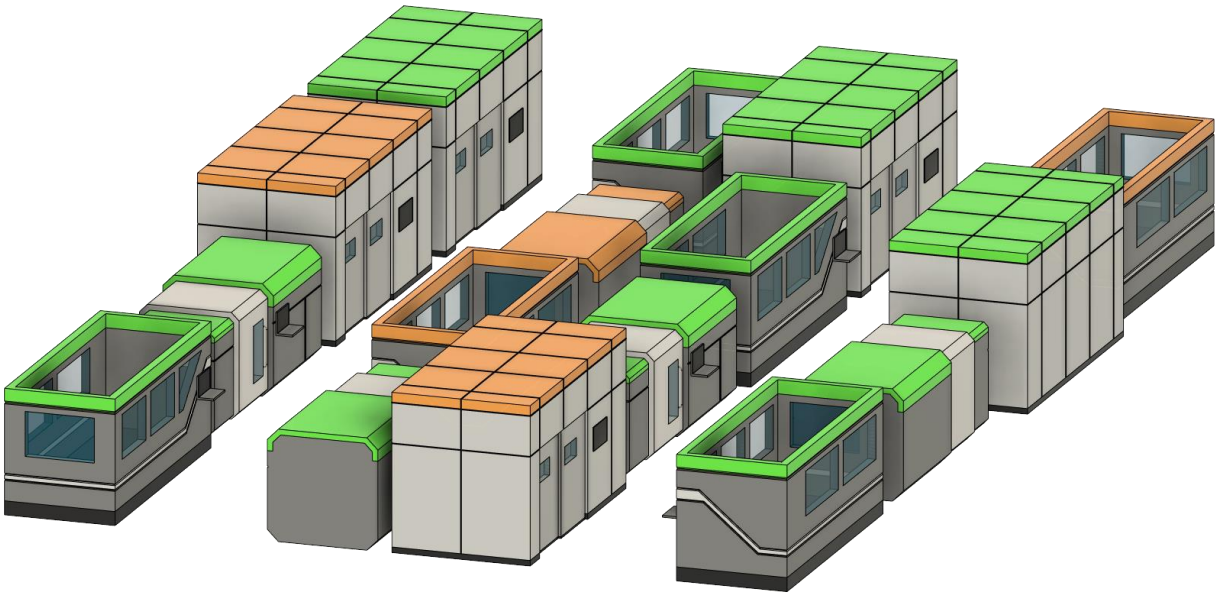


Figure 29. The visualization of the machines in the shopfloor created in Autodesk Fusion 360

5.5.2 Functional Prototype Development

The further development of the prototype started with importing the reworked visualisation of the machines. As most of the machines have irregular shapes, separate hitboxes were drawn over top of the machines, such that the correct machine would always be selected. The hitboxes can be seen in Figure 30. A

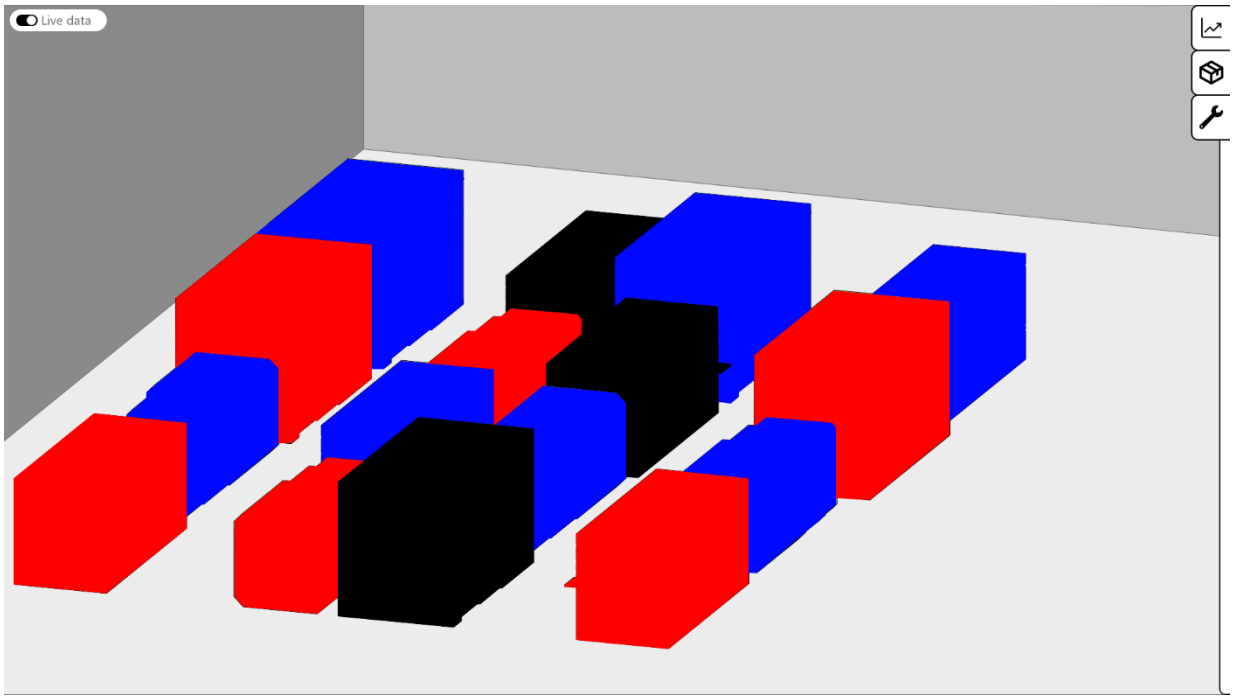


Figure 30. Drawn hitboxes of the machines in the fourth iteration. Different colours are used to be able to be able to see the boundaries of the hitboxes. The colours do not have any meaning.

long-lasting bug of this project was also fixed this way through that in previous iterations had overlapping hitboxes, which would make it so that a machine was selected the user did not mean to click on.

Further development was done in the machine information screen. This screen was reworked to house new features, as well as to look more in line with the modern look of the tool. Instead of separation lines between design elements, shadows were used to create a look that more closely resembles the modern looking Material Design by Google [44]. This was only implemented in some parts of the prototype, as to see whether the client likes this direction of the project, and so that the client could easily compare between the two styles. This rework of the machine information menu can be seen in Appendix H. As can be seen, the different machines also all have a rendered image in the header of how the machine looks like.

Additionally, a failure log button has been created. To create this button, the Auto Icon plugin has been used again to find both a cog and a warning triangle, which has been coloured red. The colour red has been chosen as this is also the colour of the machines when they fail. What also has been reworked is how the machine parameters are displayed. The parameter names are now right aligned, and the parameter values are left aligned. More space has been created in between the different parameters, and the background of the rows has been removed. This makes it so that it still provides a clear overview of the different parameters, while also fitting better with the overall design of the product more because of a more minimalistic and modern design. This button also becomes a darker colour when the user hovers over it, conveying to the user that it is a clickable item.

The same design style was applied to the overview tab, in which the background of the rows was removed to have a better with the overall product, as can be seen in Appendix H. Additionally, a drop shadow was added on the graph, to make it fit with the overall design better, as well as to make it look as if the graph is floating above all of the menus. It was designed this way with a stroke around as well as a drop shadow on the graph to make it appear to be movable, as that was a design feature the client had requested. Unfortunately, moving a window around is not possible within Adobe XD but it can be considered in the design of the tool. As can be seen in Appendix I, the header of the overview tab has remained the same as the last iteration. This was to show the client the difference between the two different styles and help them decide upon what they like better.

The maintenance tab also had content added to it. As was discussed in the last iteration, the client had provided information about what functionality was expected from this tab. This functionality was added by creating rectangles with rounded edges, as to fit with the style that includes rounded edges. Within these rectangles, the manufacturer, machine name, and date are shown, as can be seen in Appendix J. Every maintenance log entry has a button next it to bring the user to a screen that provides more in-depth information about the maintenance entry. However, that is not implemented in this iteration. This button becomes a darker colour once a user hovers their mouse over top of it, conveying to the user that this is a clickable item.

5.5.3 Conclusion Fourth Iteration

At the end of this iteration, the prototype was shown to the client to seek out additional requirements, as well as to see how the client likes the rework of the prototype. First of all, the rework of the machine information screen. This rework was very much liked by the client, as it gives the interface a three-dimensional feeling. Additionally, the way that the parameters are displayed is also very much liked by the client, as to their opinion

it works well with the new style that uses shadows rather than lines to define design elements. It is now desired that for the next iteration, the parameters that are being displayed will be realistic parameters, and so a list of realistic parameters is provided by the client that can be seen in Appendix K. The failure log button that was added to this menu was also appreciated, though it was thought that the red rectangle of the button would disappear if the machine was fully functional.

The rework of the machine visualisations was liked a lot. The machines now looked like how the client had hoped it would be displayed and reworked, thus expectations were met. According to the client, this gives much more of a high-tech feeling to the tool.

The overview tab was also reworked in a similar style as the machine information screen. The reworked design of this menu was also liked a lot. The client liked the new look of how the graph that is displayed to look like it is floating on top of the rest of the interface. This is exactly as it was designed.

The newly filled in maintenance tab was also much liked, especially that it is possible to scroll through the maintenance orders. A feature was requested for this part of the product, which is that if the button on a maintenance order is clicked, the rectangle that houses the button expands to provide the user more information about the maintenance order. Even though this would be a good feature to implement, implementing this feature would be too complex due to the limitations of the program and the time that is remaining for this project.

The product menu was not filled yet for this iteration, as this is outside of the scope of this project. However, the client requested it to be filled in a similar way to the maintenance tab. However, the client stressed that this is not a big priority, nor that a lot of time would have to be spent on this part of the project. For this reason, the products menu will largely be a placeholder.

Lastly, there were some general remarks. The first of which being that the graphs in the machine information screen was not yet working and is seen as a core feature. This is a feature that will be a high priority to re-implement for the next and final iteration. Lastly, the client said that they wanted to a machine in the visualization that is non-functional. The client would want this to be added to prototype to have a complete image of all of the functionality that this tool offers.

5.6 FINAL ITERATION

For the final iteration, just like in the previous iterations, changes and additions were implemented based upon the feedback of the previous iteration. This iteration was mostly fixing the final few things and putting the finishing touches on the prototype.

For the final iteration, the machine information screen has received realistic parameters names. This was formatted in such a way that relevant parameters are grouped together though the usage of both spacing of the parameters from each other, as well as different font sizes. The implementation of this can be found in Appendix L. As can be seen, the various gasses, liquids and power variables are all categorized under their own respective categories. OEE and workload are also grouped together through the usage of spacing, as both of them have a percentage as a unit, where the same goes for the parameters uptime and maintenance. As requested, the user is now also able to click on the various parameters, which will bring up a graph that shows the usage of the parameter selected. An example can be seen in Figure 32. As also can be seen, a scrollbar appears on the side of the machine parameters, indicating to the user that they can still scroll to view and select other parameters.

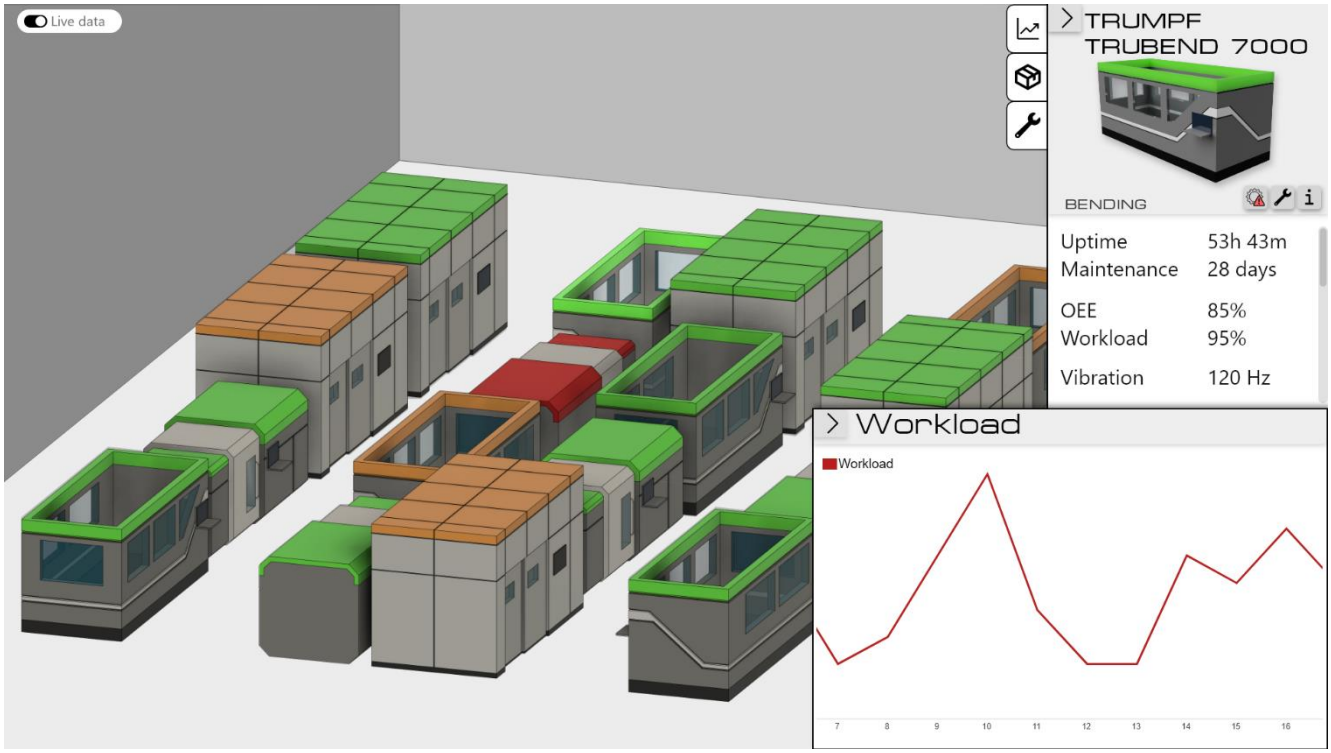


Figure 32. The workload parameter has been selected on the machine information screen

At the end of the previous iteration, it was also desired that a non-functioning, and thus red, machine would be added to the visualisation of the shopfloor. This was done by first creating a model in Fusion 360, after which the new model was implemented into the Adobe XD prototype. As was also requested by the client, is that the preview image of the machine would change if the machine was non-functioning. This caused a minor addition and change in the machine information screen, as can be seen in Figure 31. There is now a translucent red warning triangle overlapping the preview image on the top right of the screen. Additionally, red warning triangles are added next to the problematic parameters of a non-functioning machine, whereas for an "orange"

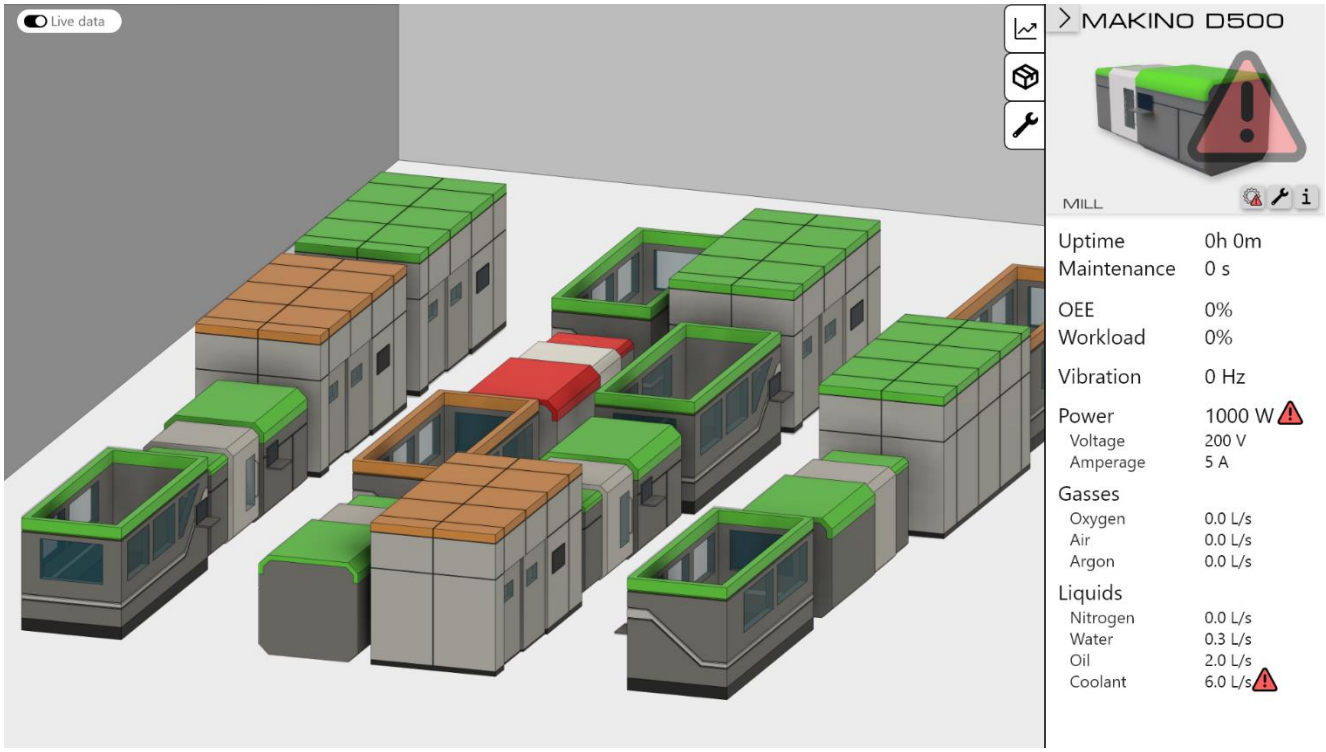


Figure 31. The screen once the non-functioning machine has been selected

machine, these would be orange. Especially the large warning triangle through the preview image is supposed to heavily introduce the colour red on the machine information screen, as to give the user more visual cues that the machine is not functioning.

The product menu has also received some attention. As this part of the interface is largely outside of the scope of this project a prototypical fill-in of this menu would suffice. A very similar style has been applied as has been applied to the maintenance tab, where rectangles with rounded corners are used, in which a small preview image can be found, as well as the name of the product. The realization of this menu can be found in Appendix M.

The overview menu also has also been partially reworked. As the machine information screen has received realistic parameters, so should the overview menu. The overview menu has received all of the parameters that a machine also has, apart from that the overview menu provides a global overview of the entire shopfloor. How this has been realized can be found in Appendix N. Once a parameter has been selected, a graph appears in the bottom right corner, which overlaps with a part of the parameters. Therefore, a scrollbar appears to the right of the parameters, indicating that they can be selected. This iteration is evaluated in Chapter 6, since it is the final iteration.

6. EVALUATION

A questionnaire was made to see how the interface is received by people who have not interacted with it yet, and only have heard very little about the development of the interface. However, since this is a product that will be used within FPC, the questionnaire was only sent to people that work in FPC, and thus are also aware of the projects that FPC is carrying out in more detail. It was chosen to not send this questionnaire to people outside of FPC, as there was little question about whether the interface functions, but more about how well the interface is received within FPC. All of the questions that were asked can be found in Appendix O, where the results of the questionnaire can be found in Appendix P. The questions were aimed to evaluate what the users thought of the look of the interface, what is expected from certain functions or buttons, as well as seeing whether the interface is self-explanatory enough.

6.1 INTERPRETATIONS AND EXPECTATIONS

A series of questions were about the functionality the user expected to see behind certain buttons, as well as how some of the placeholders and icons were interpreted. This was asked before the user could interact with the interface in a web application provided by Adobe XD. The expectations behind the first menu item were very accurate, being that it provides an overview of the shopfloor in the shape of various graphs. The first menu item was thus very well understood. The second menu item, being the product overview, was very poorly understood. Expectations ranged from that this menu-item would provide the user with an insight into a specific machine, to stock availability. The third menu item was not understood well either, but the only two things that were expected is that this menu would either provide the user with an overview of maintenance activities or settings. However, as this interface will most likely have a settings button somewhere in a future version, it is expected that this confusion will disappear once that has been implemented.

The content of the overview menu was received well. The content of the product menu was liked as far as was developed, as “The image of the product makes it very clear what the product is at the glimpse of an eye”, as was mentioned by one of the participants. Lasty the button in the top left corner to toggle live data, of which the imagined functionality is that it would show the user what machines are working at the moment, as well as having AGVs driving around the virtual shopfloor based on their actual location. This was also a well understood feature, as the majority of the participants understood the feature as intended. A couple of participants interpreted it differently, thinking it would provide a provide the user with a camera feed of the shopfloor.

6.2 USABILITY

In order to evaluate on the usability of the prototype, a series of questions were formulated about the usability of the tool in the questionnaire. The first of which being whether the very core of the concept was conveyed in an effective way to the user, being that the machines are coloured depending on their status. From the answers of the questionnaire, this was conveyed well and in such a way that the participants thought that the colours of the machines were meant to show the status of the machines.

Another point of usability was whether this style of interface actually suits within FPC, which mostly received negative answers. How the interface is built up with its various icons, as well as the modern style that was chosen does fit FPC. However, as multiple participants said, the interface lacks the branding of FPC. This would be implementing the logo of FPC in the interface. What would also help to make this more in the style of FPC would be to use fonts that are often used within FPC. Also, the accent colour of green could possibly be implemented as an accent colour, as that is the colour of FPC.

The user interaction when trying to view historical data of a parameter of a machine was not good. This was a feature that was often not found out. This can be linked to the fact that when the user mouses over a parameter of a machine name, the background nor text changes colour, shape, or size. The only thing that would change would be that the mouse cursor would turn into a hand cursor. Neither do the parameters look “clickable”, which could be done by putting an option button, radio button, or checkbox in front of the parameter, which would make the user think that this is something that can be selected. Once a parameter has been selected, a graph shows up to show this historical data. A significant number of participants said that they would want to drag this graph to another place on the interface. The fact that this was considered when the interface was designed is a good sign, as this shows that the desire is there to essentially customize the layout of the screen.

6.3 LIMITATIONS

There was a number of limitations within Adobe XD that are worth mentioning. A number of times throughout the design process, a desire was expressed by both client and designer to have moving images in the design. However, this could not be easily realized within Adobe XD, which made it so that it became a much lower priority, and therefore never executed. It was found to be possible, but the difficulty of getting this plugin to work well with the design already developed, and therefore the idea of implementing moving images was scrapped. This required the redesign of many already developed elements in Adobe XD to suit the format that the plugin requires and was thus found to be not worth it. Further limitations found within the software was found in the shape of not being able to have a number of interactions that were desired by the client. All of these

interactions came down to the same thing, which was being able to drag a screen around the interface, and thus place this screen wherever the user would want in the interface.

Another limitation of this design is that due to the way interactions and hitboxes work within this software product, a lot of hitbox related bugs were introduced. This would for example be the case that a machine could be selected by clicking in the correct place on another machine or on the side-menu. The fact that these bugs were present could have affected the user tests performed during the evaluation steps of the various iterations, as well as the questionnaire.

Adobe XD also does not allow for importing 3D-objects in the design. This made it so that all of the machine visualisations that were implemented in the end were based off of a render made within 3D modelling software. A desire was also expressed early on in the design phase that a desirable feature would be to change the perspective of the shopfloor. However, this could not be realized through this.

The current situation with the coronavirus pandemic also resulted in a couple of limitations. The first of which being that design evaluations were harder to do, as this all had to happen online. This was especially a problem for the first two prototypes, where it was hard to present to the client what I wanted. Instead, a lot of time was spent on digitalizing the first prototypes and finding out a setup which would allow for small on-the-fly adjustments. Due to the fact that evaluations were done online, user testing was very hard to do and was therefore hardly tested. Another limitation due to the coronavirus was that there was no possibility to test the interface that was designed on a large touch screen, as that would be one of the use cases. This also meant that no designing was done on a large screen, as that was not available.

Lastly, the questionnaire received a low number of responses. This was expected, but the fact that only eight people filled in the questionnaire means that no reliable conclusions can be drawn from the questionnaire and can only provide estimates of those conclusions.

6.4 Discussion

The final design of this product is of course not without its flaws, mistakes, and imperfections. As a first, the user experience is quite poor. It was very difficult to develop the user experience in any meaningful way due to the coronavirus pandemic. All evaluations of prototypes were done online, which makes it difficult to evaluate the user experience. The lack of user experience development is especially present in the machine information screen and the overview screen. Another point of improvement is that there is a lack of branding present in the interface. As this is a product that is owned and produced for FPC, with the requirements found out together with FPC implemented, it should also reflect that it is a product of FPC.

The results that were obtained from the questionnaire were all from FPC employees. All of these people are people that have a connection to the manufacturing industry, and it could therefore be argued that it this interface design is more intuitive for them. Some users of this interface will be clients and visitors of the AMC, who might not know a lot about the manufacturing industry, to which this interface could very well not be intuitive to use. This means that the results from the questionnaire are biased towards people that have some connection to the manufacturing industry.

It can also be argued that the generalist approach that is taken throughout this project was the wrong way to about it in the first place. As there are three main users, which are management, client and visitors, and

engineers, a separate interface design could be made for all of them. As this design combines all of the requirements of the different users, some compromises have to be made. For example, an engineer might not care about the visualisation of the shopfloor as much and would therefore prefer a two-dimensional grid-like visualisation of the machines. As the engineers do not have to be impressed with what FPC is capable of doing, excessively fancy visualisations are not needed when the engineer is the user.

7. CONCLUSION

The purpose of this project was to answer the research question "How can an interface be designed such that it shows the status of various machines around the shopfloor?" through the use of three sub-questions. These sub-questions were centred around what content to display, how to display this content, and how the user gets to this content.

First of all, what information to display in the interface. The main focus of the project is to display the status of the machines on te shopfloor, so naturally this comes first. Up next is the parameters of a machine, and historical data of those parameters. The list of parameters can be found in Appendix K that are used for this prototype. Historical data of the various parameters is represented in a line graph, as this provides the best insight into the data. Additionally, the physical location of the machines also has to be displayed to the user, as well as upcoming maintenance jobs, maintenance history for a specific machine, a register of when the machines has failed and why, and the capabilities of the machine. Other information that is to be displayed is which products the shopfloor is producing, as well as what the machines look like.

How to display was found out using an iterative design process. The status of the machines, the physical location of them, and how the machines look like are combined into a single design element in the interface. 3D-models have been made of the machines, which are then placed in the same way relative to each other as they are on the shopfloor. This combines the information of how they look like and the physical location on the shopfloor. The roofs of the machines are coloured to indicate the status they have, which is either red, orange, or green. This means broken down, has a warning, or is fully functional respectively.

A side-menu has been made where various pieces of information can be viewed. The menu where machine information can be viewed has at the very top identifiers of the machine, which are a 3D-model render of the machine, the manufacturer, model, as well as the function of the machine. One of the pieces of information that can be shown in this area is information about a specific machine. The machine parameters are placed in a list, and the parameters that are related are grouped together through the usage of differences in font sizes, as well as white spaces between the variables, as can be seen in Appendix L. Additionally, a button to a register of machine failures, maintenance information about that machine, as well as capabilities of the machine are displayed in this screen through the usage of buttons. These buttons take the user to another screen that displays the relevant information.

Collective maintenance information is placed in a separate side-menu. This menu displays all of the upcoming and historical maintenance jobs. The information that is seen without any further interaction is the manufacturer and model of the machine, as well as the date on which the maintenance job is performed. The products that are being produced by the shopfloor are presented in a similar way to the maintenance information, where a simple image of the product and the name of the product is seen in a list-like menu.

How the user should get to the content previously described has been done in such a way that a minimal number of clicks are required to access any information. As such, a machine can be selected during at any time, which will provide the user with the machine information screen. Historical data of the machine can be viewed by selecting a parameter of that machine, which will make a graph that partially overlaps with the parameters. To access other parameters the user might need to scroll through the list of parameters to select the one the user wants to, depending on where the parameter is positioned in the list.

8. RECOMMENDATIONS

As this is only the start of the development of an interface that allow the user to see what is going on in the AMC, a lot of work still has to be done. First of all, to replace all of the placeholder items with actual content. What this content will be, should be found out through elicitation with FPC. This means that further development will take place of the products menu, maintenance menu, as well as the content of the placeholder buttons in the machine information header.

Research should also be done to see whether it would not be better to use separate interfaces for the different users. As the range of users is very large, it is possible that more effective designs can be made by developing separate interfaces for the different users. However, it could be possible that engineers and management use the same interface, whereas the clients and visitors will get a different design interface. The fact that outsiders will be using the same interface as the people working in the company might bring privacy or transparency related issues with it.

Further design development should also be done to improve the user experience. As this was hardly possible due to the coronavirus pandemic during the development of this interface, it is likely that a lot of the interface needs changing to improve the user experience. Things that should be taken a look at especially are the interaction that non-expert of the manufacturing industry have with this interface. Since some of the users of this interface will be non-experts of the manufacturing industry, it is important that those users also find this interface to be self-explanatory enough to use. Furthermore, the branding of FPC should be incorporated. As this is a product of FPC, their branding should be used as well. This can be in the shape of their logo or through incorporating the colour palette of FPC.

Lastly, more technical development should take place. The back end would have to be developed for this interface. Research would have to be done when a machine turns from a fully functioning ‘green’ to a poorly functioning ‘orange’ machine, as well as what the conditions are for a non-functioning and thus ‘red’ machine. Not only does the back end have to be developed for this interface, but as this is a prototype that is built in Adobe XD, the entire interface will also have to be built as a web-based application such that it can be connected to a database and back end.

APPENDIX

APPENDIX A

Brainstorm Ideas

Figure 33. The hand-written brainstorm about ideas for the project

APPENDIX B

Detailed view of the side-menu

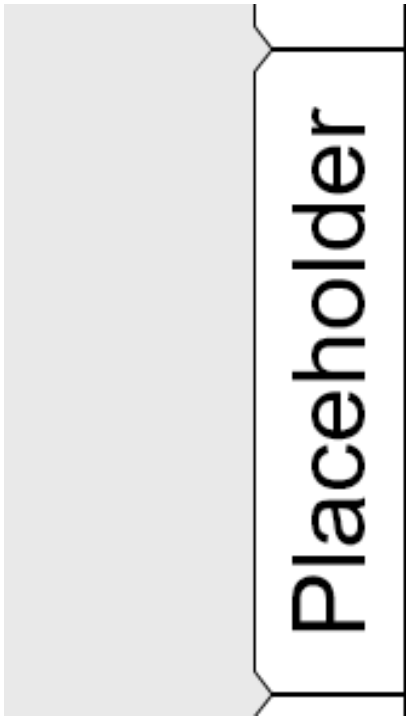
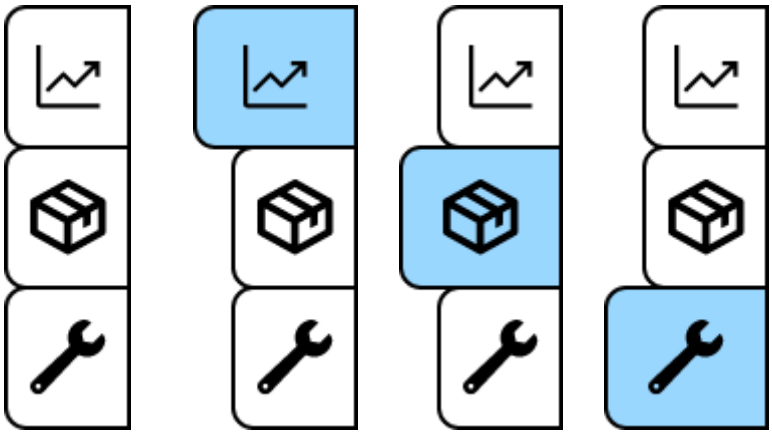


Figure 34. A zoomed-in image of the side menu on the second prototype of the second iteration

APPENDIX C

Side Menu Buttons



(a) (b) (c) (d)

Figure 35. The side menu button as of the third iteration where (a) has nothing selected, (b) has overview selected, (c) has product selected, and (d) has maintenance selected

APPENDIX D

Live Data Button

(b)

(b)

Figure 36. The live data button used where (a) has the button turned on and (b) has the button turned off

APPENDIX E

List of Potential Equipment

Manufacturer	Model	Link
Additive Industries	MetalFab 1	Metalfab1
Makino	D500	D500
Trumpf	TruLaser Cell 5030	TruLaser
ABB	3DIQ	3DQI
ABB	FlexArc 500B	FlexArc 500B
Schuler	MSC-2000	
Trumpf	TruBend Cell 7000	TruBend 7000
Everising	Column Type H-5550	H-5550
AIXEMTEC	XT-FAS 500	XT-FAS 500
Delta	LC 500 Rotary Table Surface Grinding Machine With Vertical Spindle	LC-500

APPENDIX F

Machine Rework Drawings

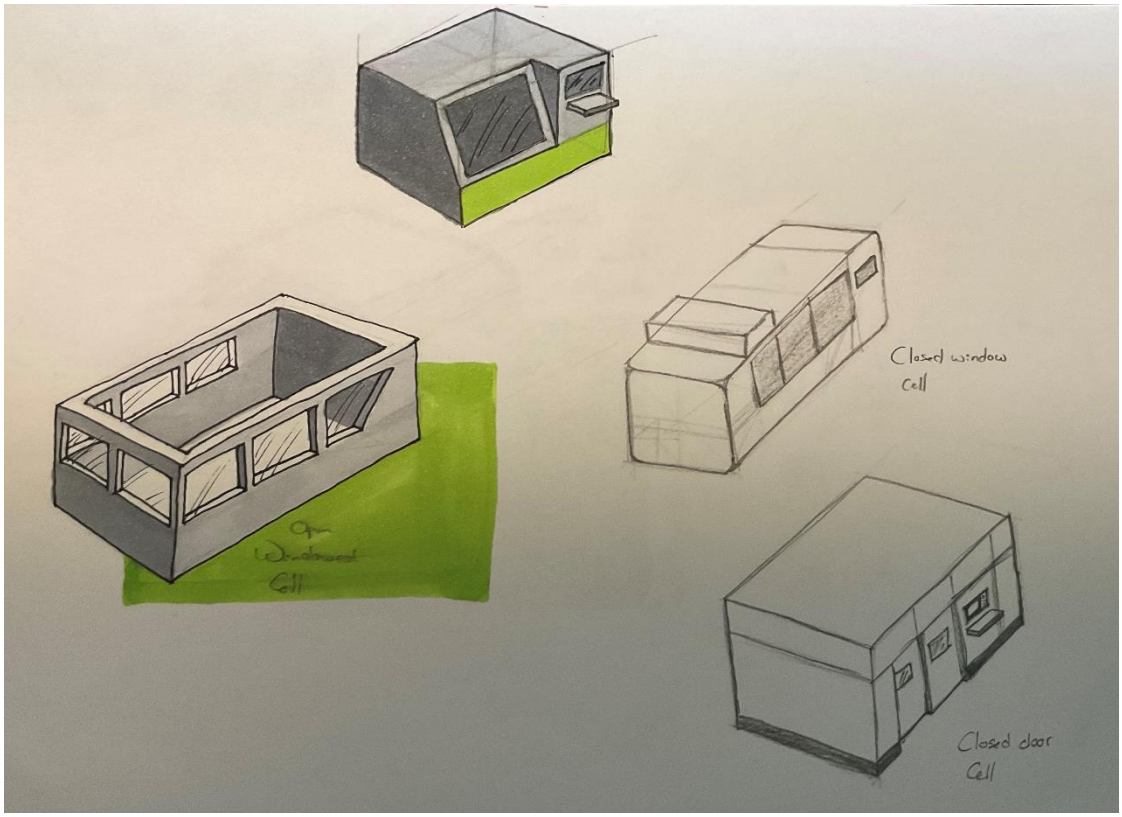


Figure 37. The first page of drawings for reworking the way the machines are visualized of the fourth iteration

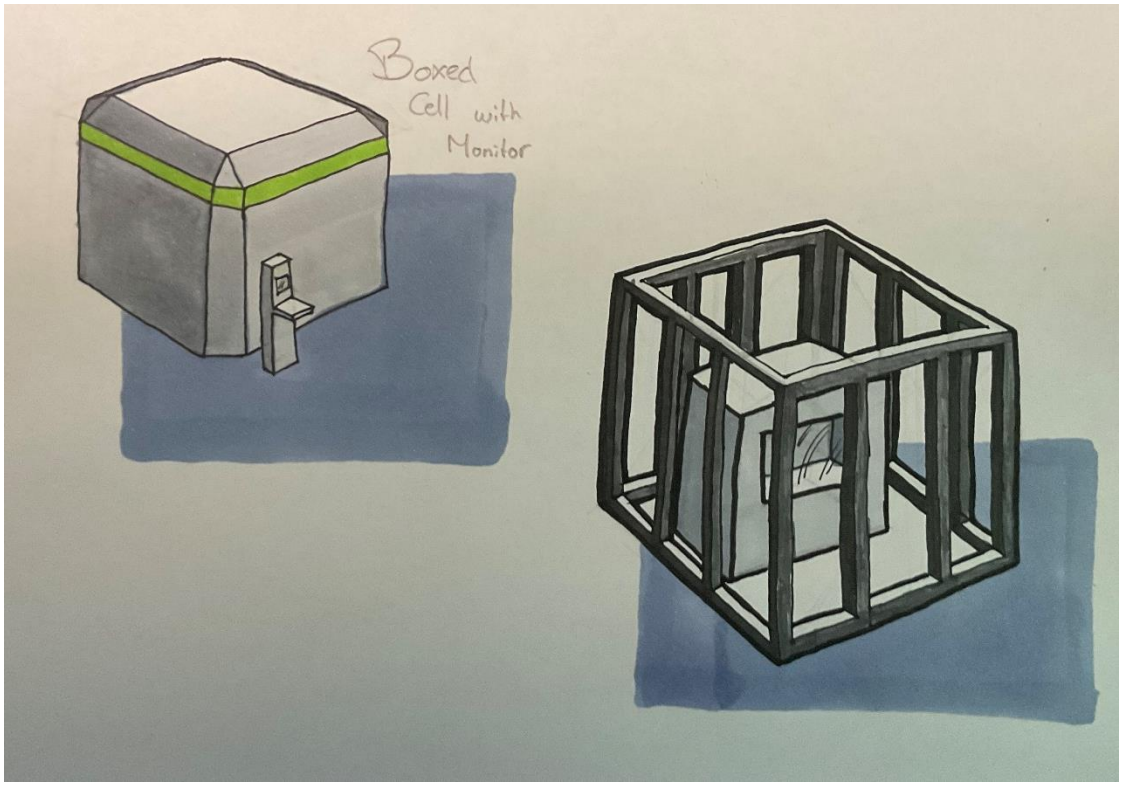


Figure 38. The second page of drawings for reworking the way the machines are visualized of the fourth iteration

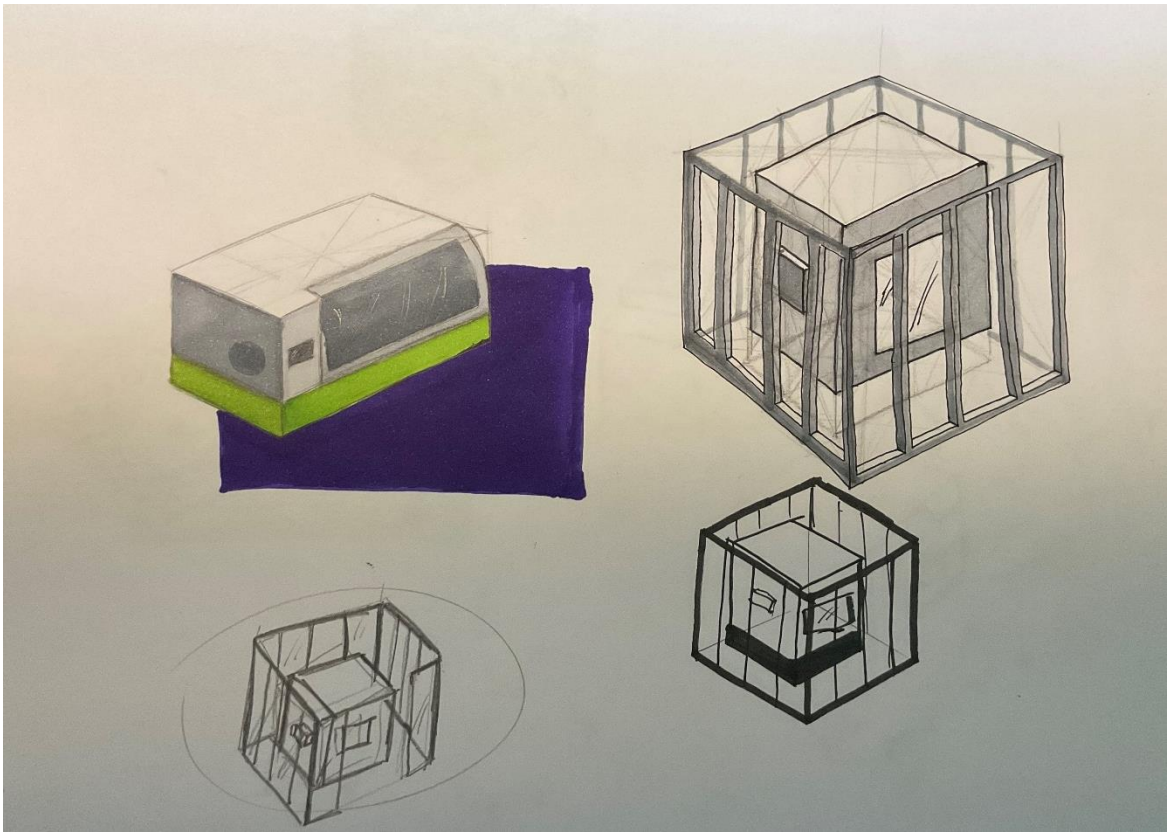


Figure 39. The third page of drawings for reworking the way the machines are visualized of the fourth iteration

APPENDIX G

Machine Rework 3D Models

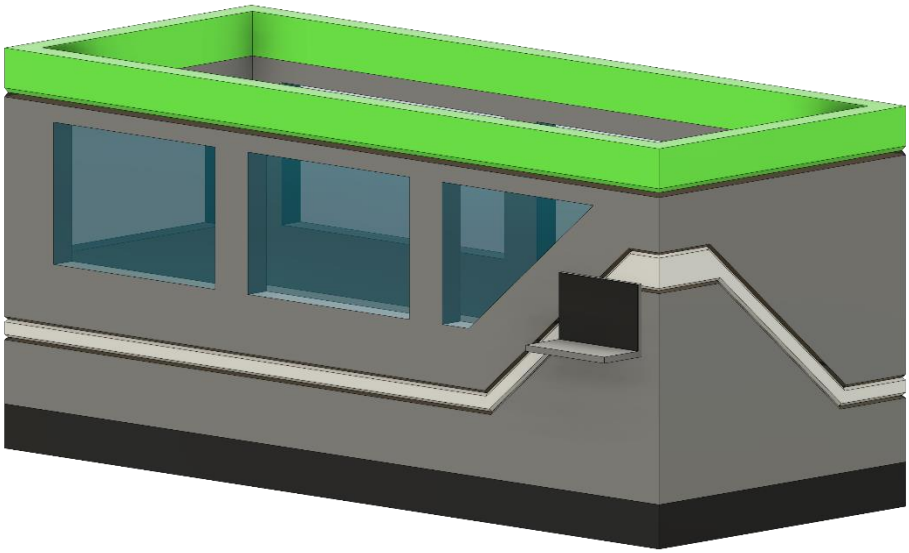


Figure 40. The 3D model of the bending machine

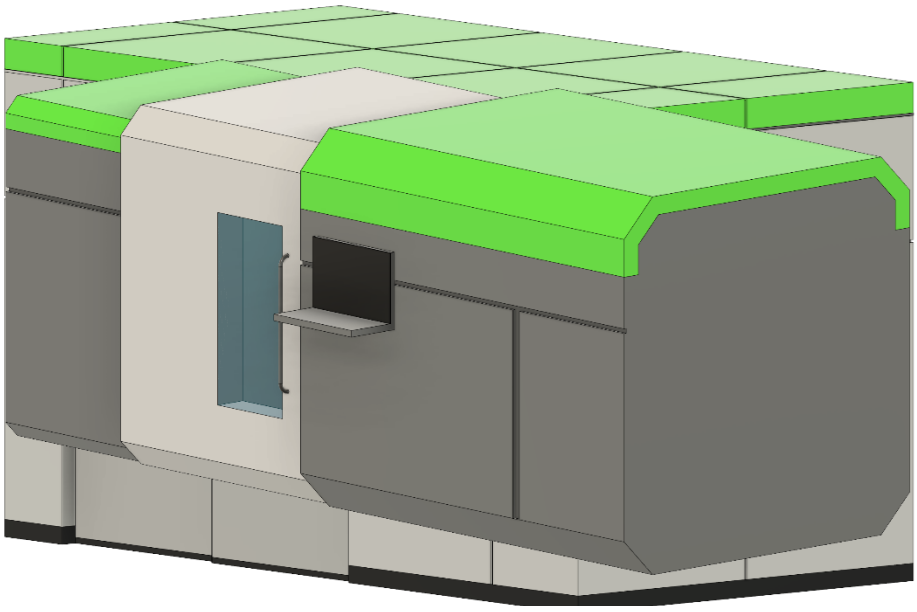
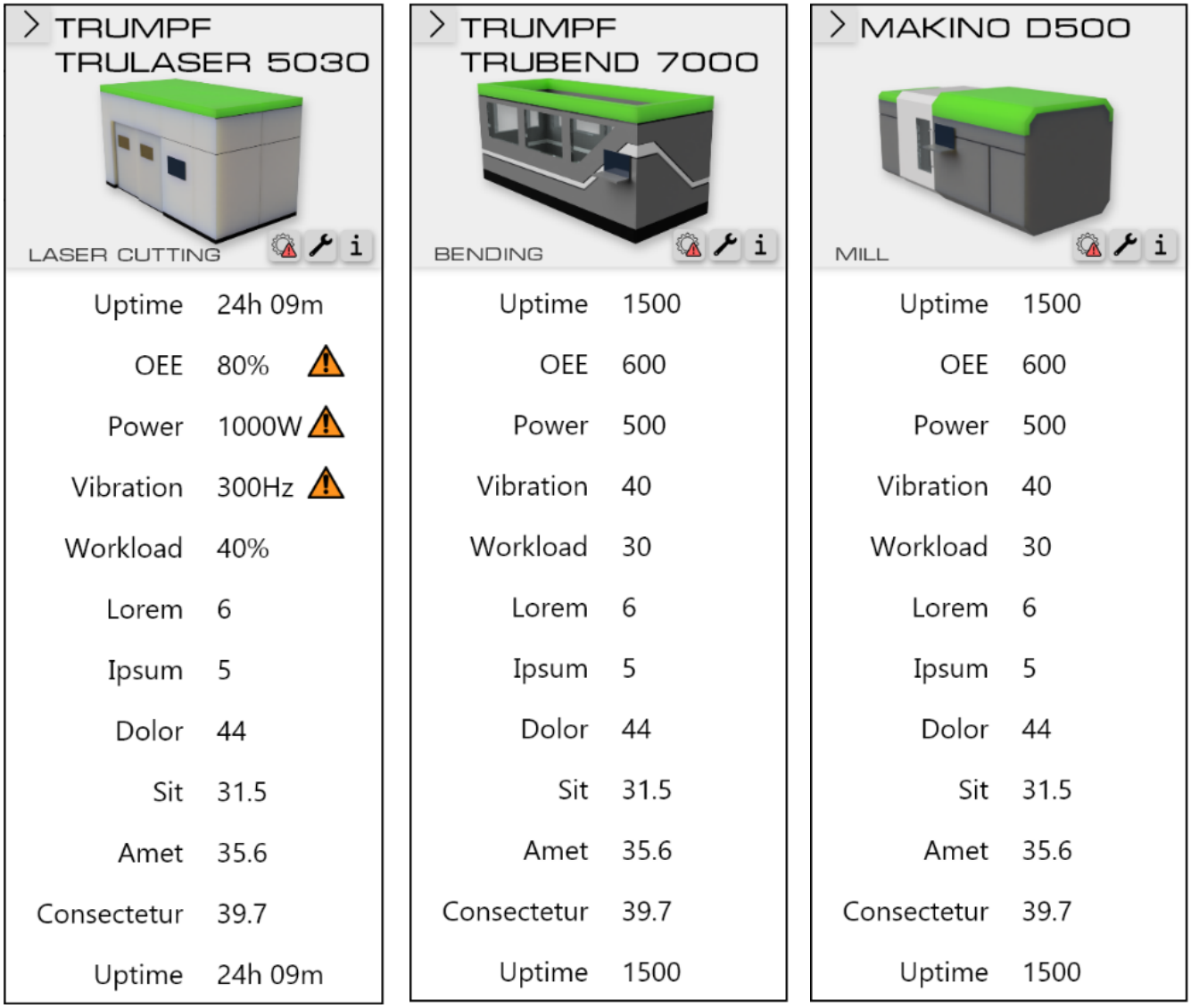


Figure 42. The 3D model of the milling machine

APPENDIX H

Rework of Machine Information Screen



(c) *(c)* *(c)*

Figure 43. Rework of the machine information menu where (a) shows information about a machine with a warning, and (b) and (c) show information about a functioning machine

APPENDIX I

Overview Tab Rework

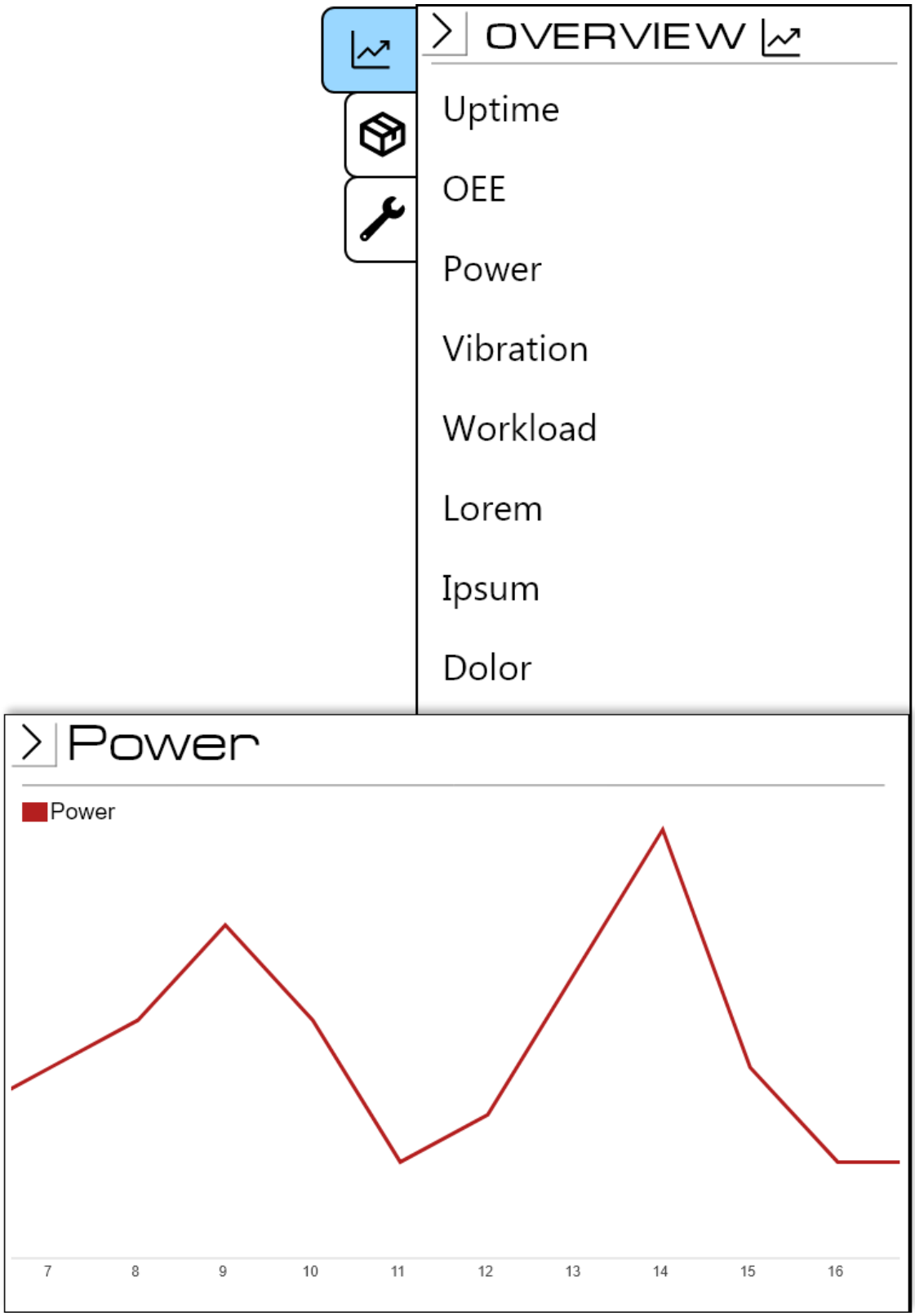


Figure 44. The rework of the overview tab as of the fourth iteration

APPENDIX J

Maintenance Tab Rework

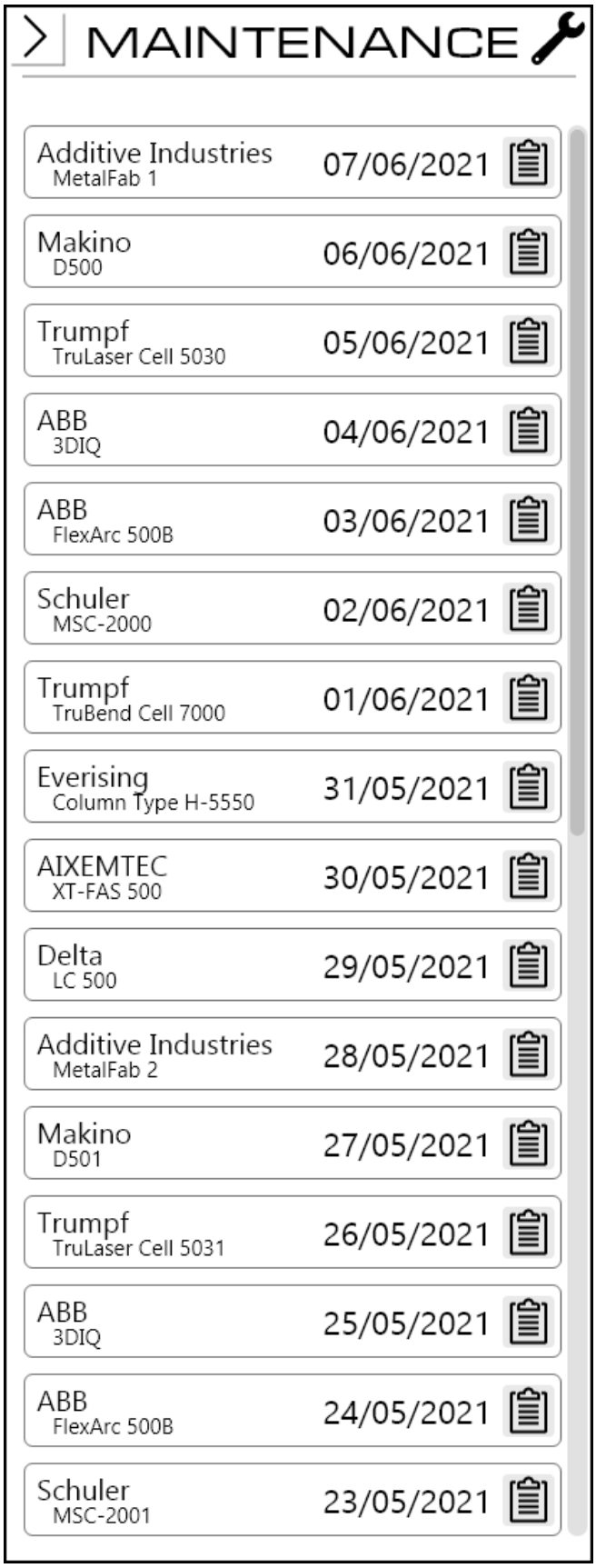


Figure 45. The maintenance tab as of the fourth iteration

APPENDIX K

Parameter Table

Parameter	Unit
Part being worked on	-
Material	-
Maintenance interval	days
Power	W
Voltage	V
Amperage	A
Oxygen	L/s
Air	L/s
Nitrogen	L/s
Water	L/s
Oil	L/s
Coolant	L/s

Table 1. Parameters to be added to the machine information screen

APPENDIX L

Finalized Machine Information Screen

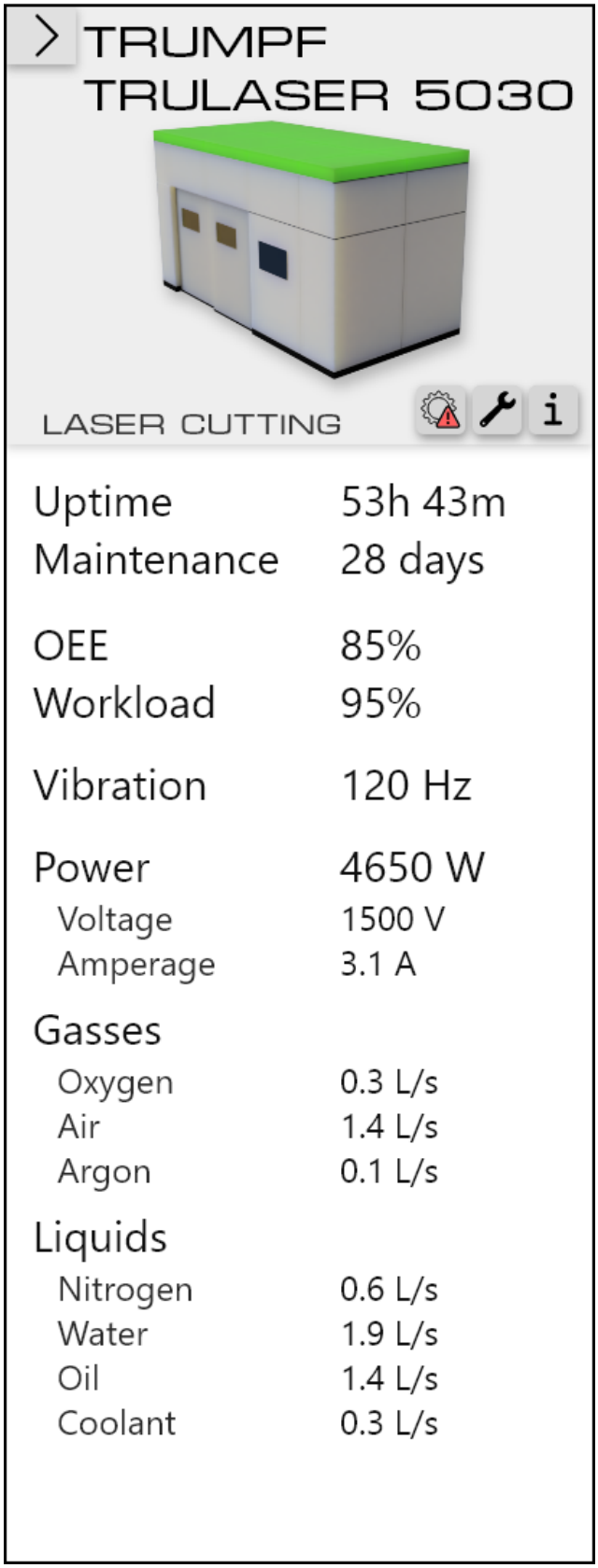


Figure 46. The finalized machine information screen

APPENDIX M

Finalized Product Menu

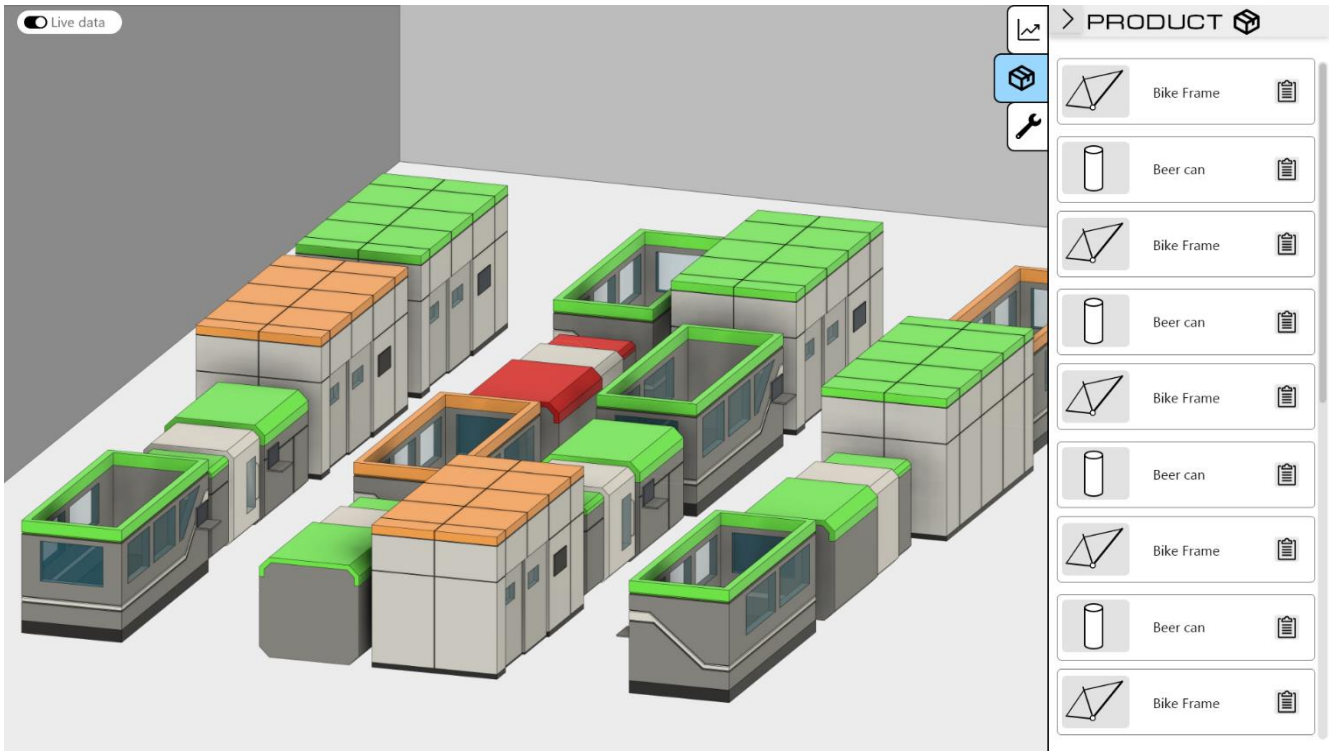


Figure 47.

The finalized product menu with a prototypical fill-in for the menu

APPENDIX N

Finalized Overview Menu

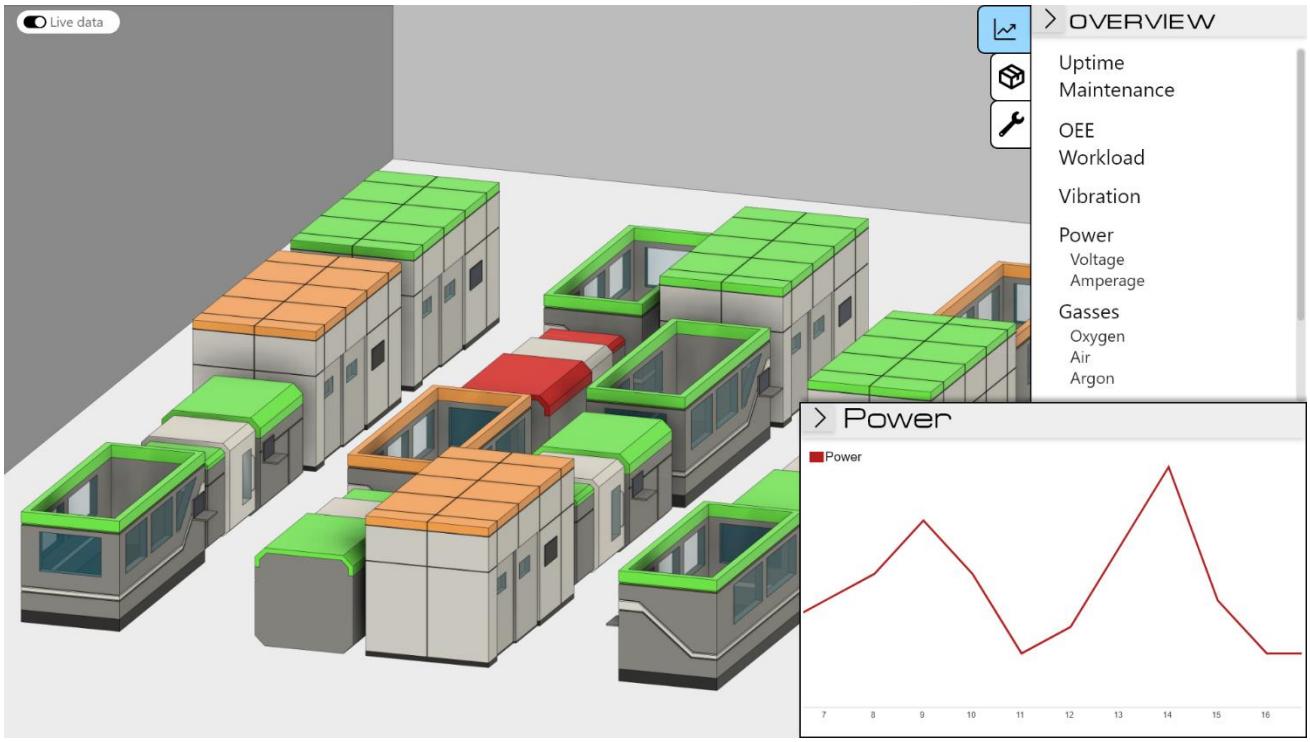


Figure 48. The finalized overview menu

APPENDIX O

Questionnaire

Information

Hello everyone filling in this questionnaire!

I am Wouter Koning, and I am nearing the end of my graduation project of my Bachelor Creative Technology for AMC. For my graduation project, I have been developing an interface to display the status of the machines that will be present on the matrix production shopfloor, in addition to a couple of extra features.

For this questionnaire I have a series of questions for you, all of which will be about the design and expected use of the interface. This questionnaire is made to evaluate upon my work, as well as provide a better list of recommendations towards AMC regarding this design. This questionnaire is not compulsory to fill in and is entirely voluntary to fill in.

No names or personal information that will be able to be linked to an individual will be asked. All of the data that is collected will be deleted after the graduation project has been finished.

If you have any questions, email me at w.l.koning@student.utwente.nl.

1. I understand and I want to participate in the questionnaire! *

Mark only one oval.

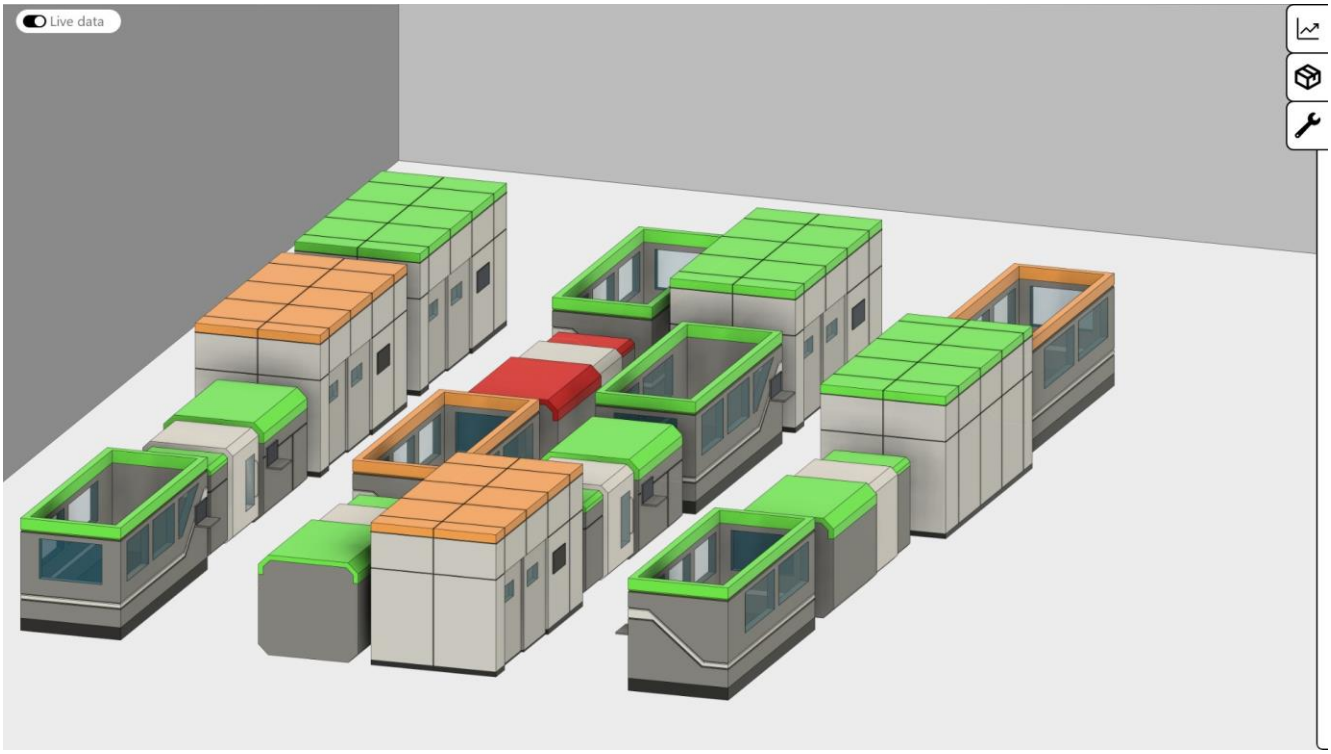
◯ Yes, I understand what I have read above and I would like to fill in the questionnaire!

Questionnaire

Thank you for participating in this questionnaire! A link will be provided whenever it is necessary to be interact with the interface.

Introduction

Below, a picture of the starting screen can be found of the starting screen of the interface.



2. A button stating "live data" is shown in the top left corner. What do you think this button does? Leave blank in case you do not know.

3. The machines that are represented in this interface all have a colour. What do youthink that this colour means? Leave blank in case you do not know.

Menu

The following questions are about the menu that can be found on the right side of the interface.

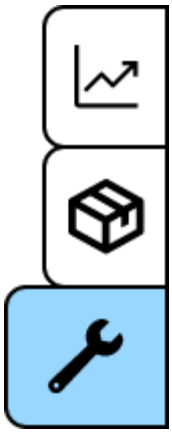
4. On the top right, a menu can be found, that can also be found below. If you click on this menu, what menu do you imagine to get? If you don't know, answer "no" *

5. What will you be able to see in this menu? Leave blank in case you do not know.

6. On the top right, a menu can be found, that can also be found below. What menudo you think this will bring you to? If you don't know, answer "no" *

7. What will you be able to see in this menu? Leave blank in case you do not know.

8. On the top right, a menu can be found, that can also be found below. What menudo you think this will bring you to? If you don't know, answer "no" *



9. What will you be able to see in this menu? Leave blank in case you do not know.

Interaction

Link to the interface!

It is finally time to interact with what I have produced. To be able to see what I have produced and interact with it, click the following link. Please interact with it for a minute, and try to seek out its features. After you have done that, please continue with the questions.

https://xd.adobe.com/view/80675d9a-6889-49fe-aa5e-0012660bc6c8-d534/?fullscreen&hints=off

This link will be provided plenty throughout this questionnaire, so do not worry about accidentally clicking away the tab.

10. I feel like I have interacted enough with the interface and I am ready to answer

questions about this interface. *

Mark only one oval.

Yes, I have interacted with the interface

Disclaimer

This is a prototype, therefor numbers might not represent reality. This interface is designed to provide the foundation for a tool that would use actual data to display the status of machines. Keep this in mind while interacting with the interface.

11. I understand that this is a prototype, and might not represent realistic figures. *

Mark only one oval.

Yes, I understand this is prototype that might not represent realistic figures.

12. Anything you would like to get off your chest before we continue with the questions regarding the interface or this questionnaire?

Machines

Link to the interface:

https://xd.adobe.com/view/80675d9a-6889-49fe-aa5e-0012660bc6c8-d534/? fullscreen&hints=off

This link will be provided plenty throughout this questionnaire, so do not worry about accidentally clicking away the tab.

13. When you select a machine, was it clear what machine has been selected? *

Mark only one oval.

- [ ] Yes No
- [ ] Other:
- [ ] _____

14. When a machine has been selected, the menu on the side expands. Did you find out that you could see historical data of machine parameter before reading this question? *

Mark only one oval.

- [ ] Yes
- [ ] No

If you have not found the graph

If you have not found a graph, please go back to the interface and select a machine parameter to make the graph appear.

15. Would you want to drag this window to another place on the interface? *

Mark only one oval.

- [ ] Yes
- [ ] No
- [ ] Other: _____

16. Anything else you would like to say about this part of the interface?

_____

Side-menu items

Link to the interface:

https://xd.adobe.com/view/80675d9a-6889-49fe-aa5e-0012660bc6c8-d534/?fullscreen&hints=off

First menu item

The following questions will be about the first menu item called "Overview".

17. The goal of this menu is to provide the user with a global overview of the shopfloor. Was this clear before reading this question? *

Mark only one oval.

- Yes No
- Other: _____

18. Do you have any other comments about the "Overview" menu?

_____

Second menu item

The following questions are about the second menu item called "Products".

This menu describes all of the products that are being produced on the shopfloor. This menu is largely aplaceholder, as this fell outside of the scope of the project. However, this is a great item for recommendations for future work.

19. In this menu, a button is placed with a clipboard icon. What information do youexpect to see behind this placeholder? *

_____

20. Do you have any other comments about the "Product" menu?

_____

Third menu item

The following questions are about the third menu item called "Maintenance".

21. Information about the machine (manufacturer and model) as well as a date is shown for every maintenence order. What other information would you like tosee at the blink of an eye? *

Mark only one oval.

- None
- Other: _____

22. In this menu, a button is placed with a clipboard icon. What information do youexpect to see behind this placeholder?

_____

23. Do you have any other comments about the "Maintenance" menu?

_____

General Questions

Link to the interface:

https://xd.adobe.com/view/80675d9a-6889-49fe-aa5e-0012660bc6c8-d534/?fullscreen&hints=off

24. Do you think the style of interface suits FPC? *

Mark only one oval.

- Yes
- No

25. Elaborate on your previous answer *

_____

26. Did you want to have certain information displayed that was not displayed in this interface? Leave blank if the answer is no

27. Now that we have looked through every menu, would you use this interface for monitoring the status of machines and troubleshooting their problems? *

Mark only one oval.

- Yes No
- Other:

Thank you!

You have directly contributed to quality of my thesis by filling in this questionnaire!

28. Would you like to receive further updates about this graduation project?

Check all that apply.

- Yes, I am interested in the thesis
- Yes, I am interested in the grade you receive
- Yes, I would like to attend the presentation (there is uncertainty about how manypeople can be invited)

29. If you answered yes to the above question, mention your email-adress so I cansend you the relevant information

APPENDIX P

Results of Questionnaire

A button stating "live data" is shown in the top left corner. What do you think this button does? Leave blank in case you do not know.

Realtime status of the machines

Update the model with live data coming from the field. For e.g. If there are moving objects like AGVs, the model will be updated with its location data and change the AGV to its current position.

Provides live feedback from Camera in the shopfloor

If activated, it shows the machineries that are connected to network and from which, perhaps, it is possible to show/extract live data on their status.

Turn on the live data

Display the live camera feed connected to actual shop floor

Show the current status of the machines.

That data on the machines is being updated live

The machines that are represented in this interface all have a colour. What do you think that this colour means? Leave blank in case you do not know.

It should indicate the status of the machines but this is not how is done in production interfaces

Showing the status of the units for e.g. green is in operation currently, Orange is in idle state and red has an alarm or error.

Categorizing machines based on common function

The type of rules/risks associated to that category of machines.

green: active, orange; waiting; red; erro

Depicting machines contains common functionality or do generate identical product output.

Green: good operation condition, Orange: Might be something at stake, Red: Error/Downtime

how efficient they are running/uptime on the machine

On the top right, a menu can be found, that can also be found below. If you click on this menu, what menu do you imagine to get? If you don't know, answer "no"

Report

Showing data analytics tool.

No

Current status

graphs

Status of process

Trend of the status of the machinery over time

a dashboard with data representations

What will you be able to see in this menu? Leave blank in case you do not know.

Report around the status of the machines

Plot various parameter graphs / data analytics of the shop floor for e.g. machine utilization throughout the year or energy consumption etc.

Busy, not busy. Current data from the running processes (e.g. is 50% of a running 3D print job done? How long will it take to be completed? Current number of layer?). Specific and total energy/gas/water consumptions.

graphs and statistics of the flow of the process

Overview table or chart containing information about the status of all the machines and job progress

Graphs (vibration, pressure, temperature, ...)

production data

On the top right, a menu can be found, that can also be found below. What menu do you think this will bring you to? If you don't know, answer "no"

Packeging or product

View toolbox.

Machine status

Data transferring

storage

Specific Machine

Product information

no

What will you be able to see in this menu? Leave blank in case you do not know.

Info about the product or packege

Different viewing options such as from different angle and different zoom levels. We can perhaps also switch from the complete shop floor to one manufacturing cell.

Which machines in the workfloor is being used and which ones are idle

Data to send and contacts.

how much stock there is avaialble

Current status and operation for a specific machine

Information about the products/processes that are made/performed by the machines.

On the top right, a menu can be found, that can also be found below. What menu do you think this will bring you to? If you don't know, answer "no"

Mentinance

Settings

Settings

Settings

maintenacne

Settings

Maintenance activities

system settings

What will you be able to see in this menu? Leave blank in case you do not know.

Info about the machines under mentainence

Possibility to change some settings of the model such as color schemes, font size etc.

Specific settings (e.g. what process parameters are being used by the 3D printer while it is working? Laser power/speed? Chamber/Baseplate temperature? etc.)

if there are maintenance actions coming up

Settings for machine operations

Maintenance schedule

settings for the application like ui color

Anything you would like to get off your chest before we continue with the questions regarding the interface or this questionnaire?

Why i can not see the shopfloor from diffrent views or even interact with it

Compared to my initial guess, this is better. I like the structure of the menu. Nevertheless, I still wish to see data transferring capabilities (e.g. being able to produce and send reports)

It looks very good (better than other MES interfaces I have seen)

so far everything is very generic and high level.

When you select a machine, was it clear what machine has been selected?

No

Yes

Yes

Yes

Yes

Yes

Yes

No

When a machine has been selected, the menu on the side expands. Did you find out that you could see historical data of machine parameter before reading this question?

Yes

No

No

No

Yes

Yes

Yes

Yes

Would you want to drag this window to another place on the interface?

Yes

No

No

Yes

Yes

No

Yes

just make it a bit more energy dense and smaller

Anything else you would like to say about this part of the interface?

Higlight the problem if there is one in the reports interface. It should be clear very fast for the user what is good and what is wrong.

it loads quite slowly,

Would be nice to actually see it change. It is now a static graph to which no data is being added.

The goal of this menu is to provide the user with a global overview of the shopfloor. Was this clear before reading this question?

No

Yes

Yes

Yes

Yes

Yes

Yes

No

Do you have any other comments about the "Overview" menu?

Change the icon

I did not find out what does live data do.

No

1. Icon next to the word "OVERVIEW" is missing.
2. Perhaps Temperature can be displayed as a variable as well.

data items are unclear what they relate to

In this menu, a button is placed with a clipboard icon. What information do you expect to see behind this placeholder?

Detail info about the specific machine

perhaps the status of the product in the shop floor for e.g. currently the product is on which machine.

The status of the production process , parameters used , machine used , time left to be manufactured

A report of the product (e.g. production time, cost, purpose/customer, needed post-processing operations, handling operations, a specific code/number, etc.)

resource requirements, amount of hours needed to be produced, capacity required, drawings

Product specifications and requirements

Subitems/parts

a todo list for service/maintenance

Do you have any other comments about the "Product" menu?

Change the icon it reminds of packeging also

No.

No

The image of the product makes clear what it is in a glimpse of an eye.

I can't see in what stage the product is in the production line so it tells me very little about the actual state of the system

Information about the machine (manufacturer and model) as well as a date is shown for every maintenence order. What other information would you like to see at the blink of an eye?

Reason for mentainance date when it had defect and vendor for the parts, status when the parts were replaced etc

its good

Due date for maintenance

A red/orange/green color scale (based on the level of importance of that specific action) that tells you if maintenance is required according to each machine's schedule.

efficiency

None

Next time till maintenance.

last and next moment of maintenance, current efficiency

Do you have any other comments about the "Maintenance" menu?

No

No

It would be nice to see when the next maintenance activities are planned.

In this menu, a button is placed with a clipboard icon. What information do you expect to see behind this placeholder?

Detail info about the specific mentaiance report

The maintenance history (planned and unplanned), the information regarding regular maintenance such as oil change/filters etc. the sensors that need to be monitored for certain predictive maintenance (or the live data from those sensors can also be good).

Due date , maitenace schedule , in charge for maintenance

Who did the maintenance, type (e.g. 3 levels: urgent/important/attention, expected or not) details on that operation (what and for how long), if and when a similar action is to be repeated, special comments

the software running, resource usage, task it is performing

Specification on the machines

Log of the maintenance activities.

Do you think the style of interface suits FPC?

No

No

Yes

Yes

No

No

Yes

No

Elaborate on your previous answer

Use the FPC colours we have a specific colour pallet / add the logo

We have a certain color theme and branding. It doesn't show that branding.

The style provide information on overall status of machines in the workfloor and it is easy to follow with a the minimalistic interface

The pure layout (lines, icons, how the machines look like) suits FPC style. Nevertheless, I would add some of the characteristic green color of FPC (or whatever it will be) to the gray background (both machine area and menu).

with the right font, and the actual logo somewhere it would beter suit

As the colors represented are in green, which can be closely approximated to depict FPC. Is there a possibility of improving color ?

Elegant yet simple. It really gives you a feeling of digitalization of a shopfloor. And it is way nicer to look at over the current MES interfaces that are being used.

To me it matches on almost none of the stylistic aspects....

Did you want to have certain information displayed that was not displayed in this interface? Leave blank if the answer is no

Yes some icons indicating the status of the machines when they are selected

On the model there must be a time/date indication

Current version of the installed interface software :)

Timeline / Schedule of the products that are being made.

depends on what I need to do with this interface... If it is only for an overview then it's oke I guess

Now that we have looked through every menu, would you use this interface for monitoring the status of machines and troubleshooting their problems?

No

May be. Not so sure. I have to see the full model with live data coming in.

No

Yes

Yes

Yes

Yes

How would I ever use this interface to troubleshoot problems? It will only tell me (I presume) when a machine has an error.

REFERENCES

[1] S. Vaidya, P. Ambad and S. Bhosle, "Industry 4.0 - A Glimpse," in *International Conference on Materials Manufacturing and Design Engineering*, Beijing , 2018.

[2] M. Rüßmann, M. Lorenz, P. Gerbert, M. Waldner, P. Engel, M. Harnisch and J. Justus, "Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries," Boston Consulting Group, 2015.

[3] K. Martin, "A review by discussion of condition monitoring and fault diagnosis in machine tools," *International Journal of Machine Tools and Manufacture,* vol. 34, no. 4, pp. 527-551, 1993.

[4] A. Janes, A. Sillitti and G. Succi, "Effective Dashboard Design," *Cutter IT,* vol. 26, no. 1, pp. 17-24, 2013.

[5] H.-N. Dai, H. Wang, G. Xu, J. Wan and M. Imran, "Big Data analytics for Manufacturing Internet of Things: Opportunities, Challenges and Enabling Technologies," *Enterprise Information Systems,* vol. 14, no. 9-10, pp. 1279-1303, 2019.

[6] A. Lavalle, M. A. Teruel, A. Maté and J. Trujillo, "Fostering Sustainability through Visualization Techniques for Real-Time IoT Data: A Case Study based on Gas Turbines for Electricity Production," *Sensors,* vol. 20, no. 16, p. 4556, 2020.

[7] V. R. Basili, J. Heidrich, M. Lindvall, J. Münch, M. Regardie, D. Rombach, C. Seaman and A. Trendowicz, "Linking Software Development and Business Strategy Through Measurement," *Computer,* vol. 43, no. 4, pp. 57-65, 2010.

[8] A. Janes and G. Succi, "To pull or not to pull," in *Object-Oriented Programming, Systems, Languages & Applications*, Orlando, FL, 2009.

[9] C. Ware, Information Visualization 3rd Edition, Durham: Morgan Kaufmann, 2012.

[10] Y. Koren, X. Gu and W. Guo, "Reconfigerable Manufacturing Systems: Principles, Design and future trends," in *Frontiers of Mechanical Engineering*, 2017.

[11] M. C. May, S. Schmidt, A. Kuhnle, N. Stricker and G. Lanza, "Product Generation Module: Automated Production Planning for optimized workload and increased efficiency in Matrix," in *CIRP Global Web Conference – Flexible Mass Customisation*, Online, 2021.

[12] J. Zenger, J. Carr and E. Fogg, *How a Former Machinist is Seeking to Empower the Shop Floor: Machine Monitoring with MachineMetrics,* Making Chips, 2020.

[13] P. Greschkea, M. Schönemanna, S. Thiedea and C. Herrmanna, "Matrix structures for high volumes and flexibility in production systems," in *Variety Management in Manufacturing*, Windsor, 2014.

[14] M. Schönemann, C. Herrmann, P. Greschke and S. Thiede, "Simulation of matrix-structured manufacturing systems," *Journal of Manufacturing Systems,* vol. 37, no. 1, pp. 104-111, 2015.

[15] A. Hees and G. Reinhart, "Approach for production planning in reconfigurable manufacturing systems," in *Conference on Intelligent Computation in Manufacturing Engineering*, Capri, 2015.

[16] C. Cristea and M. Cristea, "KPIs for Operational Performance Assessment in Flexible," *Sustainability,* vol. 13, no. 6, p. 3498, 2021.

[17] M. Trstenjak and P. Cosic, "Process Planning in Industry 4.0 Environment," in *27th International Conference on Flexible Automation and Intelligent Manufacturing*, Modena, Italy, 2017.

[18] Y. Koren, S. J. Hu and T. W. Weber, "Impact of Manufacturing System Configuration on Performance," in *CIRP Annals*, 1998.

[19] W. Terkaj and M. Urgo, "A Virtual Factory Data Model as a support tool for the simulation of manufacturing systems," in *3rd CIRP Global Web Conference - Production Engineering Research*, 2015.

[20] F. Boschi, G. Tavola and M. Taisch, "A Description and Analysis Method for Reconfigurable Production Systems Based on Finite State Automaton," in *Service Orientation in Holonic and Multi-Agent Manufacturing*, Springer, Cham, 2017.

[21] A. Laemmle and S. Gust, "Automatic layout generation of robotic production cells in a 3D manufacturing simulation environment," in *Procedia CIRP*, Póvoa de Varzim, Portugal, 2019.

[22] Siemens, "Tecnomatrix," Siemens, [Online]. Available: https://www.plm.automation.siemens.com/global/en/products/tecnomatix/. [Accessed 16 04 2021].

[23] EMA IMK, "EMA IMK website," EMA IMK, [Online]. Available: https://imk-ema.com/ema-software-suite-en.html. [Accessed 04 16 2021].

[24] Visual Components, "Visual Components website," Visual Components, [Online]. Available: https://www.visualcomponents.com/. [Accessed 14 04 2021].

[25] Katana, "Katana website," Katana, [Online]. Available: https://katanamrp.com/. [Accessed 04 16 2021].

[26] Seiki Systems, "Seiki Software," Seiki Systems, [Online]. Available: https://www.seikisystems.co.uk/. [Accessed 16 04 2021].

[27] MachineMetrics, "MachineMetrics," MachineMetrics, [Online]. Available: https://www.machinemetrics.com/. [Accessed 16 04 2021].

[28] FreedomIoT, "FreedomIoT website," FreedomIoT, [Online]. Available: https://freedomiot.com/. [Accessed 04 16 2021].

[29] TeamViewer, "TeamViewer IoT website," TeamViewer, [Online]. Available: https://www.teamviewer.com/en/iot/. [Accessed 16 04 2021].

[30] Evocon, "Evocon website," Evocon, [Online]. Available: https://evocon.com/product/. [Accessed 04 16 2021].

[31] MaintainX, "MaintainX," MaintainX, [Online]. Available: getmaintainx.com. [Accessed 04 05 2021].

[32] The Asset Guardian, "TAG The Asset Guardian," The Asset Guardian, [Online]. Available: https://theassetguardian.com/. [Accessed 04 05 2021].

[33] UpKeep, "UpKeep," UpKeep, [Online]. Available: https://www.onupkeep.com/. [Accessed 04 05 2021].

[34] Wats, "Wats," Wats, [Online]. Available: https://wats.com/. [Accessed 04 05 2021].

[35] Wube Software, "Factorio," Wube Software, [Online]. Available: https://www.factorio.com/. [Accessed 15 03 2021].

[36] J. Nielsen, "Iterative user-interface design," *Computer,* vol. 26, no. 11, pp. 32-41, 1993.

[37] Agile Business, "Chapter 10: MoSCoW Prioritisation," Agile Business, [Online]. Available: https://www.agilebusiness.org/page/ProjectFramework_10_MoSCoWPrioritisation. [Accessed 19 04 2021].

[38] S. A.K., S. J.R., W. B. and E. L.J., "Is there an artistry to lighting? The complexity of illuminating three-dimensional artworks.," *Psychology of Aesthetics, Creativity, and the Arts,* vol. 15, no. 1, pp. 20-27, 2021.

[39] Apple, "Color - Visual Design - iOS - Human Interface Guidelines," Apple, [Online]. Available: https://developer.apple.com/design/human-interface-guidelines/ios/visual-design/color/. [Accessed 23 5 2021].

[40] Trumpf, "TruLaser Cell 5030," Trumpf, [Online]. Available: https://www.trumpf.com/nl_NL/producten/machines-systemen/3d-lasersnijmachines/trulaser-cell-5030/. [Accessed 25 05 2021].

[41] Makino, "D500 | Makino," Makino, [Online]. Available: https://www.makino.com/en-us/machine-technology/machines/vertical-5-axis/d500. [Accessed 25 05 2021].

[42] Trumpf, "TruBend Cell 7000," Trumpf, [Online]. Available: https://www.trumpf.com/nl_NL/producten/machines-systemen/buigmachines/trubend-cell-7000/. [Accessed 25 05 2021].

[43] Autodesk, "Fusion 360," Autodesk, [Online]. Available: https://www.autodesk.eu/products/fusion-360/overview.

[44] Google, "Material Design - Using Material Theming," Google, [Online]. Available: https://material.io/design/material-theming/overview.html#material-theming. [Accessed 02 06 2021].