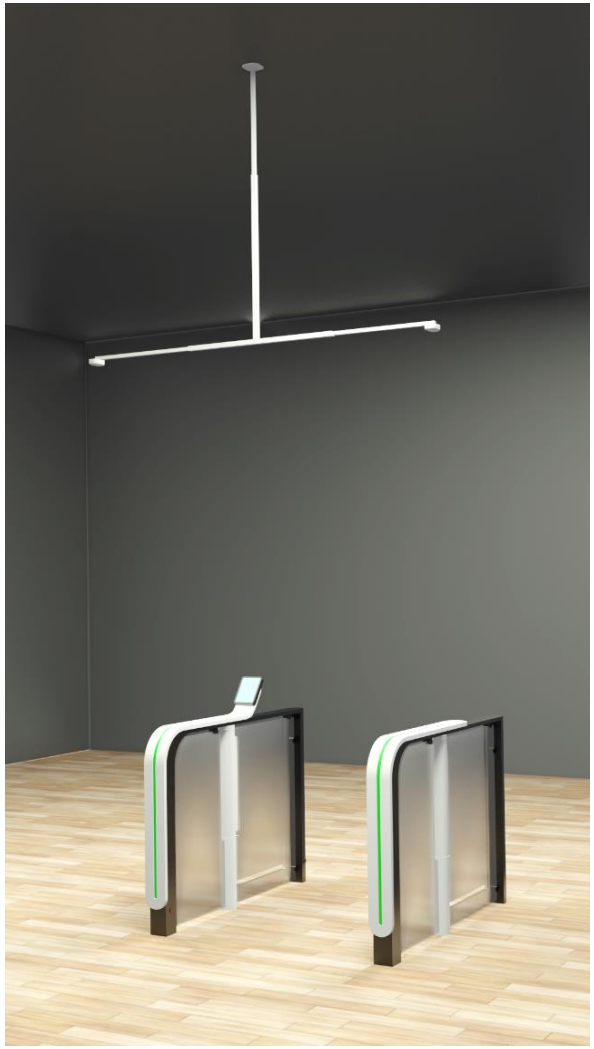
Creating seamless self-checkout areas in supermarkets using automatic customer exit control

Graduation thesis



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Abbreviations

SCO	self-checkout
WOT	walk out technology
BLE	bluetooth low energy
RFID	radio frequency identification
NFC	near-field communication

Introduction

In this thesis the design procedure of a gate and payment tracking system is discussed. More specifically, an exit-gate is designed that is intended for self-checkout areas in supermarkets. To improve customer-friendliness, seamlessness, and ease of use a system is designed parallel to the gate. This system keeps track of who has paid and who has not so that they do not have to scan their receipt anymore before they can leave the self-checkout area.

In 'Introduction to assignment' it is explained who Pan Oston, the client, is. It is discussed why Pan Oston needs the aforementioned products to stay relevant in the retail market which is always rapidly evolving and looking for more convenience, seamlessness, and speed.

In chapter 1 'Analysis' a deep-dive is done into Pan Oston, what kind of functionalities the ideal gate would have and in how an auto-passthrough system would need to work to achieve optimal seamlessness and ease of use. Conclusions are mostly made based on interviews with Pan Oston employees, Pan Oston's partners' employees and self-checkout area hosts, and based on a questionnaire focussed on people's preferences regarding adoption of technologies in supermarkets.

In chapter 2 'Prototype & testing' the conclusions from chapter 1 that need testing are tested. This is done for both the gate and the auto-passthrough system. Based on these tests more conclusions and design decisions are made. This chapter also documents the prototype that was made and contains many videos that showcase its functionalities.

In the last chapter, chapter 3 'Final Design' the final design is showcased. For the gate it is explained why the design looks the way it does, why functionalities are located in the spots they are located at, whether the design is feasible and lastly how it is able to be customized. For the auto-passthrough system it is explained how the final design works and why it is feasible.

Summary

This thesis is result of an assignment set up by Pan Oston. Pan Oston is a company who makes steel product like checkouts and kiosks for the retail market. A sizable part of Pan Oston's revenue are checkouts and self-checkouts (SCOs). It is expected that in the future of retail these products are less relevant. This is why Pan Oston has requested the design of an improved gate that will be used in self-checkout areas and in future checkoutless stores. It is also requested to design a system that replaces the currently often used barcode scanner that automatically lets people pass the gate or block them.

A gate is designed that improves upon existing gates in terms of communication, seamlessness and ease-of-use. The goal of this gate is to make it easy and pleasant for customers to leave the SCO area while supporting the SCO host by giving him/her more control. By using animated green, orange and red lights that are intuitively integrated in the gate, communication between customer and gate is optimized. Sounds are played in case of a warning or an alarm. This gives customers extra hints on what is going on but most importantly alerts the host and other store personnel of the gate's current situation so that they are always aware even if they are not looking. The gate can be customized if needed, which is one of Pan Oston specialties. In summary the gate improves upon its competing gates in communication, looks, focus on the host and theft-prevention.

For the auto-passthrough system Bluetooth Low Energy (BLE) is used. By attaching BLE signal emitter to the baskets and carts and by placing BLE signal receivers at the SCOs and gate we can keep track of who has paid and who has not and let them leave or block the accordingly. BLE is used because the system will be applied in existing and future supermarkets that use SCO areas. These are supermarkets people are often dependent on so we cannot use biometric technology like face recognition, even though these technologies are incredibly powerful. Because not all customers will like being a part of these technologies, they simply cannot be applied in these stores. The flip side is that it is now mandatory to use a basket or cart and no more than 1 basket or cart is allowed per group that shops together.

A video summarizing the results of the project can be found by clicking here.

Introduction to the assignment

About Pan Oston

Pan Oston is a designer, producer, consultor and installer of retail hardware. Pan Oston is an international company with a factory in the Netherlands, Slovakia and South Africa. Their customers are located throughout Europe, with most customers in the Netherlands and Germany. They are most known for their checkout counters, self-checkouts and kiosks, respectively shown in Figure 1. These products are built in a way where they can be easily adapted to fit the customer's needs, for example adding a barcode scanner, camera or a module for digital signatures. They are sold with Pan Oston styling but are also very often tailormade to fit the needs and styling of companies, for example Albert Heijn (Figure 2) or HEMA. Making tailored products is one of Pan Oston specialties and is a big part of what distinguishes them from competitors, and it is mainly what they are known for.

Pan Oston delivers fully equipped checkout solutions but does not make all the elements themselves, e.g. relatively simple and standard things like fencing or gates that guide customers they buy from partners. This is because Pan Oston sells too few of them to justify making them themselves (which requires very different production lines than Pan Oston's own products) so they are bought from a partner who makes them in bulk and can thus offer low prices.

Pan Oston is in business since 1969. It started as a Finnish company but moved to Raalte in 2005 from which on it became independent and functioned as a fully Dutch company. The retail market is a dynamic and rapidly changing market, and Pan Oston's age proves they have been able to adapt to this market for a long time. Originally mainly producing checkout counters, they adapted to the market when self-checkouts became the new standard, and were able to land big contracts, like becoming Albert Heijn's supplier of self-checkouts. Next to that, they started producing kiosks when it became apparent that this would be the future of ordering in fast-service restaurants. These kiosks allow customers to easily order food and pay without the need for a cashier. Their kiosks are used in fast-food chains like McDonalds and Subway, but also in gas stations and hotels where they function as a check-in counter. Pan Oston is not necessarily an innovator, but they are very aware of what developments are taking place in the retail market and are very able to capitalize on these by making quality products that are desired by big retail store chains, like Albert Heijn and Action.

This adaptive and future-minded mindset is what kept Pan Oston thriving over the years and is also why this thesis exists.

Figure 1: Pan Oston checkout, self-checkout and kiosk

Figure 2: tailormade self-checkouts for Albert Heijn

The store of the future: the WOT store

This thesis exists because of an expected change in the retail industry: the adoption of autonomous stores.

The retail industry is a dynamic, quickly changing industry. Where we originally put all our groceries on the belt at the checkout counter and let the cashier scan it all, now we have the option to scan everything ourselves, either by taking a handheld scanner with us through the shop or by scanning things at the self-checkout counter. There is a growing demand for seamlessness: we can click-and-collect clothing, let our groceries be delivered at home, buy our vegetables in fully autonomous pantries as seen in Figure 3, order our food at a touchscreen kiosk at McDonalds and even check-in in a hotel without the need for a receptionist as seen in Figure 4.

Figure 3: unmanned pantry (pantry.nl)

Figure 4: unmanned check-in in hotel

All these changes have one thing in common: convenience. Convenience is the motive for many of these changes, and it is expected to keep changing things in the future so that they are more convenient.

It is expected that in the future scanning your products and paying at a (self) checkout is a thing of the past, due to artificial intelligence powered cameras and other sensors exactly knowing what you are taking from the shelves (and even when you put it back). A good example of this are Amazon's Go Grocery stores, which allow Amazon customers to scan their account specific QR code, enter the store, take what they want and freely walk out. The amount of Amazon Go stores is growing. There are 24 stores as of writing this thesis, but Amazon has plans to grow this number to 3000 (Soper, 2018).

Amazon Go is selling this technology to enable other stores to do the same (although they require these stores to share the data the system generates). Amazon isn't the only one selling this technology, competing companies like Grabango, Aifi and Standard Cognition offer similar technologies (Waters, 2020). These stores are called 'WOT-stores', named after the abbreviation 'Walk Out Technology' referencing to the ability to just walk out the store without a payment step. Such a store already exists in Cologne, Germany (Ziv, 2021). It is owned by REWE and applies technology made by Trigo Vision. An ALDI WOT-store is coming soon to Utrecht, which will also use Trigo Vision technology (Schelfaut, 2021).

Due the success of these stores so far, the fact that they save money on personnel and that technology is being sold creates the expectation that the number of existing stores like this will rise greatly in the future. This affects Pan Oston since these stores do not need checkouts which is a big part of Pan Oston's revenue. This is something Pan Oston wants to be prepared for and why they want to start producing products which can be applied in these stores.

For these autonomous stores, it is crucial that entering the store is regulated and controlled well. Only people of which the banking information is known can enter the store, otherwise no payment can be made when the customer leaves the store. This is regulated through gates shown in Figure 5, which only open if you can show a valid QR code, which verifies the retail store has access to your banking information. Leaving the store requires no action from the customer, since if his banking information is known and the AI knows what he is taking home, the system can simply deduct the amount from the customer's account when they leave the store. No cashier is required. The gates open automatically. This is fittingly named 'Just Walk Out' technology. If the system has made an error and has charged you for an item you did not take with you, you can get a refund in the Amazon app.

Where traditionally the checkout registers were what made the store run, here it is the walk-in walk-out control, the camera's that track customers and the sensors in the shelves that make the store run. These three systems are what Pan Oston is planning to make, so they can keep a future-proof product portfolio. This thesis will focus on the design of the gates.

Figure 5: gates in an Amazon Go store

The assignment

This thesis documents the design of a walk-in walk-out solution for this store of the future so that Pan Oston can deliver a product that allows for regulated entering and leaving of the store. In Amazon's case this is a gate, but this thesis considers not only gates as a solution but also other possibilities. Through an extensive analysis phase, it has to become apparent which option is best suited to the needs of the retail industry, the customers and best suited to Pan Oston's capabilities and facilities, after which a solution will be designed and realised.

The design is not *only* for WOT stores, however. It must be designed for two horizons, with WOT stores being horizon 2, and existing stores' self-checkout (hereafter referred to as 'SCO') areas as shown in Figure 6 as horizon 1.

Horizon 1 serves the purpose of a steppingstone: it allows Pan Oston to apply the product in an existing market in existing stores to already start learning from it and improving it and to make their customers (Albert Heijn, Action, etc.) familiar with the concept. It also allows Pan Oston to tap into a big market that they already have a lot of customers in and knowledge of, as opposed to the WOT store market which is very small (for now). Having an existing and widely applied use case like SCO areas where the product will be applied also helps with designing the product, as it is easier to understand and predict the context the product will be used in.

Because existing SCO areas already widely apply a way of checking customers before they leave in the form of gates with barcode scanners, it is important the designed product adds value so that it is desirable and performs better than the current solution. Therefore, the goal is to allow customers to leave a SCO area without them having to scan their receipt. This makes the shopping experience more seamless, it saves paper due to receipts not always being necessary anymore and it solves problems with the current system, such as (but not limited to) people forgetting to take their receipt, people putting their receipt away before having used the gate, or people having their hands full and thus needing a third arm.

Horizon 2 is the aforementioned WOT store. It is expected that eventually these stores will represent a big part of all supermarkets and thus will compete and replace supermarkets that use self-checkout areas. This means less gates for SCO areas will be required and more will be required for WOT stores. These products are expected to be very similar, since in both horizons the problem to be solved is the regulation and guidance of people who enter and leave the store. Therefore, it is possible to work with these 2 horizons, as most if not all research and development done for horizon 1 directly translates to horizon 2.

The main expected difference between the product for horizon 1 and horizon 2 is that horizon 1 will need tracking/recognition capabilities, whereas the product in horizon 2 can make use of the tracking/recognition capabilities already present in the WOT store (e.g., the cameras and sensors present throughout the store). This means that the product applied in self-checkout areas (horizon 1) will need some way to determine who has paid and thus who is allowed to leave the store and who is not: the focus is very much on people who want to leave the store. A cooperation between the to-be designed product and the existing self-checkout counter might be required, because the SCOs know whether someone has paid or not. For the product applied in WOT stores (horizon 2) the focus is very much on people who want to enter the store, because their banking information needs to be known before they enter, like mentioned in 'The retail store of the future'. Nevertheless, in both cases we must check a customer before we can let them pass.

Figure 6: SCO area in Albert Heijn

Stakeholders

PAN OSTON
- Needs to make sure their product portfolio stays relevant so they can stay in business
- Want to make products that their strengths: physical products made from steel combined with purchased parts
- Wants to be more attractive than competitors
- Want a product that is quick and easy to install in stores
- Want a product that can be efficiently fabricated and assembled in Pan Oston's factory in Raalte

SOFTWARE SUPPLIER/PARTNER
- Need hardware in the product that complement the software (for example high resolution camera's if face recognition is used)
- Need hardware in the product that is controllable with software

RETAIL STORES
- Want low-cost products
- Want products that work well and last long
- Want less theft at self check-outs
- Want to keep/create a customer friendly environment

RETAIL CUSTOMERS

Fair customers
- Want a shopping experience that is easy and pleasant
- Want to be cooperative and do the right thing
- Want to be treated fairly and not wrongly incriminated

Customers tempted to steal
- Are willing to steal to save costs when opportunities present themself (gate that opened for someone else, not scanning items at SCO)
  - Opportunities should be minimized
  - It should be clear how a system works, so that they do not steal under the motto 'this retail store should've made things more clear, it is not my fault'

Customers with the intention to steal
- Will find flaws in the system, for example not scanning items and hiding them deep down in a bag or shopping cart
- Will walk out the store without paying if opportunities present themself

Figure 7: stakeholder overview

Stakeholders of the assignment

An overview of the stakeholders of this project in show in Figure 7. Next to Pan Oston themselves the major stakeholders of this project are shops with SCO areas and the customers in the store. Store with SCO areas are an important stakeholder because these are the ones paying for the product, in other words Pan Oston's livelihood. These stores need to be convinced that they need the product, otherwise there is no market.

The customers of the stores are not a stakeholder directly, but Pan Oston's customers (the stores) are very dependent on the happiness of the customer for their success. If customers in the store have a pleasant, seamless experience due to our product then that translates to a benefit for the store, who is a direct stakeholder.

Current customer control solutions used for SCO areas

In recent years self-checkout areas are being applied in stores more and more. In the Netherlands Albert Heijn was the first supermarket chain to successfully apply SCO's. Seeing Albert Heijn's success with it and how happy consumer were with it, other supermarket chains like PLUS and Jumbo soon followed. Albert Heijn's parent company Ahold Delhaize is now also applying self-checkout in its Gall & Gall liquor stores and its Etos drugstores, seen in Figure 8 (D. Hofsté, conversation, 14/2/2022).

To prevent consumers from walking out the store without paying, two solutions are currently being used: gates and/or social control. Gates are often applied in supermarkets, since they have a high flow of customers with a high volume of products being bought. This means there a risk of theft and thus a higher need for control. These gates work through a barcode scanner that scans your receipt after which the gate opens, allowing you to leave the store, as seen in Figure 9. On top of this, often a 'host' is present in the SCO area. This is an employee that supports customers who have trouble in using the SCO, but they also give a sense of supervision and social control. With a host present, people are even more discouraged to steal (C. van Braak, conversation, 15/2/2022).

Figure 8: SCO area in Etos drug store

Figure 9: barcode scanner at exit of SCO area

Figure 10: AH to Go with many SCOs but no gates

In smaller stores with less traffic, less SCOs available and thus better oversight, gates are often not used. Since there are a lot less customers per employee, the supervision of the store's employees is often enough. Also, not having gates improves how fast customers can shop and thus enhances the flowthrough in the store. An example of where this is used to its full potential are Albert Heijn To Go stores, where customers want to shop as fast as possible. These stores seen in Figure 10 have many small SCO's, all supervised by a small number of employees.

It can be concluded that there are two approaches, being maximum control (using a gate) and maximum speed (using only supervision through employees). Value can be created by combining the two, by allowing a gate to be opened autonomously without the customer needing to scan their receipt. This combines the control of a gate with the speed and ease of use of having no gate.

Why will the gate and auto-passthrough system be treated separately?

Pan Oston has requested the design of a walk-in walk-out solution (for example a gate) that manages the flow of customers entering and leaving a store or a SCO area, and the design of a system that lets people use the exit gate at a SCO-area without having to scan their receipt. Even though these two are supposed to work well together, they will be designed and treated separately. They should work and be able to be sold separately, because Pan Oston's customers will not always want to buy both. For example, a store could buy only the physical steel product and use an autonomous auto-passthrough system provided by a software partner they have or if they simply prefer another system than the one designed in this thesis. Or perhaps they do not want a smart system at all and prefer a barcode scanner. An overview of possibilities and the scope of this thesis is shown in Figure 11.

Next to that, creating something like a steel gate is fully within Pan Oston's capabilities and strengths, but making a smart software-based system is not. This means they will always have to work with a partner for this, meaning they will make less money off the system than any steel product. Therefore, the main focus of this assignment is making a physical steel product that Pan Oston can produce and sell which is desirable on its own. The automatic opening system is a secondary focus. The main goal of this system is allowing Pan Oston to be able to provide a complete solution so that the customer does not have to look elsewhere for a smart system if he desires one. On top of that it allows Pan Oston to profile itself as an innovator and further experiment with smart technology and see if it is a route they should take to maintain their position in the retail market.

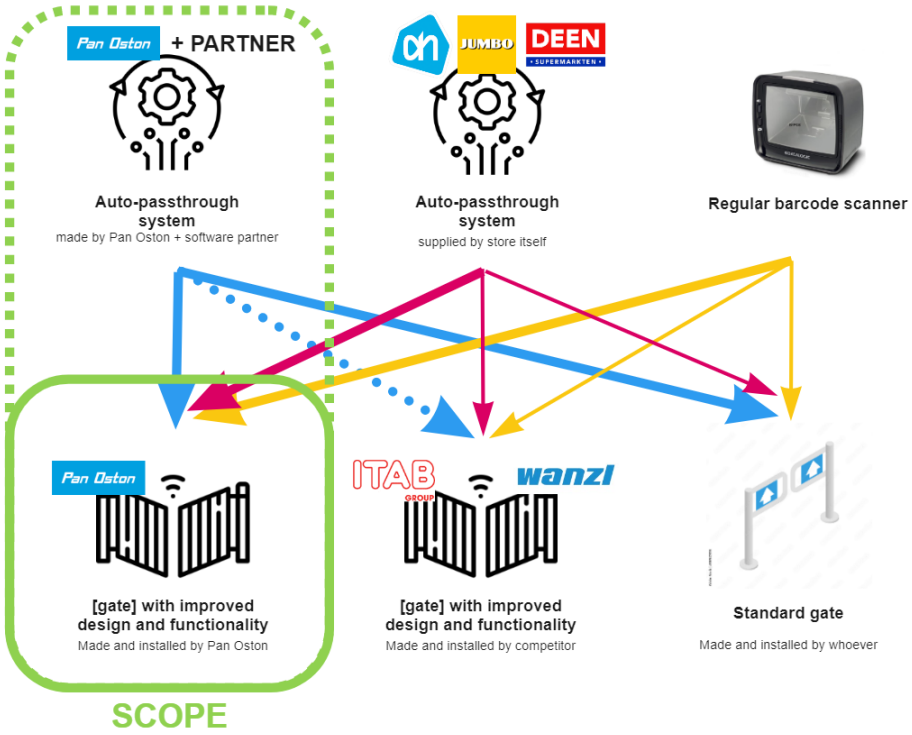


Figure 11: scope of this project with main focus marked with green line and secondary focus marked by dotted green line

CH1: Analysis

The design of any product is only effective if the company it was designed for has the resources and knowledge to produce and sell that product. Because of this, it is crucial to understand the company before designing the product. For this thesis this is no different. This is why in this chapter a good understanding will be created of Pan Oston, the retail market, customers, etc.

1.1: Pan Oston and the market

What defines Pan Oston?

Pan Oston is known for delivering high quality products that are often tailor made. Due to their factory next to their office with many skilled mechanics and good equipment, they can create steel products with a high amount of flexibility in what kind of products they make and when. One week the assembly hall will be filled with checkout counters, the other week it is filled with shelves, kiosk and gates. Pan Oston has high amounts of control due to engineers and designers being able to walk into the factory at any time to control whether things are built as planned.

This high amount of flexibility and control ensures high quality products that keep customers happy. Customers like Albert Heijn and PLUS come to Pan Oston to have their checkout counters, self-checkouts and more designed in their respective branding and then produced on a large scale. Pan Oston has specialized itself in making tailormade products by investing in a large engineering team of around 12 engineers which engineers new products, and a respectable design team of around 8 designers who design new concepts and design products corresponding to the customers' wishes and branding. In the retail market where innovation is slow, costs are always cut and where there are few leaders and a lot of followers having such an engineering and design team is unusual (D. Hofsté, conversation, 15/2/2022). This is a strategic decision that allows Pan Oston to be more flexible and produce more varied products than its competitors. The flip side of this business model is that Pan Oston is not able to provide these services for low prices and therefore loses potential customers that find lower prices more important than customizability.

That does now mean Pan Oston does not provide products for low prices, though. Pan Oston is supplier of Action, a large non-food discounter that is growing with rapid pace. To be able to provide products to customers like Action for low prices, they have factories in Slovakia and South Africa. In these factories standard products with little customization are fabricated. Because Action uses roughly the same products in all stores, products can be produced in bulk which makes them cheaper. Products are also produced based on future expected orders, so that they have products already in stock. In this way they avoid being unable to fulfil orders during peak times when a lot of stores are opened at once.

Not everything Pan Oston sells they make themselves. Some products like gates, fencing or shelves are cheaper to buy and resell than fabricate. Being able to resell these products to customers allows Pan Oston to be more a 'one-stop-shop' for customers, increasing their appeal as a supplier of shopping hardware. Because these products are bought as-is, customizability is low. When customers still want this customizability, Pan Oston will use these products as a base and add to it, for example putting a better looking, customized 'shell' around an existing Eco gate as seen in Figure 12.

Figure 12: Eco gate refashioned by Pan Oston

What do the strengths and weaknesses of Pan Oston mean for this assignment?

To better understand Pan Oston strengths and weaknesses, a SWOT and VRIO analysis were done. They can be found in Appendix A. What this means for the to-be-designed product is listed below (in no particular order).

1. Making tailor made products on large scale is what makes Pan Oston unique. Any product designed in this assignment should complement this and therefore allow for customizability.

2. Desirability is very important. For SCO areas it is convenience for the end-customer if a gate opens automatically. Not all stores will find this a necessary addition to their store. To ensure desirability, the gate should be an improvement compared to other gates on more levels than opening automatically. This could be communication, looks, serviceability, etc.

3. To better market the product, it needs to be found out what stores are generally leading in innovation and are most willing to try new technologies. Most likely Albert Heijn will be great for this, as they have many innovative initiatives, are seen as the most innovative supermarket chain of the Netherlands and they are already a big customer of Pan Oston (M. Termaten, conversation, 18/2/2022).

4. Biometric technologies like facial recognition and posture tracking are promising for building an automatic-opening system, but they are a sensitive topic due to privacy becoming a more prevalent topic. Any product designed should respect legislation and the public opinion, so that the product can comfortably be applied in stores. Research needs to be done on how customers feel regarding these technologies, and if need be, alternatives will have to be used.

5. Pan Oston has many partnerships with hardware and software suppliers. These relationships allow Pan Oston to fully focus on making high quality steel products and still being able to deliver a complete product with electronics and software (B.J. Dikken, conversation, 24/2/2022). Pan Oston is reliant on these relationships, and any product designed in this assignment would ideally complement these relationships, for example by asking software partners to create the software in the gate or buying motors from hardware supplying partners.

6. Services can be integrated into the product. For example stores could know how many people leave or enter the store in a day/week/month. Settings could be changed remotely, or notifications could be sent to Pan Oston whenever a product is broken or not functioning optimally. Such a service system could also be expanded to Pan Oston's other products like kiosks and self-checkouts, creating a store-monitoring system.

7. To ensure good customizability, it is important to keep the product as simple and flexible as possible. Ideally, the internal components are easily rearranged and the electronics and software can be expanded on, so that the product can take on most shapes and forms the customer would like while keeping the same functionality or even adding extra functionalities. The product should be well designed on its own but also function as a blank canvas when needed. Basically, the product designed should apply the same strategy as Pan Oston currently does with their products. They have their own product lines of which an example, the SLIM line, is show in Figure 13. These products are good-looking and function very well and are sold a lot as-is. However, if a customer wants personalized products, these product lines are used as a base on which a new product is designed. Pan Oston's product lines are designed so that they have more internal space than needed, already have slots for extensions and can be produced in many different colours. This modularity makes it easy and relatively cheap to customize them.

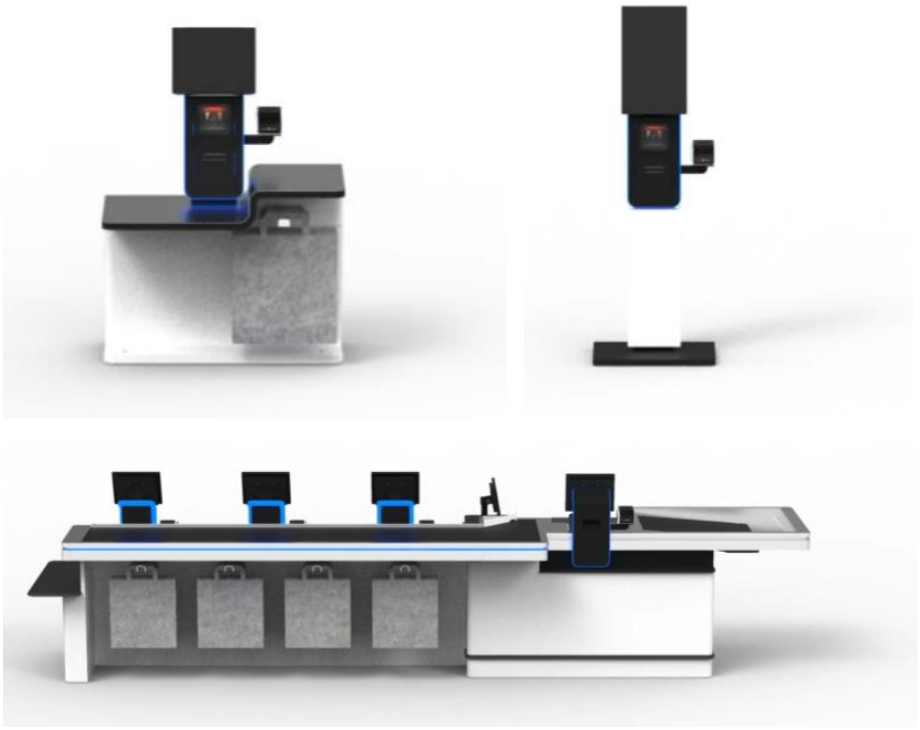


Figure 13: SCO, SCO express and merge checkout from SLIM line

What are relevant market developments?

There are multiple market developments that are likely to increase demand for well-functioning walk-in walk-out solutions. This creates a high likelihood that an addition to Pan Oston's product portfolio of such a product would be adopted by the market, allowing Pan Oston to successfully sell this new product if the product is of high quality and provides value for Pan Oston's customers. These developments allow Pan Oston to start applying gates in stores short term, and thus allowing them to quickly make gates a sizeable part of their revenue, diversifying their business model in the process.

In order of importance, these developments are listed below.

1. Only [redacted]% of stores in the Netherlands and [redacted]% of stores in Germany have self-checkout areas. This number has been growing rapidly in [redacted] for years and is expected to boom in [redacted] soon too. All these stores will need gates at their SCO areas. Since Pan Oston already supplies the checkout hardware and gates to a lot of these stores, all they have to do is sell their own gate to the customer instead of reselling gates like Pan Oston does now (C. van Braak, personal communications, 15/2/2022).

2. Within retail there is always a demand for seamlessness, speed and ease of use. This is proven by rapid adoption of online shopping, self-checkouts, grocery delivery, flash delivery like Gorillas, Getir & Flink and more. Retail stores are always looking for ways to be more attractive to the customer than the competitor. An easier to use, friendlier and more seamless gate will help stores achieve this.

3. With retail stores having very low margins, especially supermarkets, theft is a big problem. Current SCO-area exit gates have little-to-no theft detection or even an alarm. This makes it easy for thieves to quickly pass the gate when it opens for a paying customer, exit the store through the entrance gate or force open the gate by pushing (A. van der Burg, conversation, 4/4/2022). A gate that is more aware of these things happening can quickly inform staff about potential theft by for example an alarm and LED lights and in the process demotivate people from stealing, both lowering theft.

4. There are only two other companies that provide smart gates on a large scale: ITAB and Wanzl. Neither parties are specialized in tailormade products (D. Hofsté, conversation, 9/3/2022). This is a market Pan Oston could compete in

while being able to deliver tailormade products where their competitors cannot.

5. As mentioned in 'The store of the future: the WOT store', WOT stores are expected to increase in numbers in the future. For these stores something like a gate is incredibly important because customers need to provide their payment information before they can enter the store. Since these stores do not have checkout registers, Pan Oston will lose demand of these products for these stores and instead there will be an increased demand for gates or alternatives.

Which customers of Pan Oston are most likely to adopt the product?

Due to the retail market having low margins, there are few chains consistently innovating and there are a lot more followers than leaders. This is because innovation always comes with risk, and most chains prefer letting other chains do the research and experimenting after which they will copy the best innovations, cutting R&D costs in the process. This means that any product or system designed in this assignment will have to be marketed towards the most innovative supermarket chain, as this chain will be most likely to adopt the product or system. For the Netherlands this is Albert Heijn and for Germany this is REWE (M. Termaten & D. Hofsté, conversation, 9/3/2022).

Albert Heijn was the first to successfully apply self-checkouts, grocery delivery and apply a customer-loyalty system (the BONUS card). REWE is the first supermarket in Germany to experiment with WOT stores, having an already functioning WOT store in Cologne. Both are already Pan Oston's customers, so they make the ideal adopter for a new gate or alternative, or for an automatic opening system. As soon as Albert Heijn or REWE adopt it and it turns out to be a success, it can be expected that other chains will start following and more orders will come in.

A chain adopting the product would be the ideal start because it would very quickly allow Pan Oston to sell high volumes. However, chains are not the only ones that are likely to adopt the product. Generally speaking, supermarkets owned by franchisers are more free to arrange their store as they like than stores owned by a chain itself (P. Russo, conversation, 18/3/2022). This means that franchisers could decide to adopt the gate and/or automatic opening system to their store, creating multiple small orders. If these orders add up, it will help the adoption of the product.

1.2: Gates

In this chapter it is described which needs and wishes the to-be designed gate or alternative needs to adhere to be successful, and why. How these are achieved is described in chapter 2 and 3.

WOT stores & SCO areas: why to focus on the latter

Diversification of Pan Oston's product portfolio is needed in the anticipation of the rise of WOT stores, and stores with SCO areas are used as a 'steppingstone'. This way Pan Oston can immediately start diversifying its product portfolio, increasing revenue and start learning from gates that they sell. This way they increase their market position and prepare for a future where checkouts are less needed.

Gates are currently being used in WOT stores and SCO areas. The main difference between the two is that for WOT stores entering the store needs to be most controlled whereas for SCO areas leaving the store needs to be most controlled. They are more similar than they might occur, though. Both gates need to block people that are not allowed to pass and inform staff when people still do. Both gates need to be built to withstand people pushing them but also be able to open easily when evacuation is necessary. Because the similarities are rich, it is possible to fully focus on designing an exit-gate for SCO areas while still creating a product that is also very useful in WOT stores. Therefore, in this thesis the focus will mainly be understanding SCO areas and how to design a check-out solution for that.

It might be the case that WOT stores never really take off and that SCO areas stay the norm. In this case Pan Oston has still diversified its portfolio and strengthened its market position. Strategically, there is no reason to not design a check-out solution for SCO areas.

What solutions are out there?

Let us first take a look at gates used in supermarkets, see Figure 14 for an example. At first glance the function of a gate at a SCO area seems to be to block people who haven't paid and let through people who have. While this is a big part of the gate, it

serves a broader function than this. Next to physically blocking people, the gate gives control to the host so he/she can fulfil his/her job: being hospitable and kind. The host can be rest assured people are not likely to just walk out giving him/her confidence to help people in the SCO area without constantly having to keep an eye on the exit. The time gained by this can then be used on helping people and being kind instead of policing.

The physical barrier allows the host to keep in check who just entered to SCO area, who has been paying for a while, and who is about to leave. Generally, people understand what they have to do before they are able to leave and will not try to leave without paying. The gate also gives the host a valid reason and confidence to check a customer when the gate is not opening for them (ECR Loss Prevention, webinar, 10/3/2022). Customers are demotivated to try to steal, since the gate functions as a barrier between them and the store exit, which they have to cross. If there would be no barrier, the only thing deterring customers from stealing is ethicality and social control. Since 1 host is responsible for sometimes up to 16 SCO's (D. Hofsté, conversation, 4/4/2022), this would become impossible for the host to control.

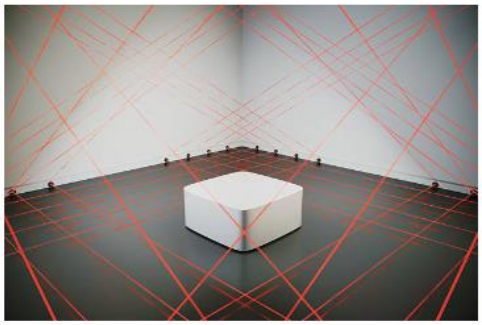
Figure 14: exit gate used in Albert Heijn SCO area

But supermarket gates are not the only check-out solutions out there. We can learn from other industries as shown in Figure 15. For a more extensive overview, please refer to Appendix B. The following points are concluded from this overview:

1. If speed is important, sensors are often placed some distance in front of the gate, so that the gate has time to open before the user passes the gate.
2. What product is applied can be very dependent on culture. Barcelona's subway uses big walls in their gates so no one can pass without paying, whereas in Japan people always pay for their tickets and so the gates are a lot smaller and easily jumpable. Higher security solutions are also more often used in more aggressive environments like football stadiums.
3. Social pressure is a very often used and very powerful tool to let users behave well.
4. People behave better if consequences are likely to happen if they don't behave. Good examples are bouncers in front of a nightclub, or conductors handing out fines in the train.
5. Biometric technologies such as fingerprint scanning and facial recognition are more used and more accepted at high-security areas like airports.
6. Security systems can be very visible to discourage people from misbehaving but can also be hidden to catch people who will misbehave anyway.

As we can see, many of the advantages of a gate are not limited to gates. There are many physical barriers and even psychological barriers that fulfil the supermarket gate's tasks similarly.

NS Stations
2 way gates, with QR code scanner and NFC reader
2 variations, one high and one low
signage LEDs implemented, screen inside



Security systems
Alarm is triggered when somewhere where he is not allowed to be
Can be made to be invisible or made to be as visible as possible

Bouncer
Social pressure, intimidation, prospect of violence

Figure 15: methods of control used in other industries

What else is possible?

If we try to look past what is already out there and are willing to consider anything, what other things are possible to discourage and/or stop a thief? To list some examples:

- Shooting a net out of the ceiling to catch a running thief
- Thieves get a shock from shock-devices integrated in carts and baskets
- Closing the store exit, locking them in the store
- Activate a trip wire hidden in the floor
- Fatally shoot the thief

Of course, many of these things are way too extreme to be applied. But they teach valuable lessons:

1. By slowing down the thief we can give the store personnel more time to react to the situation.
2. The store needs to be and stay a safe environment where customer feel comfortable doing their groceries.
3. Sometimes it is better to have items being stolen than to lock up and aggravate the thief and create a dangerous, unpredictable situation.
4. The best cure is prevention: demotivating thieves by giving the image of being well-secured is effective.
5. There is a trade-off to be made: safety vs. ability to stop thieves. Extreme theft prevention leads to decreased safety and customer friendliness and vice versa. The ideal spot is somewhere in the middle.

Is a gate even necessary?

So, if there are so many options, do we need a physical barrier at all? One could argue that gates are not customer friendly because you are 'locking up' customers until they can prove they paid for their groceries. One could also argue that before SCOs, stores did not even have gates and that worked fine. Even currently, many stores do not use gates, even stores with SCOs. For example, HEMA has self-checkouts placed near the normal checkout registers (Figure 16), so without a gate and even without a specific SCO area. Or look at Albert Heijn, who uses gates in their normal supermarkets but don't use a single gate in their AH to Go stores, even though these stores can have just as much self-checkout registers than normal stores, as seen in Figure 17.

Figure 16: HEMA SCOs placed near the regular checkouts

Figure 17: AH To Go with no gate but a high density of SCOs

Unfortunately, supermarkets do require a physical barrier. This has to do with a combination of lack of control over customers since SCO areas can be very large and there is often only 1 host for a whole SCO area, and because of the risk of theft due to supermarkets having many high value items such as meat and alcohol. Supermarkets could hire more hosts, but this is too expensive. And of course, removing the high value items out of the store is also not an option. The reason why HEMA and AH to Go are able to function without physical barriers is due to HEMA having a low amount of SCOs and they are placed directly next to the regular checkouts so there is a lot of social control, both from the HEMA cashier and the customers in line for the regular cashier's register. AH to Go does not have high value items, and their SCOs are placed very close to each other and very close to where the host is, making people feel watched, demotivating theft (D. Hofsté, conversation, 28/3/2022).

The number of customers and volume of groceries leaving the SCO area, combined with how much bigger SCO areas in normal supermarkets are than AH to Go SCO areas makes it impossible for a host to keep control if everyone is able to just walk out. Forcing people to prove they paid after they *just* paid is not ideal, but it's a necessary evil for the store to stay profitable and be able to provide a SCO area for its customers. Plus, because the physical barrier offers the host more control, he/she can focus on being hospitable and kind, making up for the (currently applied) inhospitable gate.

Host interviews

These conclusions are further supported by two hosts that were interviewed: E. [redacted] and L. [redacted]. Both worked as a host and team captain. The full conclusions of these interviews can be found in Appendix C. One host worked for Albert Heijn, the other for Jumbo.

Both hosts confirm that their job scription describes that their main function is being kind and hospitable and that checking customers comes second. However, for both these hosts this is made difficult because the gate applied in both stores do not have an alarm built in. [redacted]: *"People regularly push through our gate, it happens about every 20 minutes. Especially when I am checking someone else and have my back turned, people take the opportunity to force themselves through the gate".* Similar stories are told by [redacted]: *"Our gate has no alarm and closes slowly. It happens every day that people walk out without paying. If the gate would do its job better, being a host would be a lot easier, since I would have more control".*

We can conclude that a host can only perform his/her task of being kind and hospitable if customers are not able to leave the SCO area without being punished. A more aware and communicate check-out solution will allow a host to perform his/her job better, while also decreasing theft.

Why this project still needs a gate specifically

As we have seen in 'What solutions are out there?', there are alternatives to using agates, like only applying alarms (like a car alarm) or just checks in random intervals (conductor in a train). A gate is still the best option for supermarkets, due to the following reasons:

- A gate is not human and therefore has no salary, making it affordable compared to hiring something like a bouncer
- A gate is a very visual deterrent for thieves. It's meaning is very clear, allowing the store to make very clear that anti-theft measures are in place
- Stores with gates have better loss prevention than stores without gates. [redacted] who originally didn't want gates because they wanted to be customer-focussed is now also applying gates because they are losing too much money (B. Bosch, interview, 28/2/2022).
- A gate does not allow for everyone to just leave the store, giving the host more control and peace of mind.
- Whenever a gate refuses to let someone through, the host has a valid reason to check that person, giving the host more confidence and lowering the

chances of there being a confrontation. Sometimes confrontations occur because people feel 'attacked' when randomly checked (ECR Loss Prevention, webinar, 10/3).

- Many countries and store chains are just now realising what gates have to offer and are just now starting to apply them (ECR Loss Prevention, webinar, 10/3).
- Not having a gate is a very hard sell in a market where there are low margins and a lot of theft (B. Bosch, interview, 28/2/2022).

This does not mean all gates are created equally: some perform these tasks better than others. If we understand the needs of the users and the shortcomings of competitors, we can create ideal gate.

Who will use the gate?

It must be understood who will use the to-be designed gate so that we can take their needs and wishes into account. Because the product is supposed to be installed in supermarkets the user demographic is very broad. Basically, everybody who can do groceries falls under the group of potential users. But the users are not limited to being customers: employees also have to use the gate. A full overview of potential users can be found in Figure 18.

Figure 18: different groups of people that can use a SCO area

This broad group of users means that there are a lot of demands the product has to adhere to before it can bring value to all customers. These will now be explained.

Dimensions

First of all, it should not be easy to jump over or climb under the gate arm. Children can climb under the gate more easily than adults, but they are probably less likely to steal high value items. We still need to block them from climbing under the gate arm though, because even if they do not steal, they are still likely to trigger sensors and confuse the gate. We can block anyone climbing under the gate arm by extending the gate arm to the floor. An example of this is shown in Figure 19. As for blocking people trying to jump over the gate, we can extend the gate arm so that it is impossible to jump over, similarly to NS gates seen in Figure 20. This however makes the gate into a sort of wall which can make customers in the SCO area feel locked up. For train stations where the main focus is functionality this works fine, but in a SCO area where we want to be hospitable this is not an option. Instead, it is a good idea to decrease the amount of grabbable parts that someone can hold onto to push themselves over the gate. As seen in Figure 21, current gates often use tubular structures that look like they are climbable and can hold a lot of weight. We can replace this by thin transparent material, similar to what is done in Figure 19.

Figure 19: ITAB SigmaGate

Figure 20: high gates at NS station

Figure 21: widely used, cheap tube-structure gate

Secondly, the gate has to be wide enough to let a variety of vehicles through. Scoot mobiles, shopping carts, customers with wide grocery bags in their hands, baby strollers, wheelchairs and employee's carts have to be able to pass. A width of roughly 1000 mm is successful in letting all these vehicles through. This can be concluded by looking at the gates Pan Oston has been selling for years, which have no problems in letting these vehicles through (G. van den Heuvel, interview, 14/2/2022). Most of these gates are made by Eco, a fabricator out of Italy. The dimensions of one of the most applied gates can be found in Figure 22.

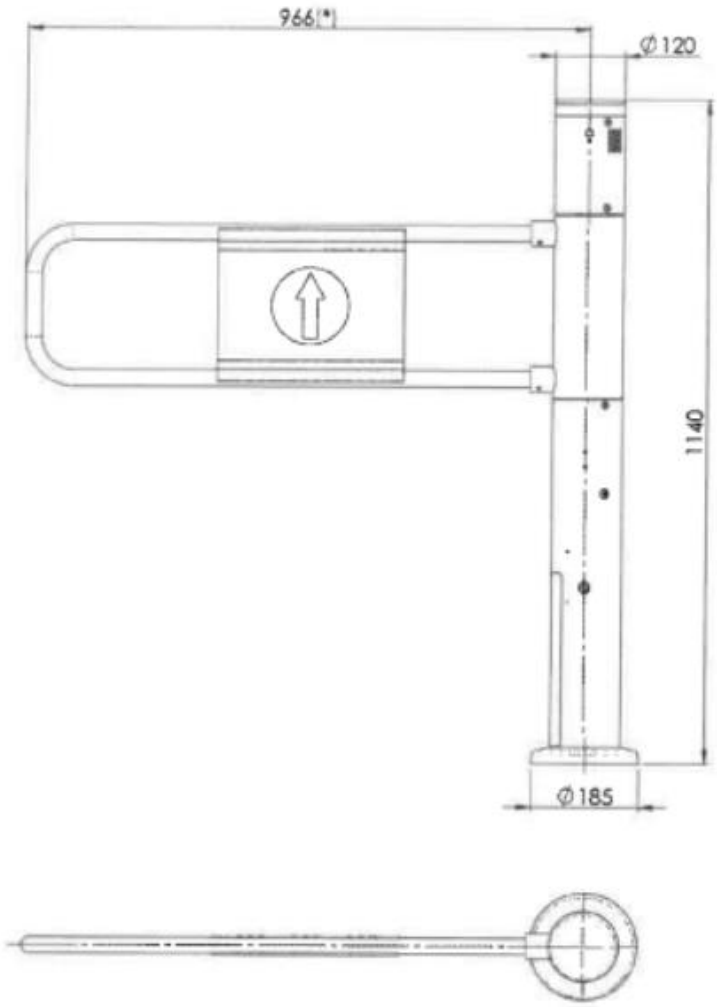


Figure 22: dimensions of Eco OverGate 4.0

As seen in Figure 23, Pan Oston applies and services a range of gates. As an extra check the arms of these gates were measured and they all had similar lengths, around 950 millimetres as seen in Figure 24. Note that this is 50mm short of a full meter, since a gate arm never fully reaches the end because of pinch hazards (G. van den Heuvel, interview, 14/2/2022).

Figure 23: range of gates Pan Oston installs and services

Figure 24: measuring of many gate arms

One aspect of the gate's dimensions that should not be overlooked is whether it fits on a pallet (or multiple pallets if need be). Pan Oston mounts their products to EUR pallets with a size of 1200x800 millimetres as seen in Figure 25. Smaller products are mounted to half-size EUR pallets, so 600x800 millimetres. Any designed product should fit these dimensions, or at least do not overlap the pallet on more than two sides. If the product is top heavy, it should be shipped disassembled so that it does not bend in transport (P. Russo, conversation, 4/3/2022).

Figure 25: disassembled kiosk mounted to EUR pallet for transport

Build quality

As mentioned, a lot of different vehicles use the gate. These vehicles can seriously damage a gate and there have been many cases where currently used Eco gates have been destroyed by being (repeatedly) hit by scoot mobiles or an employee's cart (G. van den Heuvel, interview, 14/2/2022). Therefore, the gate should have a structurally strong front side since this side is directly in front of the direction of movement, and therefore will be hit the most. If this proves to be expensive, costs can be cut by using guards as shown in Figure 26, which will prevent vehicles from being able to touch the gate.

Figure 26: furniture guards shielding equipment from impact

Universal understandability and ease of use

Because the types of customers in a supermarket are so varied, the gate should be as easy to use as possible. This is also where seamlessness comes in: the more we do automatically, the less the customer has to do themselves which means the less errors they can make. This means when designing the gate and auto-passthrough system, we should not add any steps the customer has to undertake before being able to leave the SCO area, and ideally, we remove steps. Some tasks we cannot remove like paying for groceries or walking out of the SCO area. For these tasks we need to make sure that if anything is wrong, customers know precisely and quickly what the problem is. This is best done by applying concepts that are universally understood, such as the colours of a traffic light. Green means go, orange means caution and red means stop. In our case this would mean that green light shows when someone is allowed to leave, and red light is showing when a customer is not allowed to leave the SCO area but is trying to. It is important to use these signals carefully though, as a supermarket is a place of hospitability and kindness. We should only label people as thieves if they show very strong thief behaviour, like pushing through a gate that is closed or free-riding off of paying customers. To prevent situations where customers are incorrectly labelled as thieves, a warning system needs to be integrated. Imagine a customer is confused and tries to leave without paying, then we should warn and inform them before they force open the gate not knowing they are doing anything wrong. This can be done by showing them light, animations, icons or text that explain what is wrong and/or we can inform the host who can then help this customer.

Good communication

Any communication should also be interpretable by disabled customers, such as the blind, colourblind, deaf or hearing-impaired. To achieve this, we need to add layers of communication that convey the same message. For example, if we have a red light that flashes combined with an audio alarm, we have three layers that can be understood separately or together. If a disabled person is unable to perceive one of these layers they can still rely on the other ones.

A brainstorm was done together with Pan Oston colleagues to come up with potentially good ways of communication. These can be found in appendix D. The best ideas are collected and shown in Figure 27. Sound, animated light and information through a projection or a screen seem promising. Combined they are likely to function as the multi-layered communication we want to achieve. These will be tested in chapter 3.

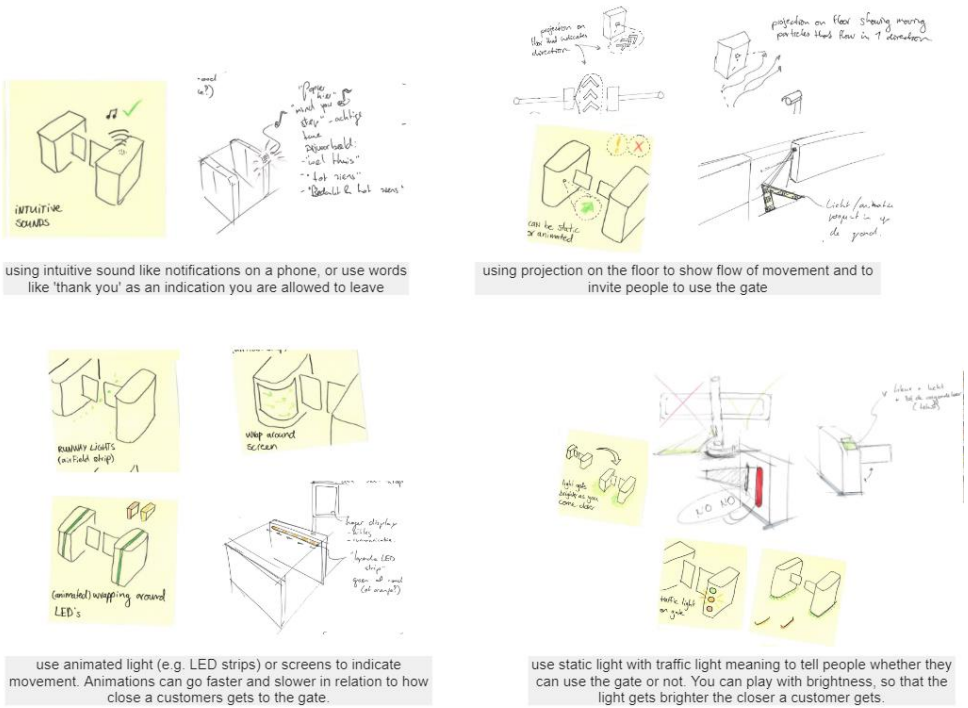


Figure 27: best ideas from brainstorms about communication

What if the gate is always open?

To further enhance ease of use and seamlessness we can rethink the concept of a gate altogether: what if the gate is normally open instead of normally closed? This is inspired by the Tokyo Metro gates, seen in Figure 28. These gates are usually always open allowing for maximum flow of passengers. While passing the gate you need to scan your ticket, otherwise the gate will still close. This is very nice customer-focussed, seamless approach towards letting people through which can also be applied in SCO areas. This way customers do not have to wait for the gate to open making this process quicker while also letting the SCO area feel less enclosed. Of course, customers still need to pay so a system needs to be in place that checks this. This can be done with the system described in '1.3: Auto-passthrough system' or another smart system. Whenever a customer has not paid but tries to leave, the gate closes. At first this may be confusing for customer because they are used to the gate being closed and then opening, not the other way around. This is why it is important that aforementioned ways of communication are integrated, so that people that are allowed to leave the store get extra cues on top of the open gate like a green light and positive sound, and people that are *not* allowed to leave get a friendly warning that explains they are not allowed to leave *yet* and what exactly is the problem.

Figure 28: Tokyo Metro gates

An always-open approach should be an option in the gate's software that should be able to be changed, though. Since only the software between these two modes is different this is easily doable. It is expected that an always-open approach would create value for the average supermarket but would increase theft in highly theft-sensitive areas such as Amsterdam or Rotterdam, since in these areas there are more people with bad intentions who will be more motivated to steal when a gate is always open. Of course, the gate will close, but that often does not stop these people (A. van der Burg, interview, 4/4/2022).

Speed

Speed is relevant in two ways: how quickly the gate arms close and open and for how long the timeframe is for one or more people to leave after payment has been successfully verified.

As just mentioned, the easiest to use and most accessible gate would be one that is always open, and only closes when someone is trying to leave who is not allowed to. This means we need a certain amount of time between the trigger to close the door and when the door is actually closed. To create this reaction time, customer guidance will need to be present at the front of the gate. This customer guidance is a 'pathway' the customer has to walk through to be able to use the gate, see Figure 29 for an example. We can then place our system that checks if someone has paid or not in the front of this customer guidance. Customer guidance also allows to place photocells in the front and back of the gate. Photocells are devices that emit directional light which is reflected by a reflector. This light is disrupted when someone or something walks through them, triggering the sensor. This way, free-riders or backflowing customers can be detected.

Figure 29: Barcelona subway with customer guidance at front and back of the gate

The length of time of how long the gate should stay open (or period in which customers are allowed through in case of an always-open gate) is hard to determine exactly because there are a lot of variables. For example: elderly are slow, children may hold up their parents while trying to leave, groups that shop together and have to use the gate after each other, there is no perfect length of time that suits all situations. The solution to this problem is assuming everybody is slow and thus leaving the gate open for longer than needed. It can be assured that everybody can leave safely by only using little force when the gate closes. If it then so happens that not all people belonging to the transaction have left yet, they can simply hold open the gate for themselves using little force, after which the gate is closed again after the complete group has passed.

A flip side of this is that it introduces opportunities for people trying to free-ride of off paying customers since the gate may be open for longer than needed (*when using the automatic-opening-system designed in this thesis this is solved by identifying the free-riders basket or cart as 'unpaid' and closing immediately).* If no system is in place that checks for free-riders, it is up to the store manager's preference. Either the gate can be closed quickly which has the downside that slow people and groups have to hold open the gate themselves which is not customer friendly, or we keep the gate open for longer and risk an increase in theft because of free-riders. Most importantly, the length of time should be easily changeable so that it can be adapted to the store.

Safety

As mentioned earlier, the gate will be used by a wide variety of users. From slow walking elderly to curious unpredictable children, we have to take safety into account. To have a safe product, the gate has to comply with the CE (Conformité Européenne) norm. This means its safety is up to European standards. To be specific, the gate has to comply with 'machinery and amending Directive 2006/42/EG' since a gate is a machine and it does not fall under any exemptions (Conformité Européenne, 2006).

While it is not possible to receive the CE mark in this thesis due to time and budget constraints, it is possible to design the gate in a safe manner according to machinery and amending Directive 2006/42/EG since it is still a great guiding document on what makes a machine safe. Relevant topics are pinch hazards, sharp edges, risk of sharp particles like glass, risk of static shock and lastly ability to use the gate when evacuating.

To prevent pinch hazards multiple things should be done. First, space should be left between the gate arms when the gate is closed, and there should be room between the gate arm and the gate itself when it is open, similar to Figure 30. Second, the slot over which the arm rotates (see Figure 31) cannot be bigger than 5 mm so that no fingers fit inside (corresponding to CE norm). Lastly, the torque of the motors of the gate arms needs to be limited so that customers are not crushed if they are caught between the two arms. The torque limitation also ensures that the customer can deliver enough force to force open the gate in case of an emergency. This is called

'evacuation mode' and is mandatory for all gates (A. van der Burg, interview, 4/4/2022).

Figure 30: Wanzl GalaxyGate

Figure 31: potentially dangerous grooves

To avoid cuts and scratches glass should be avoided since it shatters when broken, and no sharp edges can be present. The design cannot contain sharp corners that customers can fall onto. Since Pan Oston specializes in sheet metal which can have very sharp corners and edges this needs much attention. Luckily Pan Oston is experienced with this and should be able to produce gates without untreated sharp edges.

Lastly, there can be no risk of electric shock meaning all parts should be grounded and any power supply should be mounted and isolated well.

What can we learn from the ultimate hospitality industry: hotels?

Users want a pleasant shopping experience and supermarkets want their customers to be happy and feel welcome so that they will return. Customer friendliness is one of the biggest focal points for supermarkets. Among other things, this is proven by supermarkets issuing returns if you are not happy with what you bought, by hiring hosts that welcome you and help you, by cashiers saying hello, or by employees wearing vests with 'ask me anything!' printed on them. So if hospitality so important, what is there to be learned from the ultimate hospitality industry: hotels?

A full overview of what makes hotels so customer friendly can be found in Appendix E. All these things have 3 things in common:

1. Through personal attention you are made to feel like you are special, preferably by humans instead of machines.
2. You are unburdened as much as possible so that staying in the hotel is a seamless, pleasant experience.
3. Help is always close by, whether you go to the front desk, use the phone in the room or approach staff in the hallways.

This strengthens the conclusion that was already made that the main function of the gate is to support the host, so that the host has more time to give personal attention to customers and to help customers in need. Human interaction seems to be connected to hospitality making it very important. Technology should support the employee, not replace him/her. This makes it likely that hosts will keep being applied in supermarkets, creating even more arguments to design a gate that supports hosts. This is in line with [redacted]'s plans for the future, which are planning to '*support the employee with technology, so that repetitive tasks are removed, and the employee can focus fully on fulfilling their hospitality role*' (C. van Braak, [redacted], 13/4/2022).

Things in *and* out of our control that influence how well a gate functions

The users of the gate and their needs are known, so we know what to do. If we then take this knowledge and compare it with how gates are currently being applied, we can learn what external factors influence how well gates function, and we can learn from where other gates went wrong and thus learn what *not* to do.

The following list of bullet points are a result of an interview with Pan Oston service planner A. van der Burg on 4/4/2022 and the aforementioned host interviews shown in Appendix C.

- The average lifetime of a gate is 6 to 7 years.
- In franchise stores customers and employees are more careful with equipment as opposed to chain-owned stores since franchisers pay for most equipment themselves and there is a closer relationship between franchiser and customer or employee.

- If sensors like photocells or radars that need to trigger when a customer approaches are at the wrong height, they are unable to see shopping carts resulting in the gate not opening and it being rammed open.
- Gates break quickly if they are forced open by employees that are too lazy to manually open the gate, slow customers or forced open because the gate did not see the customer due to malfunctioning photocells or radars and did therefore not open. The damage is even larger if the employee forces the gate open with carts or if a customer forces the gate open with a scoot mobile. Lazy employees are the biggest problem.
- In theft-sensitive areas like Amsterdam gates are often tampered with or rammed open by shopping carts full of groceries.
- Gates without an alarm are forced open more often because there is no punishment for the people that do this.
- If the arm of the gate blocks part of a walkway behind the gate it is pushed away often.
- If there is container with discount items or a large sign next to the gate, people often stop to take an item or read the sign, resulting in the gate being closed again by the time they want to pass it, forcing them to force it open.
- The more often the gate is used, the faster it will break. One gate per 12 SCO's will break earlier than one gate per 4 SCO's. It is likely that when a gate uses a normally-open approach it will open and close less often resulting in a longer life.
- Gates' settings can usually only be changed by a service mechanic, which has to travel to the location.
- When evacuation mode is triggered because someone forced open the gate with great force, it has to be manually reset by a service mechanic, which, again, has to travel to the location.

From this it can be concluded that on top of the aforementioned user needs, an ideal gate has easy passthrough for employees by for example integrating a NFC reader in both sides of the gate that scans employees' tags or cards, is not placed near any attention-grabbing container or sign, not placed blocking (part of) a pathway, has well-placed sensors, has changeable settings, is easily resettable after evacuation mode was triggered and has a form of punishment like an alarm that triggers when the gate is forced open.

What do Pan Oston's competitors offer?

If the things just learned were to be applied in a new design for a gate, would Pan Oston get an edge over the competition? Pan Oston's competitors in making smart gates will be Wanzl and ITAB. They are both big companies that make smart gates and can also deliver a complete hardware package for a store like Pan Oston can (D. Hofsté, conversation, 5/4/2022). Wanzl's and ITAB's most innovative gates and their features are shown below in Figure 32 and Figure 33 respectively.

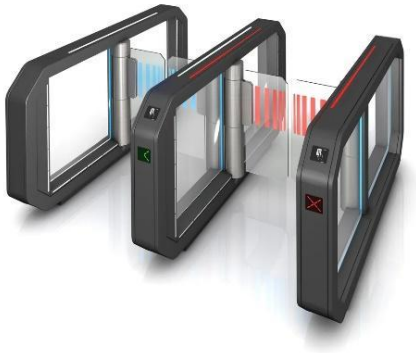


Figure 32: Wanzl GalaxyGate 1.1

Figure 33: ITAB SigmaGate

Lighting in glass panes and gate arms	Lighting in gate arms and grooves
Indicative LED strips on top	Can come with a system that lets gate open automatically based on camera footage
Indication of direction of movement in small screen	Novel side-sliding doors
Beeping sound if someone is not allowed through	Beeping sound if someone is not allowed through
Configurable in width, height and 3 colours, option to add accessories like temperature camera	Comes in 2 colours, glass panes can be engraved with custom logo or text
https://www.wanzl.com/nl_NL/producten/geleidings-en-veiligheidssystemen/toegangssluizen/galaxy-gate-r-1.1~p4854	*https://itab.com/products-and-services/products/security-gates/entrance-exit-solutions/sigmagate*

Both gates are interesting to see, and they contain useful features like indicative lighting, integrated receipt scanners and an alarm. They definitely leave room for improvement though since both gates use a buzzer that can only beep and not play any other kind of sounds. Their lighting is limited to static green and red, so no animations or a warning mode that gives customer a chance to correct themselves. This means that a gate that improves on this can definitely compete with Wanzl and ITAB, especially since Pan Oston can offer the possibility of full customizability which they are so good at and specialized in. ITAB and Wanzl offer a configurator, but a redesign of the gate is not possible. Pan Oston has a great advantage here. Wanzl and ITAB are large corporations with €700 million (Wanzl, 2017) in 2017 for Wanzl and €840 million (ITAB, 2022) in revenue in 2021 for ITAB. These companies are roughly 20 times larger than Pan Oston who has around €40 million in revenue (C. van Braak, conversation, 5/4/2022). Their business models are not based on low-volume highly customized products, but instead on low-customized high-volume products (D. Hofsté, conversation, 5/4/2022).

Pan Oston can get an edge on the competition in two ways. First, by making a better gate. Like described in previous paragraphs, there are features that can be integrated in a gate that the competitors have not applied, which can be capitalized on. Second, by making tailormade gates. Pan Oston's flexibility and experience with customization can give them an edge over ITAB and Wanzl, making them a competitor for low-volume orders that need to represent the style and wishes of the store buying the gates.

What should the gate look like?

Even though Pan Oston does a lot of customization, they have their own product lines, with each line having its unique consistent styling. Pan Oston's flagship lines is the SLIM family and the BLUE FIRE kiosk family, both show in Figure 34. These products can be sold as-is, or customized to suit the customer's needs.

Figure 34: SLIM line (top) and BLUE FIRE line (bottom)

Both product lines have sleek lines with many rounded corners and elegant styling. The gate has to fit this styling to be a true Pan Oston product, but also allow for customization. The moodboard in Figure 35 was created to capture the mood of these product lines. If the aesthetics of the gate fits this moodboard, it is a good design.

Figure 35: moodboard of Pan Oston most high-end products

Material-wise the product should mainly be made out of steel since this is Pan Oston's specialty. Pan Oston powder coats their own products so there are many possibilities in colours and textures. However, as can be see seen in the moodboard Pan Oston mostly uses black and white in their own products with the occasional blue. Colour is often added to their product in the form of LED lighting which they regularly apply. Existing Pan Oston products were inspected resulting in the photos seen in Figure 36. These give a good idea of what is possible.

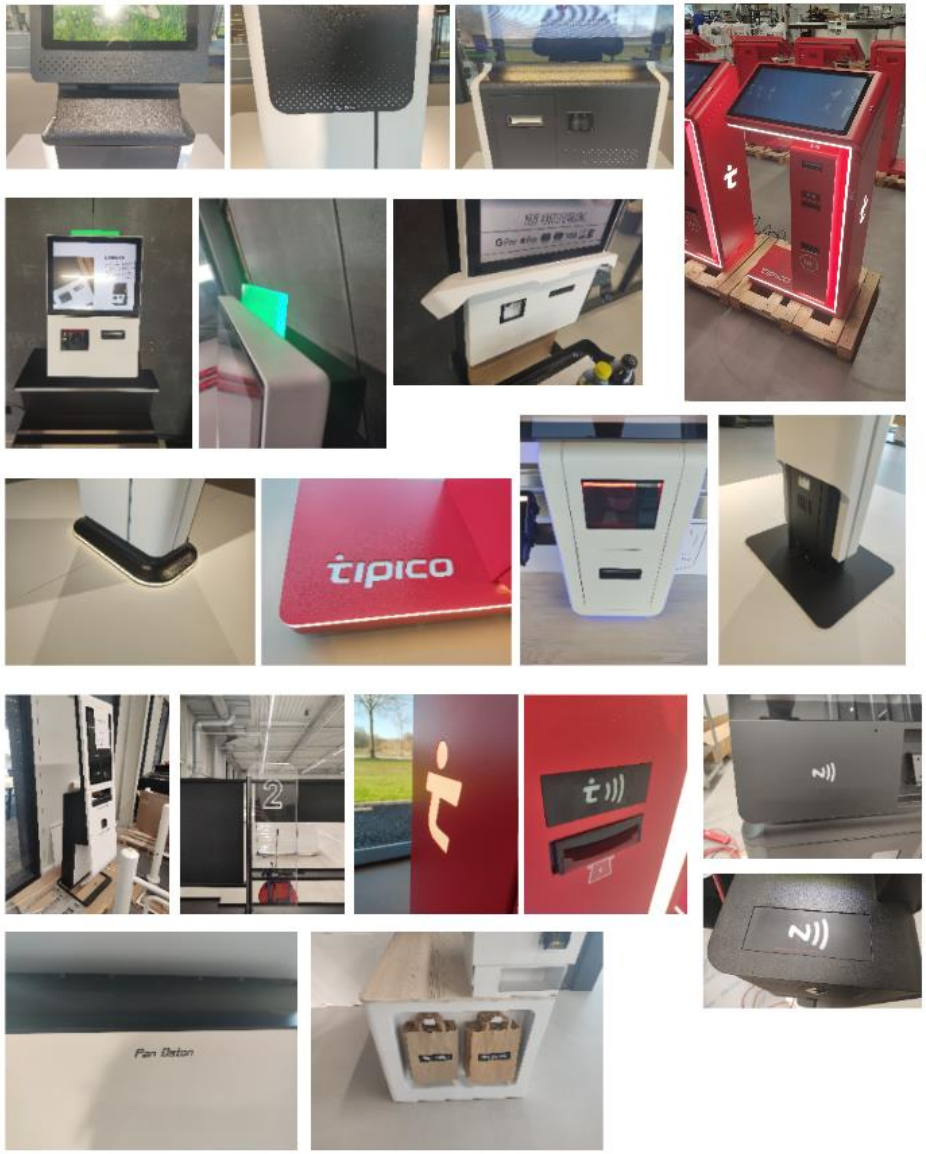


Figure 36: overview of different nuances in existing Pan Oston products

What mechanisms are there to close a gate, and which is most suitable?

Gates come in many different styles, all with their advantages and disadvantages. Which one suits the SCO area best? A wide variety of mechanisms was considered, as seen in Figure 37. The coloured dots communicate which mechanism would suit and which would not. An overview of the advantages and disadvantages of all mechanisms can be found in Appendix F.

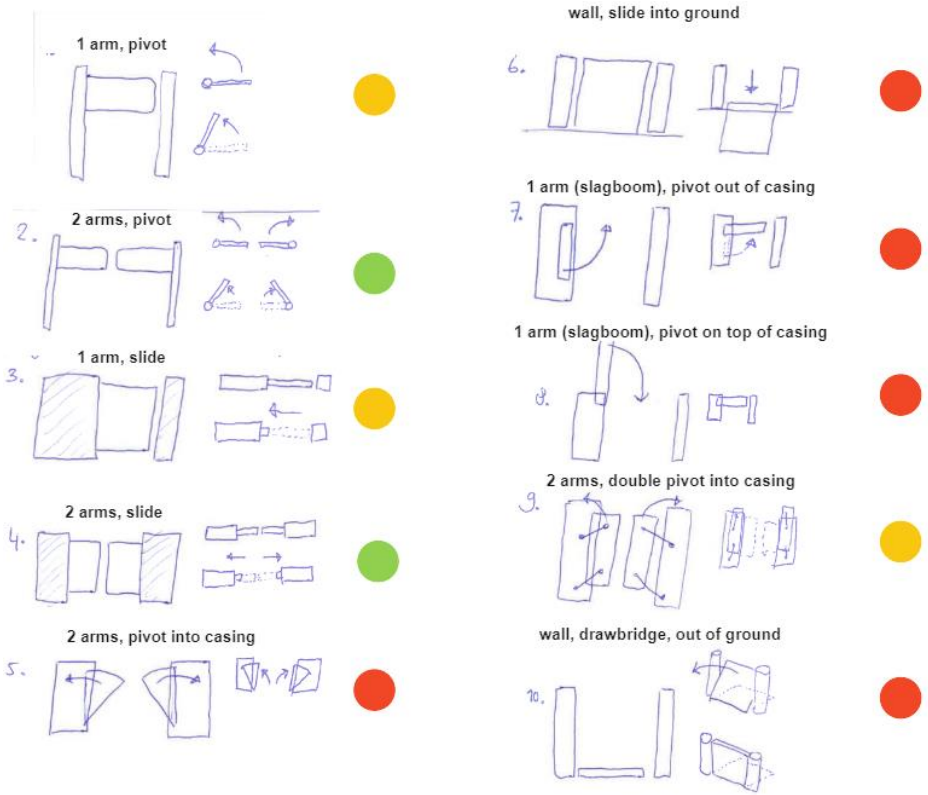


Figure 37: variety of considered mechanisms

It was concluded that either 2 pivoting arms or 2 sliding arms would work best. This is because both options allow for a wide passage and both options can be closed quickly. Using 2 shorter arms instead of 1 larger arm also allows for faster closing and opening of the gate (assuming similar rotational speed).

In Figure 38 examples of these mechanisms are shown. As shown, both mechanisms are widely used throughout different industries.

Figure 38: examples of pivoting arms and sliding arms

After comparing both mechanisms, the 2 pivoting arms mechanisms appears to be the best for the SCO area. There are multiple reasons why this is the case. First, because this mechanism allows people to start walking through the gate while the arms are still opening, as opposed to the sliding doors that people cannot pass before it has opened widely enough for them to fit through. Secondly, the pivoting arms need no room at the left and right sides of the gate, allowing them to be placed more easily in a store. Third, the mechanism has a certain *flow* to it, almost as if it gestures you 'welcome' or 'goodbye'. It is reminiscent of closing and opening human arms. The sliding doors have more of a guillotine movement which feels cold and robotic. Lastly, pivoting arms are a lot more intuitive and easier to push open in case of an emergency, or when the gate closes too early. A full comparison between the two can be found in Appendix G.

It can be concluded that 2 pivoting arms suit the gate and SCO area the best and is therefore the best mechanism to integrate.

To conclude: how do we make the best gate?

A full program of requirements and wishes can be found in appendix H.

In this chapter many things have been concluded about what makes and what would make a gate function the best. If we distil these conclusions, we get our design goal. The design goal describes what the gate should be capable of to be the best possible gate out there. The design goal is as follows, in no particular order:

1. All customers should be able to use the gate without exceptions. The gate is easy to understand so that it is easy to use, preventing frustration.
    - This achieved by removing as many tasks for the user as possible so that there is minimal room for mistakes. By using universally understood colours the gate communicates to the user whether he/she is allowed to pass or not. This communication is combined with sound and animations so that it is multi-layered. Multi-layered communication ensures that disabled customers can always pick up at least one layer if they are unaware of the other layers due to blindness, colour-blindness, being deaf, etc. Also, by making the gate wide we ensure we include customers with vehicles like scoot mobiles or wheelchairs.
2. The gate supports the host in keeping the SCO area under control, so that he/she has more time to be hospitable and help customers. It supports the host, is does not replace it.
    - Firstly, this is achieved by clear communication between gate and customer, preventing hold-ups caused by confusion. Secondly, the gate informs the host about situations that need attention through lighting and sound. For example, when someone forces the gate open, red light shows and an audio alarm triggers. This way the host what is happening even when he/she has his/her back turned, and it demotivates thieves so that even more control is gained.
3. The gate supports shopping in the store as a customer-friendly, pleasant, and seamless experience.
    - On top of good communication, the gate enhances hospitality by offering an always-open mode, allowing paying customers to walk through without having to show a receipt or having to wait for the gate to open. *A smart system (such as described in '1.3: Auto-passthrough system') is required for this to work.*
4. The gate is a physical barrier that communicates a sense of security and demotivates thieves.
    - A gate is a physical barrier that thieves need to pass to get away. The concept of a gate is well-known and it has been a successful barrier in stores for years. By showing green, orange and red lighting combined with sound, it is clear to customers a system is in place that checks for payment. Thieves will be aware of this and realize their chances of getting away unscathed are lower as compared to currently applied gates without lighting or alarms. The gate is impossible to climb under and difficult to jump over. By placing photocells in the front and the back of the gate we can detect movement before it has reached the gate arms. This way we can analyse whether someone is trying to free-ride off a paying customer, trying to use the gate from the wrong way around or is trying to leave the SCO area without their basket or cart.
5. The gate respects the customer and helps him/her with successfully using the gate. Wrongfully labelling customers as thieves when they make honest mistakes should be avoided.
    - This is done through a warning. Whenever someone has been standing in front of the gate for a while without the gate opening, this most likely means the customer is confused as to why the gate is not opening. We notify and explain them they did something wrong so that they can correct themselves before they decide to force open the gate out of confusion or frustration. This is done with lighting, sound and information on a projection or screen. This way the host is also notified, who can then help this customer if necessary. This way we can kindly and proactively help customers.

Non-design-goal conclusions but just as important:

1. The gate fits the Pan Oston aesthetic but is built in a way where it can be customized if needed.
2. The gate is targeted towards Albert Heijn and REWE (Pan Oston most innovative customers) since these are the most likely to be first adopters of the gate.

3. The gate is safe and CE-mark compliant (not feasible in the timespan of this thesis, but should still be designed like it is), and is able to be pushed during an emergency.
4. The gate has a structurally strong front side so it can take a hit, and is preferably not bigger than an EUR pallet so that it can easily be shipped
5. Employees have the ability to quickly use the gate without needing to force it open, for example by scanning an NFC tag
6. The gate uses a mechanism with 2 pivoting arms so that it is fast, customer-friendly, easy to use and safe.

These conclusions can be illustrated and summarized by the 3 metaphors shown in Figure 39: metaphors that summarize what the gate should be like.

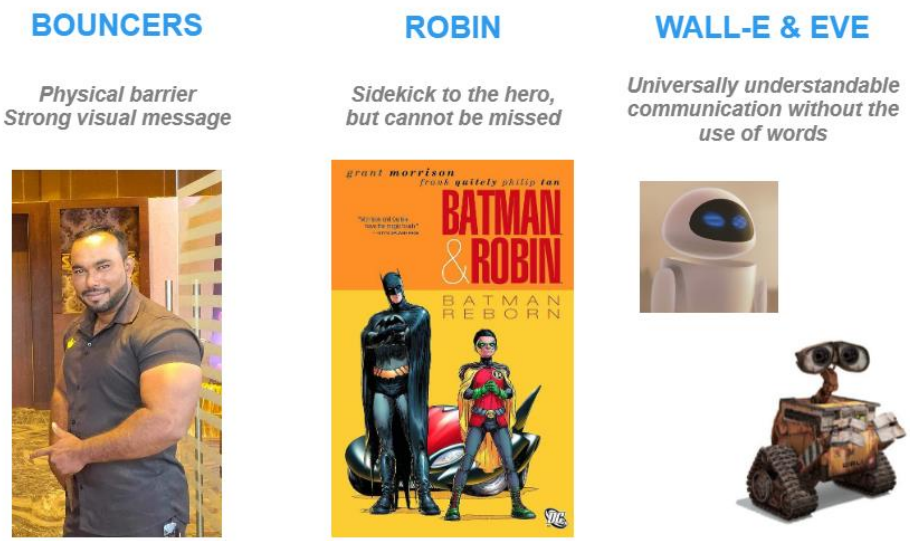


Figure 39: metaphors that summarize what the gate should be like

1.3: Auto-passthrough system

In this chapter it is described how a system is designed that automatically can determine whether customers have paid or not and letting them pass the gate or blocking them accordingly. In this chapter the system is researched and designed, concluding with a summary what the system needs to be capable of. Creating and testing of the system can be found in chapter 2 and 3.

Why should such a system exist?

Supermarkets strive to be the best supermarket so that customers come to them instead of the competitor. Customer friendliness, speed and ease of use are important factors that create this pleasant shopping experience, as mentioned before. Currently when users check out in a SCO area, they are required to scan their receipt at the gate so that they can leave the store. Having to scan your receipt seconds after you paid gives customers extra things to do which does not fit this customer friendly, speedy, and easy-to-use approach, decreasing the supermarkets appeal. Luckily for supermarkets, the majority of SCO areas use a barcode scanner, giving customers no reason to switch supermarkets. Therefore, placing a system in a supermarket which removes the need to scan your receipt makes the shopping experience better for customers, in turn making the supermarket more attractive to shop at. It would be an innovation that is in-line with the many improvements supermarkets have gone through over the years which made shopping a more pleasant experience, such as SCO areas, grocery delivery or smartphone apps.

To further demonstrate the need for such a system, a questionnaire was created to understand people's views on current SCO areas and how they should be improved in the future. This questionnaire was spread through Pan Oston and several student communities and families. Since every person is a potential customer of a supermarket, all participants give representative information. This questionnaire was answered by 83 participants. The full questionnaire and results can be found in Appendix I. One of these questions was *'After payment, would you like to be able to directly leave the store without having to scan your receipt?'.* As we can see in Figure 40: distribution 'Would you like to leave the store without having to scan your receipt?', 54,2% said 'Yes' and 7,2% said 'No'. 37.3% did not mind.

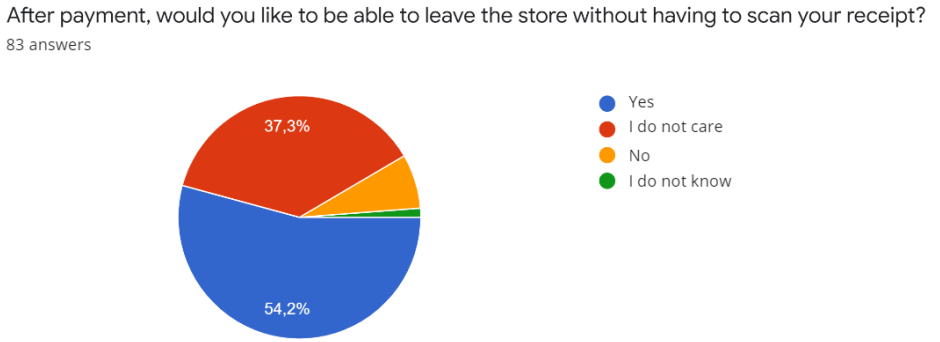


Figure 40: distribution 'Would you like to leave the store without having to scan your receipt?'

Participants had the opportunity to explain their answers. Among others, the following things were mentioned.

- *"I have already paid, why do I need to do more than that? Furthermore, I usually have my hands occupied with groceries or I already put away the receipt."*
- *"I am simply looking for convenience."*
- *"The time I gained using a self-checkout is undone by all the trouble I have to go through to open a gate."*
- *"After payment I am the owner of my groceries and therefore they have no right to stop me afterwards."*

It can be concluded that there is adequate demand for such a system due to the majority of participants caring for such a system. Similar to self-checkouts, not all customers find it necessary, but as long as it does not hinder or hurt anyone it can only improve the supermarket.

Why to design for existing stores with SCO areas and not WOT stores

In the introduction of this thesis it was described how this thesis was born out of an expected rise in WOT stores and therefore a product portfolio extension is wished for. It was also described how existing and future *normal* stores with SCO areas can be used as an immediate design case and testing ground for the introduction of a Pan Oston gate. The auto-passthrough system designed in this chapter is also designed for the

SCO area. This is because WOT stores are already set up in a way where they have systems that analyse and track customers. This is necessary to know what a customer is taking with him/her so that they can be billed accordingly. These stores already have the hardware and software in place to automatically open an exit gate when a customer wants to leave. On top of that, in WOT stores customers have provided their banking information, enabling the store to deduct customers' total from their bank account. This means anyone can just walk out and there is no check before you leave, meaning no auto-passthrough system is required.

In regular stores with SCO areas there is no such hardware or software in place, meaning a system has to be designed before SCO areas can automatically check and let people pass and thus can start to offer the same seamlessness to customers as WOT stores do. This is why the system is being designed for SCO areas.

Why to replace the barcode scanners instead of adding to them

Arguments can be made for keeping the barcode scanner that is currently used in SCO areas. For example, it can function as a back-up if the system does not work. However, the system is best designed in a way where there is no more barcode scanner. There are multiple reasons for this:

- An auto-passthrough system is superior to a barcode scanner because it removes steps and it checks customers automatically. The system should not be applied before it functions correctly, and if it does, there is no reason to keep the barcode scanner.
- Having an auto-passthrough system in place but still having a barcode scanner in sight is confusing. Customers are used to scanning their receipt and will likely still try to do so, even if the gate is already open and signalling that they are free to leave.
- It is a statement for Pan Oston, showing to the industry that they have a seamless, customer-friendly system that can *replace* the barcode scanner without using biometric technology. 'Replacing' sounds a lot more attractive and advanced than *adding to*.

In the end it is up to Pan Oston's customer. If the customer wants a barcode scanner next to it, Pan Oston will deliver that. However, if a customer does want to replace the barcode scanner, Pan Oston should be able to deliver. They are not able to if the system is designed in a way where there is always a barcode scanner to fall back upon.

Why biometric technology should not be applied

Modern biometric technology is very powerful and is useful for a wide variety of applications. Examples of biometric technology are face recognition, posture tracking, voice recognition and emotion recognition. These technologies usually work through artificial intelligence which analyses data provided by a sensor, usually a camera. This way complicated tasks can be automated such as recognizing faces or recognizing suspicious behaviour through posture and emotion. These technologies were originally mostly applied in high-security areas like airports or nuclear facilities, but they have found their way into everyday life. Face recognition and fingerprint readers are used for unlocking phones and home assistants like Amazon Echo or Google Home listen for our voice and recognize what we are saying. WOT stores are also an example of biometric technology playing a role in everyday life.

Over the past years awareness regarding privacy has been growing. People are starting to realise how much of their behaviour is being tracked and how much data is saved, often expertly hidden from them (Hazari & Brown, 2013). For supermarkets, this is no different. In the aforementioned questionnaire questions were asked about participants' opinion on face recognition technology applied in the supermarket. One of the questions in the questionnaire was '*If face recognition enables me to leave the supermarket without having to scan my receipt, I am OK with this'.* This question was repeated for personalised face recognition (meaning the store knows who the customer is) and anonymized face recognition. Interestingly, the amount of people disagreeing with the use of the technology jumps from 57.0% to 18.6% when the technology is anonymized as seen in Figure 41.

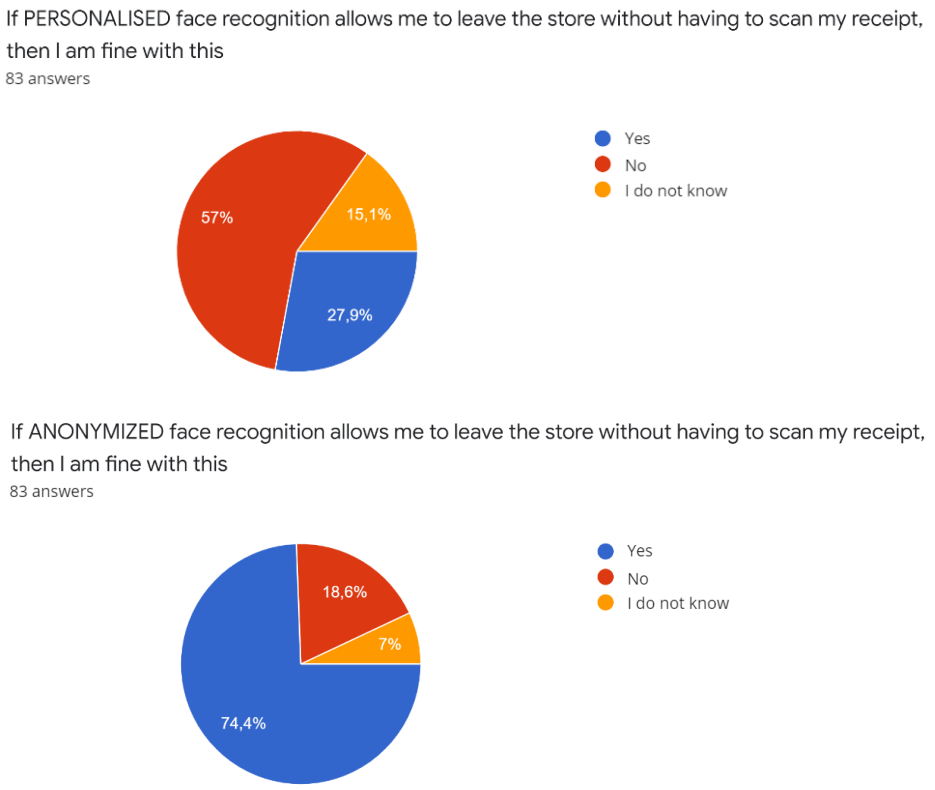


Figure 41: difference in customers' opinions between personalized and anonymized face recognition

18,6% is by far not a majority so the argument could be made that applying anonymous face recognition in supermarkets is viable. This is not the case, however. Problems are created when we factor in the factor of choice. Biometric technologies can be used for phones, smart homes and WOT stores because people *can choose* whether or not whether they want to take part in it or not. In fact, these technologies are heavily legislated under the General Data Protection Regulation (GDPR) so that you need to give written approval to for example Google before they can start analysing and tracking you. This is what the Terms and Conditions are for (which most people agree with without reading). You value your privacy? Then you don't buy a Google Home or you don't visit a WOT store. The ability to choose gives these technologies a right to exist. But for the supermarkets in which this auto-passthrough system will be placed, this does not apply. This is because people are dependent on supermarkets for groceries. People will have to come to the supermarket and in turn will have to use the auto-passthrough system that would be placed in the supermarket. Since the system determines whether people have paid or not and this being crucial information for the supermarket, customers cannot avoid having to use this system (if they use the SCO area). Thus, if biometric technology is applied in a supermarket and 18.6% of customers decides not to come anymore, that is a massive hit for a supermarket. In theory this 18.6% could still let their groceries be delivered so that they don't have to visit the store but of course this is a solution that benefits no-one. The decrease in shoppers will be lower in rural areas where there is only 1 supermarket to choose from, but this is still no argument for biometric technology since the relationship between customer and supermarket is so important. Leveraging the lack of supermarkets besides yourself is bound to make your customers start disliking you, which is not good for the customers nor the store. You simply cannot apply biometric technology in a store people are dependent on.

An extensive comparison between biometric technology and non-biometric technology and more justification for the choice of not applying biometric technology can be found in Appendix J.

Seamlessness means running in the background

The system is designed for supermarkets. Like just mentioned, this is an environment where people are dependent on, especially in rural areas where there are less supermarkets to choose from. This means that everybody in the store has to be able to use the system and be comfortable with it, making it so that we cannot rely on customer-loyalty cards or smartphone apps since not all customers have or even want these. The only real way to successfully and seamlessly apply an auto-passthrough system is to make it run in the background. This way, no extra tasks are generated for the customer, meaning they cannot make any errors, and maximum seamlessness is retained. Because we are not analysing customers based on their personal features, we do not need to worry about GDPR and do not need permission from the customer, further enhancing seamlessness.

Making carts and baskets smart

To achieve this, we need something we can differentiate customers with and this 'something' should be used by all customers. The solution: baskets and carts, seen in Figure 42 and Figure 43 respectively. Everyone is familiar with using a basket or cart and they are already designed so that everybody can use them. If the baskets and carts can somehow be tracked and identified, it is known which carts and baskets have been past a self-checkout and which have not. We then also know when a basket or cart is approaching the gate, after which we can check for payment and let them pass or block them accordingly.

Figure 42: widely used supermarket basket

Figure 43: shopping cart

There are comprises we must make however to let such a system run efficiently in the background without using biometric technology. One downside is that groups of people shopping together are now limited to one cart or basket per group. Having one cart/basket per group makes it easier to track whether they have paid or not and let them pass the gate accordingly. If groups would have multiple carts and/or baskets we need some sort of way to know which carts/baskets belong together, which is best done with autonomously by cameras if we do not want to give the user extra tasks like typing group size into a computer. Cameras are not an option due to aforementioned GDPR and public awareness issues. Having to only account for 1 basket or cart per group makes the system a lot more predictable because we do not have to account for any wandering carts or baskets that are not located near the other carts or baskets in the same group. This is especially difficult to account for when trying to figure out which cart or basket is paying at a SCO or is trying to leave the SCO area. The assumption is made that groups generally do not shop with multiple carts and/or baskets anyway, making this requirement not much of a problem.

Another compromise is that it is now mandatory for customers to use a cart or basket if they want to make use of the self-checkouts. Mandatory carts or baskets were also the case during the COVID-19 pandemic which worked well for Albert Heijn, stated by their Format Manager (R. Bakker, email, 14/4/2022). Making it mandatory for an auto-passthrough system would be less strict than during the pandemic since during the pandemic *everybody* needed a cart or basket, whereas for this system only one basket or cart is needed *per group*.

To understand customers' opinion on a mandatory cart or basket, a follow-up questionnaire was sent to participants of the aforementioned questionnaire who were open to more questions. 22 participants gave their opinion of which 86,4% have no issues with a mandatory basket or cart if that means that they can leave the SCO area without scanning a receipt, see Figure 44.

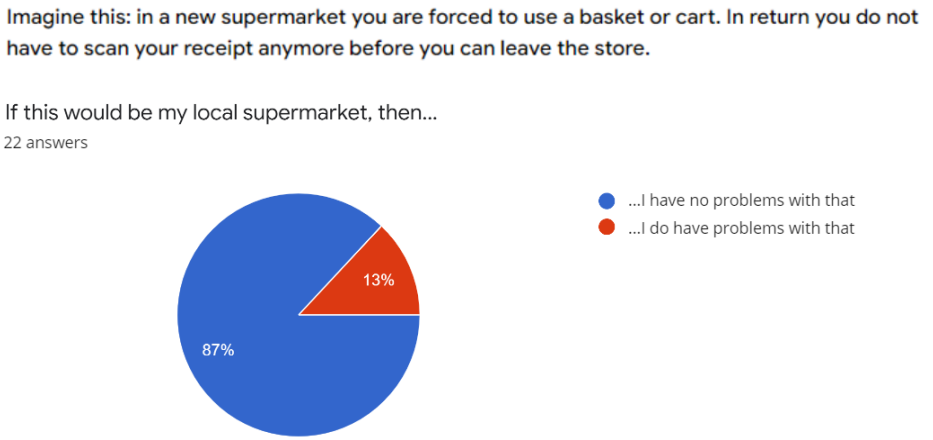


Figure 44: distribution of answers on whether have problems with a mandatory basket or cart

To conclude, it is possible to create a non-biometric system that knows which customers have paid and which have not and let them pass the gate accordingly. This is done by integrating identifiers into the carts and baskets of the store so that they can be differentiated. Whenever a cart or basket have been at a SCO for some time and this SCO has received successful payment, this cart or basket is listed as 'paid'. Whenever such a cart or basket would use the gate, they will be let through accordingly. Whenever an 'unpaid' cart or basket approaches the gate, it would block this person. For this system to work, all SCO area users are obliged to use a cart or basket, and groups are limited to 1 cart or basket per group.

The alternative to biometric technology: RFID and BLE

The technologies that can make the aforementioned system feasible are Radio Frequency Identification (RFID) and Bluetooth Low Energy (BLE). Both technologies rely on radio waves for communication and are already widely used for indoor applications. Well-known examples are anti-theft gates for RFID and smart tags such as the AirTag for BLE, shown in Figure 45 and Figure 46 respectively.

Figure 45: RFID gateway

Figure 46: Apple AirTag

What is RFID and how can it be applied?

RFID works through a transceiver that emits radio signals. These radio signals are absorbed by a microchip on an RFID tag which gives it enough energy to emit its own radio signals. These signals are then interpreted by the transceiver. The data on the RFID tag is now read. This is visualized in Figure 47.

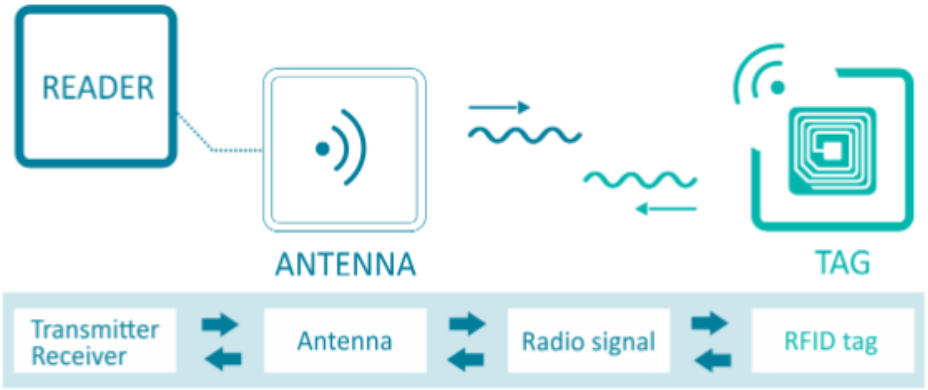


Figure 47: explanation of RFID (source: https://www.aucxis.com/en/rfid/rfid-technology)

Using this system, it is possible to identify any RFID tag that passes a RFID transceiver. A transceiver is usually applied in the form of a gateway shown in Figure 45or as a ceiling-mounted antenna as shown in Figure 48, although this is more expensive (D. Hofsté, conversation, 28/3/2022).

Figure 48: NEDAP ceiling mounted RFID transceiver

Because we can identify RFID tags whenever they are in the RF field emitted by the transceivers, we know that they are present in this field whenever they are identified. If we attach RFID tags to the carts and baskets, we can distinguish them. If we place RFID transceivers at every SCO and at the gate, we can determine which carts or baskets are near them. This knowledge can then be used to automatically determine who has been at a paid SCO and who has not, as explained in Figure 49.

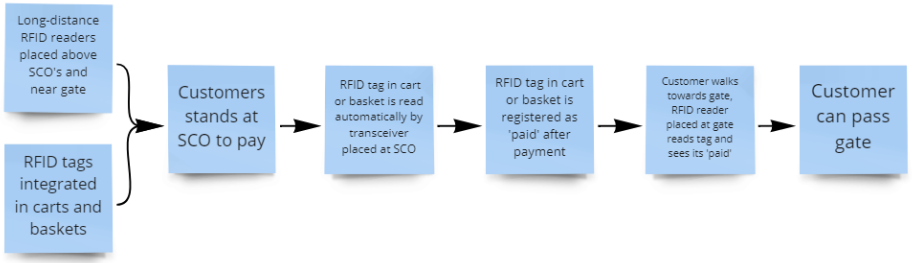


Figure 49: steps to autonomously check a customer using RFID technology

The downside of this system is that we need a transceiver as shown in Figure 45 or Figure 48 at every SCO and at the gate. This is incredibly expensive as these transceivers can easily cost €2000 each (D. Hofsté, conversation, 28/3/2022). Since SCO areas can easily have 10 SCO's, the cost of such a system is more than €22.000 in RFID hardware alone.

These transceivers are also difficult to nicely integrate into the SCO area. Because enough energy needs to be emitted for the tag to emit its own signal and because the distances to be travelled are relatively long (around 1 to 2 meters), large antenna are needed, making these transceivers large in size. Floor space needs to be sacrificed to place the gateways, or ceiling-mounted transceivers need to be used which are more expensive.

What is BLE and how can it be applied?

Another possible technology is BLE. BLE is the low energy variant of Bluetooth. It is able to use low amounts of energy by sending information at relatively long intervals, usually around 100-1000 milliseconds. By not sending information more often than needed and by not using sending out a signal stronger than needed, energy is preserved.

BLE is often used for so called 'beacons'. These are small Bluetooth-capable devices that send out the same packet of information over and over. Because it only sends information and does not have to listen or process any information, it preserves energy. It is a form of one-way communication very comparable to a lighthouse on a beach: it always sends out light for ships to see, but it has no idea whether any ships are present, and the ships do not send the lighthouse anything.

The information sent out by BLE beacons can then be interpreted by Bluetooth receivers. They can read the information in the message meaning they can identify the beacon and read any other message the beacon sends out. On top of that, the receiver can determine the signal strength of the message sent by the BLE beacon. The higher the signal strength, the closer the beacon. This is very useful and gives BLE the possibility to know a beacon's *proximity*, whereas RFID reader can only know whether a RFID tag is *present* or not. This offers great possibilities like approximating movement of direction or triangulation a beacon's position. A successfully applied use case of beacons are the table identifiers McDonald's uses to locate customers in their restaurant, seen in Figure 50. The signal broadcasted by these devices is received by receivers placed in the store, after which this signal is triangulated, allowing the location of the customer to be known.

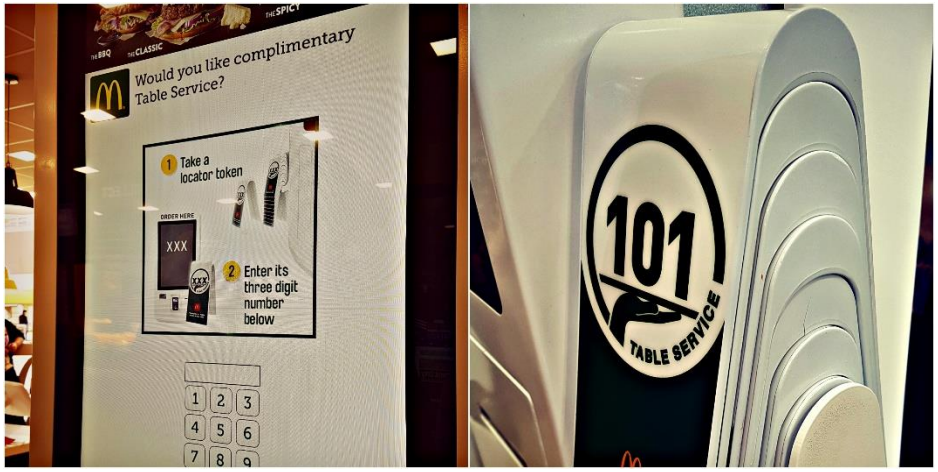


Figure 50: McDonald's TableTents that determine the location of customers so food can be brought to them

The features of BLE give the possibility to track carts and baskets within the SCO area based on real-time movement or proximity detection, as explained in Figure 51.

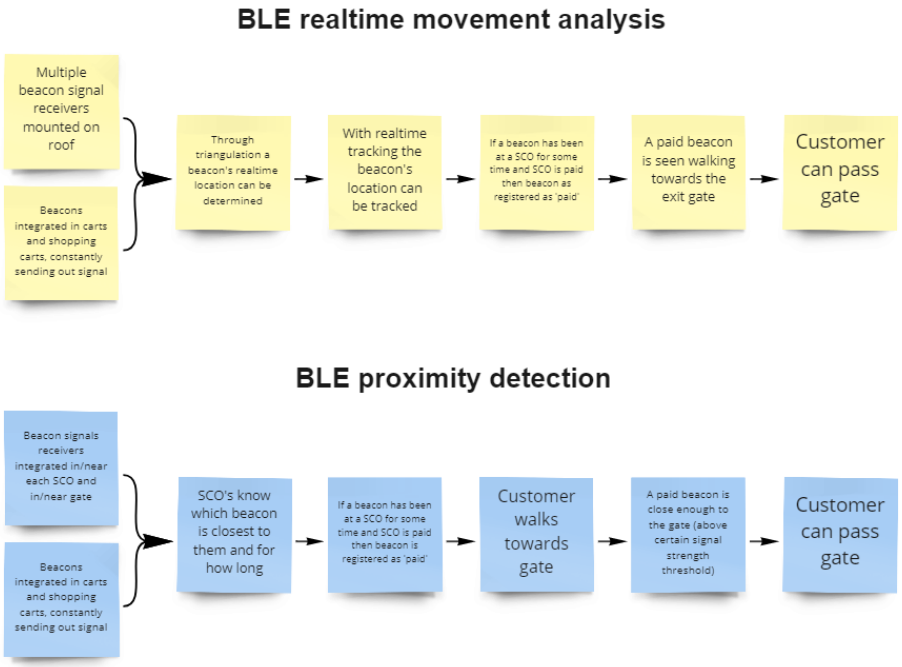


Figure 51: ways to use BLE to enable an auto-passthrough system (triangulation and proximity)

Real-time movement tracking can be done through triangulation. This means that with a minimum of 3 signal receivers the signal strengths of 1 BLE beacon can be compared, after which the location can be approximated. This is similar to how GPS works. This would only require at least 3 BLE receivers, saving hardware costs. However, because a triangulation software is required this system is much more complicated and error-sensitive than the alternative, which would be placing a BLE receiver in every SCO and the gate, looking only at the signal strengths without doing triangulation. This is viable because Bluetooth is a low-cost accessible technology making the hardware affordable. This way it can be determined to which SCO a basket or cart is closest by simply comparing signal strength values. The gate could then decide what to do with someone if their signal strengths meet a certain threshold, meaning that this person is close enough to the gate so that the gate needs to do something.

Figure 52: stackable restaurant pagers that charge while stacked

The downside of BLE beacons is that they require batteries to function. Although these can last up to years (Ciurkot, 2022), they will still need to be replaced eventually. The power with which signals are emitted and the interval between messages will influence battery life. If changing batteries appears to be a problem, the baskets can be charged while stacked in a similar way to how restaurant pagers are being charged while stacked, seen in Figure 52.

Which option is best?

If we compare a system based on RFID transceivers that can only detect the presence of a cart or basket with a system based on BLE that can also detect proximity, the BLE system wins. Even though RFID transceivers work incredibly quickly and reliably (D. Hofsté, conversation, 28/3/2022) which is also proven by the clothing industry where they are widely used, the ability to analyse proximity instead of only presence adds a lot of robustness to the system. The system will not be limited to RF fields emitted by RFID transceivers but can instead rely on BLE signal which easily reaches 20 meters and can reach up to 100 meters (Bertuletti et al., 2016), giving the system more time to makes its decisions. A comprehensive comparison between RFID and BLE can be found in Appendix K.

Triangulation or proximity?

Within BLE there is still a choice to make: whether to apply triangulation, or solely rely on proximity derived from signal strength. Although a triangulation system is easier to install since we only need 3 receivers on the ceiling instead of 1 receiver integrated in every SCO and the gate, it is likely that the system will introduce too many errors. It relies on signal strengths to determine a location of a BLE beacon, but the signals strengths are influenced by whether a human body stands between the beacon and receiver, as seen in Figure 53. Human bodies absorb signal, causing a lower measured signal strength. This misleads a triangulation system causing it to display a wrong location. Since humans move around all the time in a SCO area, this is a real problem. This is why a proximity system is better: by strategically placing the BLE receivers at the SCO's, we make it difficult for human bodies to obstruct the signal, allowing for more

predictable and consistent readings, as also seen in Figure 53. A BLE receiver located on a SCO is also much closer to where the cart or basket will be placed as compared to a BLE receiver placed somewhere on the ceiling in the middle of the SCO area. This is likely to increase measuring accuracy. By going with a proximity detection instead of triangulation we lose the location information, though. The assumption is made that this not a showstopper, since all that needs to be known is whether someone has paid or not and whether someone is trying to pass the gate. A proximity system can provide this information.

Figure 53: signal affected by human bodies

BLE proximity proof of concept

Since Bluetooth is a low-cost, accessible technology it is possible to build a functional BLE proximity system within the timespan of this thesis. To do this, multiple ESP32 development boards (Figure 54) were bought and explored. These boards are cheap and have built-in Bluetooth and Wi-Fi capabilities. They support BLE technology, making them the perfect development board for this project. The ESP32 is similar to an Arduino and is coded in the same language as Arduino, but it is less accessible and less well documented. Even with no previous ESP32 experience or knowledge, a BLE proximity proof of concept was achieved as seen in Video 1 and Video 2.

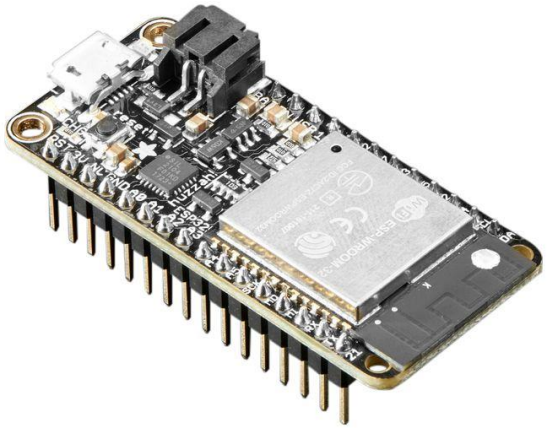
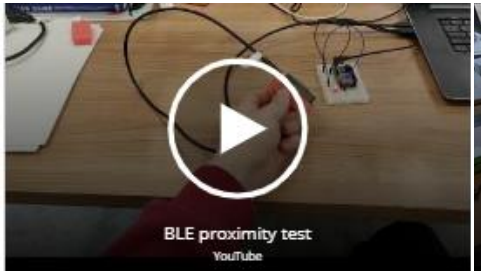


Figure 54: ESP32 used for all BLE prototyping



Video 1: BLE proximity test

Video 2: 1 meter proximity BLE test

In Video 1 can be seen how a red LED lights up if the proximity is above a certain threshold. Video 2 proves that this also works long range (the same LED can be seen lighting up on the corner of the table). In this video, the LED triggers when a basket with a BLE beacon is roughly within 1 meter range.

These videos prove that a system can determine the proximity of a BLE beacon and can make decision accordingly (in this case turning on a LED). We can conclude this is a technology we can continue development with.

Conclusions: what should a BLE system do and how should it be applied?

A full program of requirements and wishes can be found in Appendix L.

In this chapter many insights have been gained regarding how an auto-passthrough system should function so that it functions in the best possible way. If we list these conclusions, we get the following overview (in no particular order):

1. An auto-passthrough system enhances the customer-supermarket relationship because it creates a seamless, customer friendly experience. It improves the current situation which is regularly experienced as a hinderance.
    - This is because such a system removes the step where customers have to scan their receipt seconds after they paid. This is experienced as a hinderance by customers as shown in a questionnaire answered by 83 participants. The majority of participants (54,2%) would like to walk out of the SCO area directly after paying.
2. An auto-passthrough system should only be designed for regular stores with SCO areas, not for WOT-stores.
    - WOT-stores are set up differently than regular stores with SCO areas. WOT-stores do not require the design of such a system, as they already have a smart system in place that continuously tracks and checks customers. This removes the need for checking customers before they leave, since everything about the customer is known, including banking information.
3. The system *replaces* the barcode scanner, it does not *add to it*.
    - This is most important because Pan Oston needs to be able to deliver such a system if a customer asks for it. This is also important because it prevents confusion and it makes Pan Oston come across more innovative than if the barcode scanner was still there.
4. An auto-passthrough system used in regular stores with SCO areas should never use biometric technologies.
    - This is because people are often dependent on these stores. Especially in rural areas where supermarkets are scarce, people have no choice in at which supermarket they shop. By placing biometric technology in such a store you force your customers to take part in it. Not all customer will be okay with this, especially due to increasing public awareness regarding privacy. 18,6% of questionnaire respondents would not be okay with biometric technology in their supermarket, even if it is applied anonymously. Ignoring this disapproval is bad for the customer-supermarket relationship which is very important for the supermarket industry.
5. Because the system is placed in regular supermarkets where people are used to a certain routine and way of shopping, minimal to no steps should be introduced and the system should be as seamless as possible.
    - This is achieved by letting everything run on the background and instead of tracking people, we track the carts and baskets in the store. This comes with the comprises that using a cart or basket is now mandatory and that groups that shop together are limited to using one cart or basket. The questionnaire shows that the majority of respondents (86,4%) has no problems with this.
6. By use of BLE technology we can track carts and baskets within the SCO area using proximity detection and determine who has paid and who has not and let them pass the gate accordingly.
    - We attach BLE beacons to all carts and beacons. The beacons send out a signal in intervals which is interpreted by BLE receivers located at all SCOs and the gate. These receivers can read the unique ID of the cart or basket and based on the signal strength the proximity of the cart or basket is known. When a cart or basket has been very close to a SCO for some time and this SCO has received successful payment, this cart or basket is registered as ‘paid’. When this cart or basket approaches the gate this is recognized because the signal strength reaches a certain threshold meaning a customer is close, after which it is checked whether this cart or basket has paid or not. If so, the customer is let through. If not, the customer is blocked.

CH2: Prototype & testing

In the previous chapter a lot of conclusions were made regarding what a gate and auto-passthrough system need to do and be capable of so that they will be successful products. Some of these conclusions are facts like how important customer-friendliness is for a store, but other conclusions need more data like how important good communication is. What is good communication? In this chapter research is done using prototypes so that it is better understood how the information gained in chapter 1 applies in the real world.

What should be tested?

In Table 1 an overview can be found of all things that should be tested to gain the knowledge to create a good final design. To do these tests, we need 3 different prototype elements:

1. A working gate with 2 arms
2. BLE beacons and BLE receivers
3. Communication system to be able to test communication between the gate and customers, and to test whether the host can understand what is going on at all times.

#	What tests will be done?	Who will be needed to test it?	#	What tests will be done?	Who will be needed to test it?
1	How well do people understand the following combination: 1. Using green/orange/red light 2. Green light brightness gets brighter as person approaches 3. Sounds corresponding with relevant situation (go/no go, etc.)	1. Jesse (checking set up, instructing participant) 2. Random Pan Oston employee 3. Questions/questionnaire afterwards	**5**	How is the signal of BLE sender in a basket/cart influenced by groceries and humans? Based on this, what is the best position for a BLE receiver (or multiple) at SCO's and the gate?	1. Jesse 2. Random Pan Oston employee(s)
2	How well do people understand the following combination: 1. Using green/orange/red light **that is animated** 2. (Possibly: animation gets faster when someone approaches) 3. Sounds corresponding with relevant situation (go/no go, etc.)	1. Jesse (checking set up, instructing participant) 2. Random Pan Oston employee 3. Questions/questionnaire afterwards	**6**	Based on BLE sender signal strength, can a SCO automatically detect which basket/cart belongs to the person paying at the SCO? Can this still be reliably done if multiple other baskets/carts are closeby?	1. Jesse (checking set up, instructing participant) 2. Multiple random Pan Oston employees
3	How well do people understand the following combination: 1. Using green/orange/red animations projected on floor 2. Sounds corresponding with relevant situation (go/no go, etc.) 3. How well can the projection be seen? What is this dependent on? Do people instinctively look at the projection area? Does it add anything compared to LED lights?	1. Jesse (checking set up, instructing participant) 2. Random Pan Oston employee 3. Questions/questionnaire afterwards	**7**	Can a host easily hear the sounds of the gate, and see the lights that come off it? Is this obstructed?	1. Jesse (checking set up, instructing participant) 2. Multiple random Pan Oston employees 3. Questions/questionnaire afterwards
4	Can the gate consistently be opened/closed based off basket/cart signal strength? Is customer guidance needed for this?	1. Jesse (checking set up, instructing participant) 2. Random Pan Oston employee	**8**	Can the gate slow down someone who is trying to steal?	1. Jesse (checking set up, instructing participant) 2. Random Pan Oston employee

Table 1: tests that need to be done and who/what is needed to do them

Overview of built prototype

These 3 elements were built and combined into 1 functional prototype existing out of re-used Eco gate hardware, wooden frames, cardboard, and hobby electronics. This prototype was subsequently used to do user tests and trial-and-error testing and improvement. Figure 55 shows this finished prototype.

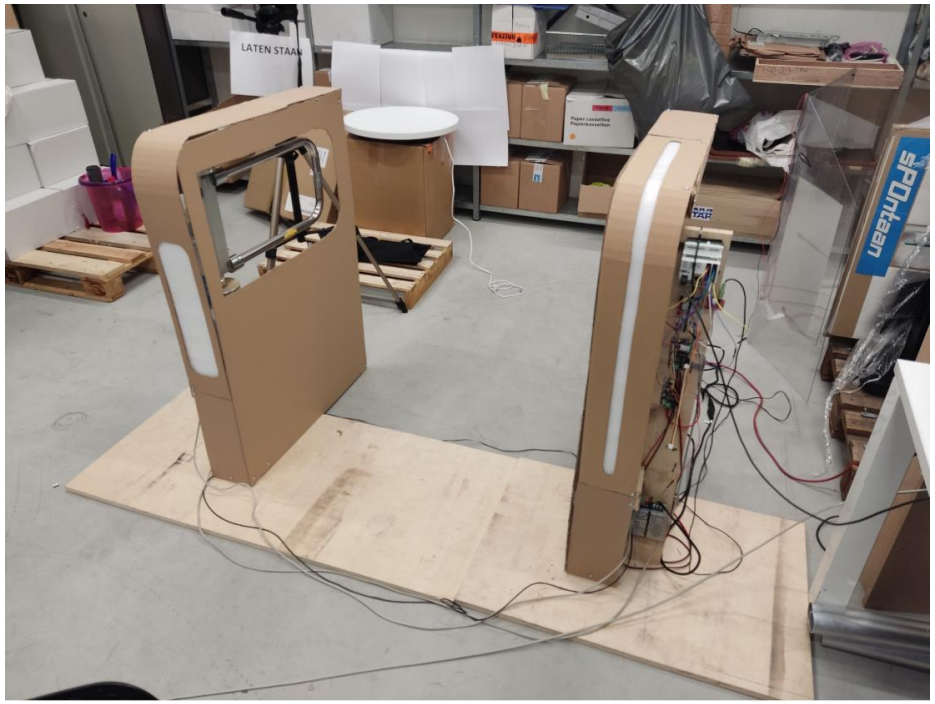
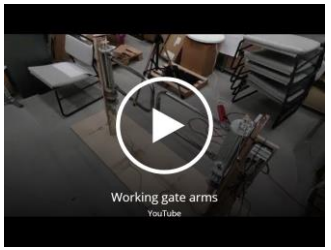


Figure 55: prototype built from recycled Eco gate assemblies, wooden frame, and cardboard

The prototype uses a Controllino MAXI development board which controls two gate motor assemblies that were recycled from old Eco Overgate 4.0 gates. The existing electronics were ripped out of these assemblies and replaced by Arduino-controllable 24V motor controllers (Figure 56). By connecting potentiometers (Figure 57) to the same axis of rotation as the gate arms, we always know the position angle of the arms. The working skeleton of the system is shown in Video 3.

Figure 56: 2-way DC motor controller

Figure 57: potentiometer



Video 3: working gate arms

An overview of how the electronics communicate with each other can be seen in Figure 58. The ESP32 boards communicate with each other using ESP-NOW, a built-in protocol that can rapidly send messages between ESP32 boards using Wi-Fi technology. Because ESP32 boards use the same antenna for Bluetooth and Wi-Fi, it is not stable to let an ESP32 board listen for ESP-NOW messages and listen for BLE signal at the same time. Listening for BLE signal and *sending* Wi-Fi signal is not a problem. This is why there is a dedicated ESP32 placed at the gate which only listens for BLE signal. Whenever a BLE beacon is close enough it notifies the *other* ESP32 belonging to the gate (ESP-NOW master), which in turn decides to let the person through or block him, after which it informs the Controllino of its decision.

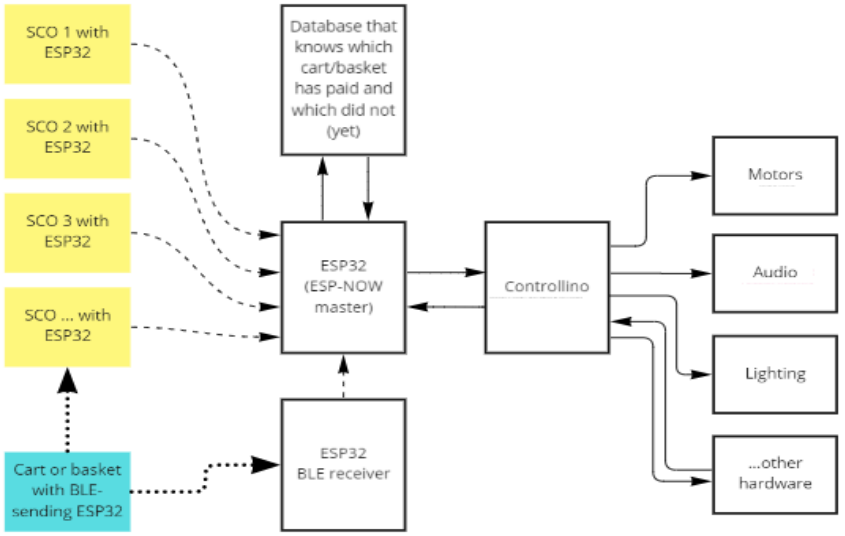


Figure 58: overview of prototype electronics and communications

2.1: Gate

Test set-up

In Figure 59 and Figure 60 the test-setup can be seen. This setup was used for all tests. In figure a small ‘store’ can be seen that gives the impression of being in a real supermarket. Next to this is the ‘SCO area’ with a wooden block functioning as a SCO. The exit of the SCO area is the gate seen in Figure 60.

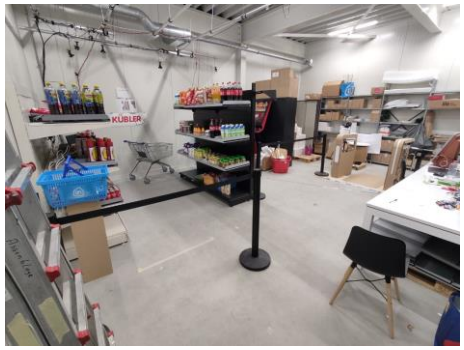



Figure 59: complete test-setup area with store, fake SCO, gate *Figure 60: prototype*

Communication

Based on the conclusions found and the brainstorms done in 'Universal understandability and ease of use’ three variations of communications were thought of as seen in Figure 61.

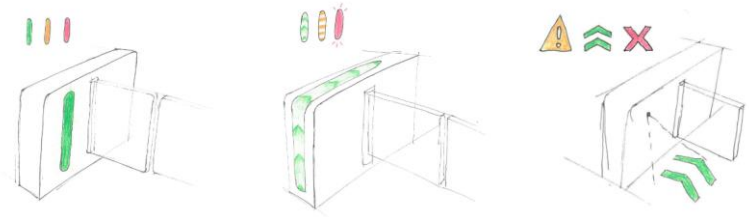
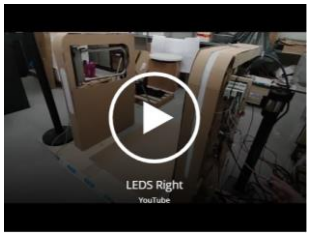
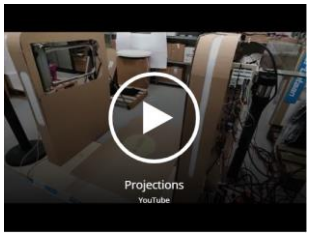


Figure 61: three forms of communication built into the prototype

These were built into the prototype and their different situations were programmed. These are ‘free to go’ (green), ‘warning’ (orange) and ‘alarm’ (red). These 3 ways of communication can be seen in Video 4, 5 and 6.





Video 4: LEDs left *Video 5: LEDs right* *Video 6: Projections*

On top of the visual communication, audio was created using synthesisers (Figure 63) to accompany the light and to achieve the multi-layered communication discussed in ‘Universal understandability and ease of use’. These sounds can be listened to by clicking Figure 64.

The colours are difficult to see correctly on video, so in Figure 62 you can see a representation of what they look like in real life.

Figure 62: representation of colours used in the prototype

Figure 63: creating sounds

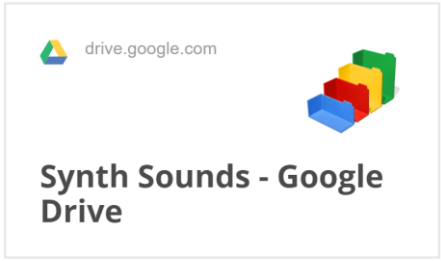


Figure 64: link to sounds that were made

To find out what form of communication works best, user tests were done with 20 participants, all of which random Pan Oston employees. Participants were asked to walk through the gate whenever they thought they were allowed to do so. They were also asked to think out loud. Intermediary questions were asked based on their thoughts to get a better understanding of their reasoning. The gate was controlled by a button instead of automatically based upon the proximity of the basket, because this is more consistent and would ensure that the tests do not vary in execution. The test followed to following sequence:

1. Green, orange and red situations are tested for the LEDS on the **left**
2. Green, orange and red situations are tested for the LEDS on the **right**
3. Green, orange and red situations are tested for the projections
4. Participant was asked whether they found the LEDs left, LEDS right or projection the most helpful
5. Green, orange and red situations are repeated for the way of communication they think is most helpful, and this time sound is added ('Confirmation1' for green, 'Warning1' for orange, 'Alarm1' for red).
6. Test is ended and questionnaire is filled in by participant.

The filled-in questionnaires of all 20 participants can be found in Appendix M. Based on the questions asked during the user tests and the questionnaires, the following conclusions were derived:

Conclusions

1. Green and red are very clear, yellow/orange is not. People often think this means there is a malfunction in the gate. More information needs to be provided, possibly through a screen or projection. They know something is wrong, they just don't know what.
2. Sound is not needed for green, but it helps with orange/red
    - For orange, it would be better if the sound doesn't trigger instantly but instead triggers after a few seconds if the person has not understood the warning signal from the orange light. This way, the orange alarm gets triggered less often and more accurately. It will make the system more forgiving, which is what we want for orange.
    - For red the sound should be more aggressive and louder. It is currently too friendly.
3. Sound helps a lot for people that are colour blind. The animated light also helps because it gives more information than only a colour. For example, a flashing red light is easier understood than a static red light. This was proven by one of the user tests done with a Pan Oston employee who was colour-blind.
4. 5 different sound will be used, for the following situations: alarm (someone forces the gate open), warning (someone has not paid), backflowing, employee is passing through, free-riding. They can be listened to here.
5. The right LED strip is the best because it is large, easy to see from multiple perspectives, easy to see by the host and it 'walks with you' in the same direction that you are walking in (even without animations)
6. People find the projector very interesting and see potential in it, but it is not bright enough. Looking at the floor is also not optimal and hard to see for a host or if you are using a shopping cart. The great advantage of the projector is that you can explain what is wrong with icons. People do not have a common opinion about how fast animations should be. The problems created by a projector can be solved by applying a screen, which will be done in the final design. A comparison between a screen, projection or audio files can be found in Figure 65.
7. People are often startled by the green LED turning on and they need a second to process what is happening. This is because they do not expect any light to turn on. The gate is open already, so they are already convinced they can leave. This time needed to process the light turning on makes it less seamless. It would be best if the green LED gradually increases in brightness and/or animation speed. This would create a less extreme switch than ON/OFF
8. Lights (and gate closing if necessary) should be done in time so you can react
9. The biggest trigger to stop walking is the closing gate, not light or sound
10. People expect/prefer the same lights to be on both sides of the gate, to create symmetry

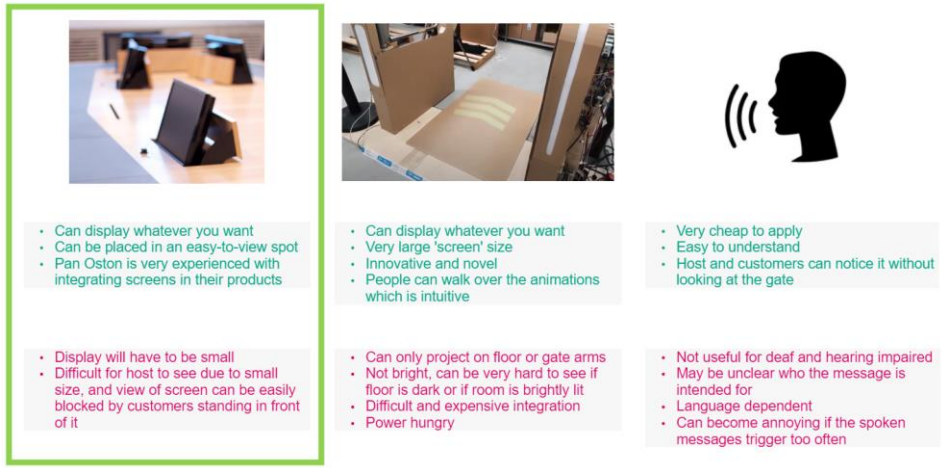


Figure 65: screen vs. projections vs. audio

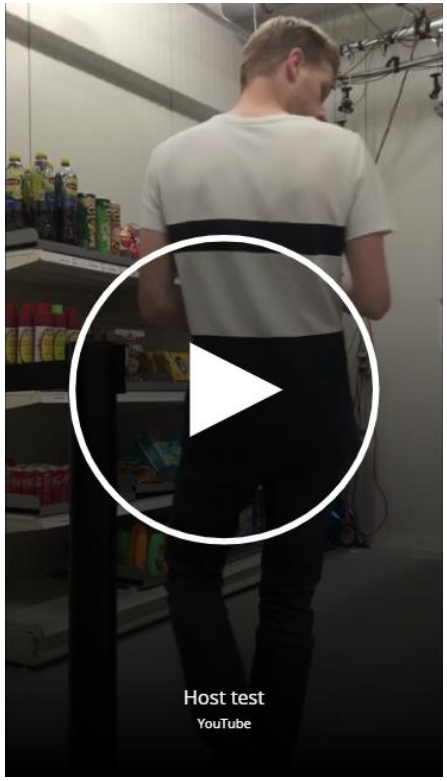
Host role

As we have concluded in chapter 1, it is very important that the gate makes it easy for the host to always understand what is happening at the gate, even when his/her back is turned. This gives the host more control and more time to be kind and hospitable. Three 'host tests' were done with Pan Oston colleagues. One of these tests was recorded and can be seen Video 7. The tests followed the following procedure:

1. Six different sounds were learned by heart. These sounds can be listened to by clicking on this link. These sounds are meant for the following situations: Confirmation that a customer is free to pass the gate, warning that a customer is trying to pass the gate without paying, alarm that the gate has been forced open, notification about employee passing the gate, warning that someone is free-riding off a paying customer, warning that a customer is trying to use gate the wrong way around. Learning the sounds by heart took around 2 minutes for each participant.
2. The participant was placed between the shelves with no view of the gate. They were tasked to play the game 'Doodle Jump' on a phone. This ensured they were busy and could not fully focus on the sounds.
3. The noise of a supermarket was simulated by supermarket noises through speakers. This can be listened to by clicking on this link.
4. The 6 sounds were played randomly after which it was checked whether the host could recognize the sound.

Based on these tests, the following things were concluded:

1. 'Employee' and 'Free-rider' are too similar. 'Free-rider' needs to be more aggressive and alarming, since it most likely means someone is trying to leave without paying.
2. The 'employee' sound is difficult to hear if you are not familiar with it but is easy to pick up if you are trained to listen to it. This is great, because customers do not need to understand it, only the host does. This is due to the sound being low-pitched and short.
3. The sounds are easily learned by heart and well distinguishable. This means they can support the host as intended.



Video 7: Host test

2.2: Auto-passthrough system

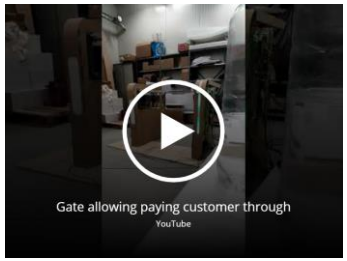
Next to all the tests done with the gate, tests were done to test and improve the BLE proximity system. The prototype BLE proximity system exists out of multiple ESP32 boards of which some are connected to the gate, some to the basket and some to the 'SCO' (represented by a wooden block). As a reminder, the system and relations between the ESP32's can be seen in Figure 58.

Proof of concepts

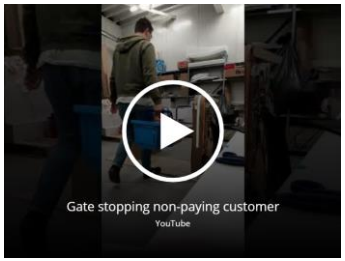
To test and improve parts of the BLE proximity system, proof of concepts were built. These are necessary to test with and improve upon, but they also function as proof that a BLE proximity system can really work.

Letting customers through and blocking them based on proximity

In Video 8 and 9 proof of concepts can be seen of the gate allowing a customer through or stopping the customer. Note how the gate starts to provide information as soon as a customer is in proximity of the gate, and only takes action when the customer has made its intention clear to leave the SCO area by coming very close. This is so that customers can correct themselves or are extra assured of their permissions to leave, as discussed in 'Universal understandability and ease of use'.



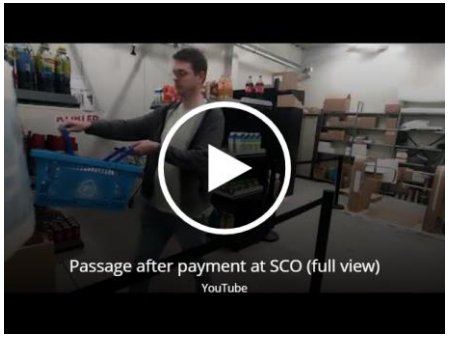
Video 8: Gate allowing paying customer through



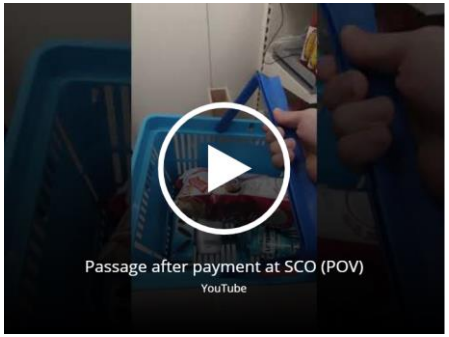
Video 9: Gate stopping non-paying customer

Blocking and letting through a customer based on whether they paid at a SCO or not

In the BLE proximity system, SCO's can autonomously detect when a cart or basket is nearby and register this cart or basket as 'paid' after successful payment. This information is then sent to the gate, which can then make the right decision when this customer approaches the gate. This is shown in Video 10 and 11. Multiple angles are provided to prove that there is not someone else in the room changing the gates' settings.



Video 10: Passage after payment at SCO (full view)



Video 11: Passage after payment at SCO (POV)

BLE Beacon placement on cart and basket

The BLE signal-emitting ESP32 is placed on the edge of the basket, in the middle of the basket as seen in Figure 67. Through trial and error this is proven to be the best location for the BLE beacon. First off, placing it on the edge of the basket allows it to still be stacked on a tower of baskets. Secondly, placing it on the edge makes it hard for groceries to be in the way of the signal. This happens when groceries lay on top of the beacon or hang over the beacon. High volumes of liquid like milk cartons are the strongest signal blockers. This was concluded from multiple tests trying out different groceries. As we can see in Figure 66, the same kind of basket is used in practically all supermarkets. The trolleys used have more variations, but all trolleys and baskets have the ridge at the sides that the BLE beacon can be mounted on. This means that a solution that is installed on the ridge will work for all baskets and trolleys.

Figure 66: almost all baskets are the same (top). Trolleys have more variation (bottom)

Figure 67: basket with BLE beacon attached

Figure 68: cart with BLE beacon attached

In Figure 68 it can be seen how the BLE beacon was mounted on a shopping cart. The BLE beacon is placed on the outside of the cart, near the front. This once again prevent groceries from blocking the signal. Because it is placed at the front of the cart, we give the system more time to react to the cart than when it would be placed at the handle part. This is roughly a meter of extra reaction time for the BLE system. Also, since children can sit in the child seat near the handle part, their body would block BLE signal coming from the handle, as seen in Figure 69.

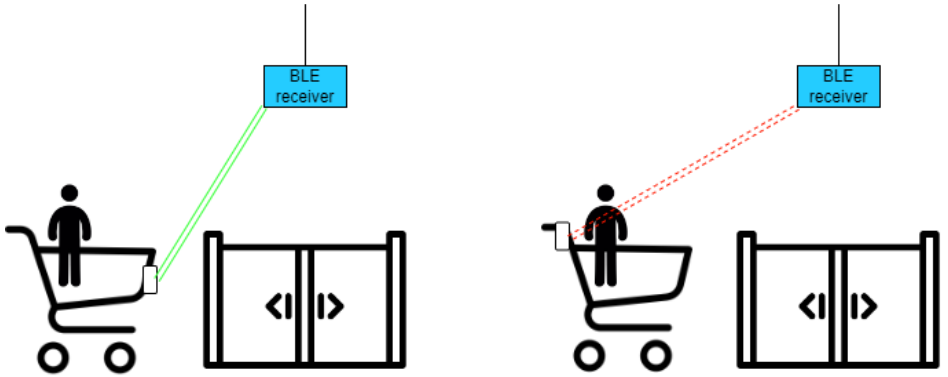


Figure 69: child influencing BLE signal

Placement of BLE receiver at gate

As we have also just seen in Figure 69, human bodies block BLE signal. This was found out after repeating the tests in Video 8 and 9 multiple times with different basket positions. When a body was directly between the BLE beacon and BLE receiver, signal strength was reduced. Because of this, the BLE receiver is placed on the ceiling instead of on the gate. This makes it harder for a body to directly block the signal, as seen in Figure 70.

However, even with the BLE receiver placed on the ceiling the signal can be blocked. This is especially the case if a customer has a basket close to his/her body and is close to the gate. This is solved by using double BLE receivers. If the signal for one receiver is blocked, we have the other to fall back upon. This problem and solution are shown in Figure 71.

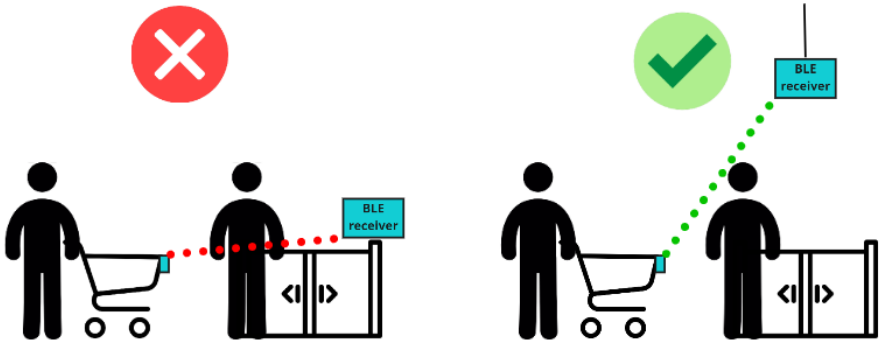


Figure 70: better BLE reception due to high placement of receiver

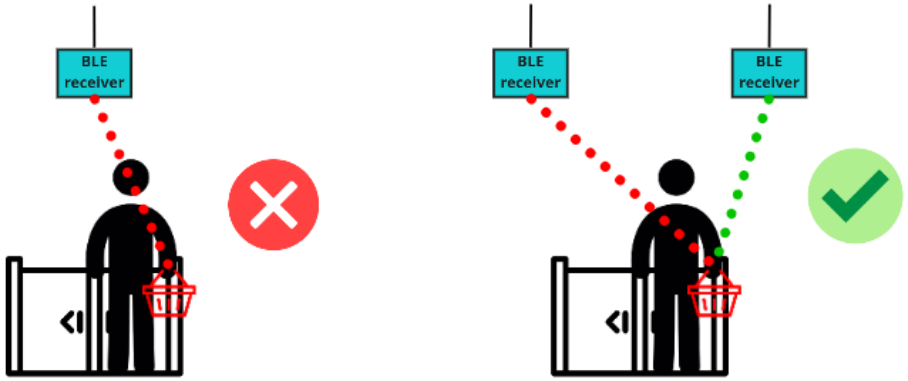


Figure 71: if one receiver is blocked, we can rely on the other

Placement of BLE receiver on SCO

The BLE receiver should be placed in the middle of the SCO with an unobstructed view. This ensures the BLE receiver on the SCO can receive a strong signal from the BLE beacon in the basket or cart so that it can determine which cart or basket is currently paying at the SCO. As can be seen in Figure 72, placing the BLE receiver at some height in the middle ensure maximum signal strength. Baskets placed on the SCO can be detected, but carts placed next to or near the SCO can be detected too.

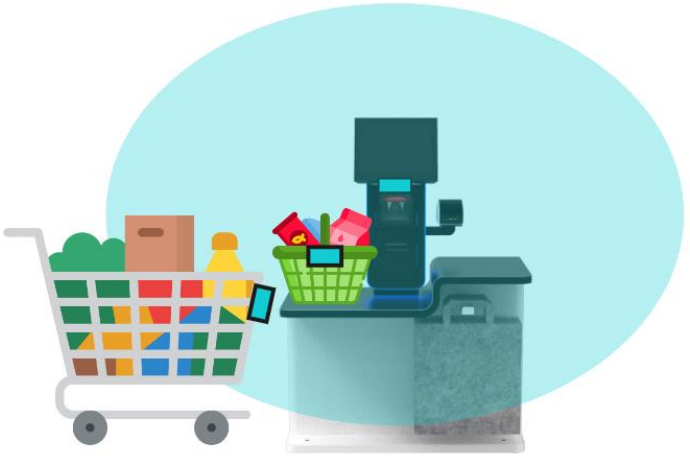


Figure 72: visualization of readable area of BLE receiver on SCO, with BLE receiver in the middle marked in light blue

2.3: Conclusions

From the prototypes that were built and the tests that were done it can be concluded that using traffic light colours for the situations 'free to go', 'warning' and 'alarm' is very well understood and that multi-layered communication using light, animations and sound support disabled customers (a test was done with a colour blind participant). The LED strip that was integrated in the prototype to the right was easy to see due to it being a long, wide strip of light that spans over 2 surfaces. It can also be concluded that the lighting and sound are visible and understandable for a host, even if he/she is occupied with another tasks and has no direct view of the gate. It is concluded that there is need for 5 sounds for 5 different situations, which can be listened to here.

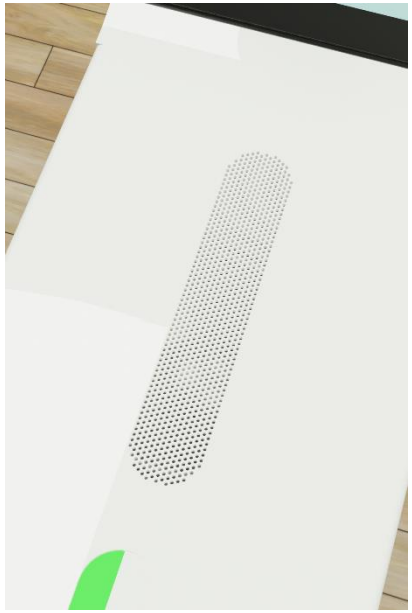
Finally, it can be concluded that a BLE proximity system works and that it can autonomously keep track of carts and baskets and in this way allow the gate to let pass and block customers accordingly. By placing BLE beacons strategically and placing BLE receivers near the ceiling in stereo, the likelihood of human bodies blocking the signal is as low as possible.

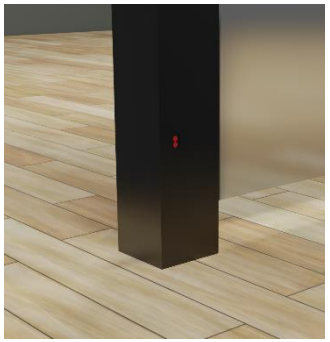
What needs to be in the final design?

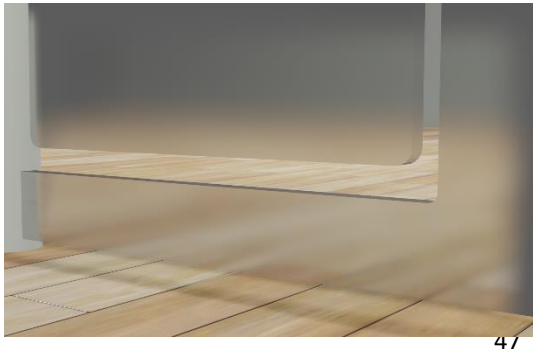
If we take all the conclusions and tests from chapter 1 and chapter 2 and we distil what parts we need to combine it all into a final design, we get the following list:

Part	Reasoning
Green LED light	To show people when they are allowed to walk through the gate. Light should be animated and brightness and animation speed should increase as customer comes closer
Orange LED light	To warn people they are not allowed to leave the SCO area yet because no payment was found. Light is static. Orange LED triggers based on proximity of non-paying customer
Red LED light	To alert staff and people around the gate that the gate is being opened by force. Triggers when the gate is forced open when not allowed
Speaker	To play warnings, alarms, and specific notifications when there is freeriding or backflowing happening or when an employee uses the gate.
Customer guidance after gate arms	This comes with the arms automatically, because they need space to be stored when the gate is open. This customer guidance allows for placing of a photocell that blocks any backflowing customers. The longer the guidance, the more time for the gate to react on a backflowing customer.
Photocell after gate arms	So that wrong direction of movement can be recognized (backflowing), and it is an extra sensor so that it is known when a customer has walked through the gate
Customer guidance in front of gate arms + photocell	So that we can know when someone passes the gate even if they do not have a basket or cart. This trigger can allow us to close the gate when someone without basket or cart is trying to leave (note that it would not trigger shortly after a paying customer has left WITH basket or cart, because they are likely to belong together).
NFC reader in front and back of gate	So that employees can use the gate without having to force it open. NFC reader should be hidden so it does not confuse customers.
2 acrylic/glass swivelling gate arms	So that customers can be let through and blocked accordingly. 2 arms close faster than one, and the swivelling movement/gesture is friendly and familiar. Transparent material allows the gate to feel spacious and open. It also demotivates kids to climb on it.
2 motors	To drive the gate arms
2 position sensors	So we know the arms' position at all times and can power the motors accordingly
PCB/Motherboard	To connect and control all components, and to be able to connect internet capabilities so we can remotely update and change settings. This is also needed to receive information from SCO's for which basket/cart have paid.
Display	So that it can be explained what is wrong when a warning is triggered, or to display any other useful information
Stereo BLE receivers	**[only needed when auto-opening system is applied]** So we know which baskets/carts are in proximity, and so we can decide who to let through and who to block.

3.1: Final Design: CLEARGATE







In the collage on the previous page the final design can be seen. It is called CLEARGATE due to it having clear communication and it creates a clear, open space. CLEARGATE's different features are shown in this collage. The final design will now be explained. No text was marked blue since everything in this chapter is important.

Colour and material choice

CLEARGATE exists out of black and white colours to fit in with Pan Oston's SLIM and BLUE FIRE product line. These are very neutral colours which means the gate can be deployed in many stores and still blend in. Making the frame of the gate black and making the front piece with the integrated LED white accentuates this front piece. This puts more focus on its shape which together with the LED communicates a movement of direction, *a flow through the gate.* The black also helps hide the photocells at the bottom of the gate and the employee NFC card reader area, which are both not important for the customer to see. Making the middle pillar white instead of black further enhances a feeling of space.

Frosted PMMA is applied to give CLEARGATE an open, spacious aesthetic. This is important to keep the SCO area feel light and spacious to not let customers feel enclosed or caged. By using frosted PMMA instead of transparent PMMA we make sure the PMMA panes are still easy to see so that we prevent customers from not seeing them and accidentally ramming into them. Frosted PMMA still lets light through and is semi-transparent, so we keep the open and spacious aesthetic.

Form and shape

The gate is made as thin as possible to strengthen a sense of space once again and to put more emphasis on the wide exit created when the gate is open. Because the gate is a lot longer than it is wide, the length of the gate is emphasized which in turn helps put focus on the movement direction. Many rounded corners are applied to fit the Pan Oston aesthetic.

Because the screen, the white front piece and LED are pointed to one direction and the other direction only has the back of the gate, which is black, the direction of movement is made even more clear, preventing people from being confused and trying to use CLEARGATE from the wrong side.

Placement of features

Photocells are placed in front and back black pillars to catch any free-riders or backflowing customers. They are not important for the customer to see, so they blend in with the black pillar. The same is true for the employee NFC readers. These NFC readers are marked by a groove as can be seen in the top right of the collage. Employees will know where they are, so it is not important that these readers stand out. On the contrary, we do not want customers to notice them and think they should do something with them.

The screen and speaker are located at the end of a white front piece. Due to the shape of this front piece and the LED your eyes automatically follow the line and end up at the screen. This screen is put under an angle so that it is easier to see and read. The speaker is placed under the screen. This draws the customer attention the area where the screen is also present and vice-versa. This increases the likelihood a customer will notice the screen in a situation where audio is needed which would often be a warning or alarm.

Wherever possible, parts are used that Pan Oston already applies in their products, like the NFC reader, photocells, LEDs and screen. This way we utilize the knowledge and partners that already exists within Pan Oston.

Customizability

The dimensions of the CLEARGATE's parts can easily be changed since we are not dependent on things like moulds for injection moulding. An example of an adaption to the gate so that it is usable from both sides can be seen in Figure 73. As can also be seen, the gate is easily placed next to each other, creating an access control wall.

Figure 73: version of CLEARGATE usable from both sides. Can be easily placed next to each other.

Because Pan Oston does their own powder coating, many different colour combinations are possible as can be seen in Figure 74. This is helpful when the gate needs to fit the colours of the store it is in, especially since supermarkets often use colours so they are recognizable (Jumbo is yellow, Albert Heijn light blue, PLUS is green, etc.).

Figure 74: steel exterior parts can be powder coated in any colour combination

Since CLEARGATE is built from sheet metal and has a lot of empty volumes, we can easily include third party hardware, whether it is integrated like Figure 75 or extra arms need to be extended from the gate like figure Figure 76. In these figures two Datalogic barcode scanners are shown, both widely used in the industry.

Price estimation

Following Ir. E.W. Thomassen's price estimation tool, CLEARGATE costs €2.017,84 to fabricate. The buyer pays €3.891,64 after overhead, profit margin and 21% VAT. No cut for middlemen is calculated since Pan Oston generally sells directly to its customers. A 20% error margin is included in the calculation. Note that this price is **without** the EZ-GO system. No good estimation for this system can currently be done as it is highly dependent on the PCB design and the cost of outsourcing the software for the system. Both are out of the scope and knowledge of this thesis.

This price is a competitive price (B. Bosch, conversation, 23/6/2022). The estimation can be found in Appendix N.

Desirability

During the annual Pan Oston International Sales Meeting, CLEARGATE and EZ-GO were presented. This is a meeting with all Pan Oston sales staff where new innovation projects are presented to the sales staff. CLEARGATE and EZ-GO were received with loud applause and the consensus was that they would absolutely sell since they solve problems currently existing at many of Pan Oston's customers.

Figure 75: mini Datalogic scanner integrated

Figure 76: arm extension with Datalogic scanner

Features and internals

CLEARGATE is designed so that it can be produced in Pan Oston's factory with minimal outsourcing. This means the gate is built up out of mainly sheet metal and hardware Pan Oston has applied before. As can be seen in Figure 77 the gate exists out of 3 main parts: the frame (black), the cover (white) and the arm-pillar (white). How the gate is built up will now be explained in detail.

Technical drawings of CLEARGATE's most important parts can be found in Appendix O.

Frame

The frame is the main part of CLEARGATE, to which the cover and arm-pillar are attached. The frame is welded into two parts as seen in Figure **78**, after which they are welded together to form the U-shaped frame. The frame is built up out of sheet metal parts that lock together with puzzle pieces as shown in Figure **79**. This makes the welder's job easier. All corners that are bent use a radius of 1.75 mm, 21 mm or 44 mm, matching Pan Oston's available tools for bending sheet metal.

Figure 78: the 2 welded structure that are combined into 1

Figure 79: sheets fit into each other using 'puzzle pieces'

Figure 77: exploded view of CLEARGATE's internals

The frame holds most of the hardware the gate needs. The power supply (Meanwell UHP 24V), Raspberry Pi, PanIO and soundboard (14W 4-8 Ohm) are mounted to a hardware plate which is easily installed into the front of the gate by means of a slot it falls into, after which it is bolted in place by 2 threaded studs ('lasbout' in Dutch). Pan Oston often works with Raspberry Pi's and have developed their own I/O board (PanIO) to be able to control motors and other mechanical devices. Therefore, these are applied in this gate too. See figure below for visual representations.

Figure 80: from top to bottom: soundboard, PanIO, Raspberry Pi, power supply

Figure 81: hardware plate neatly placed in frame

Figure 82: hardware plate falls into welded-on slot

Figure 83: plate is screwed tight on welded threaded studs

To make the frame extra stiff and more resistant to being hit by for example shopping carts, plates are welded into the front pillar as seen in Figure 84. These plates have a half-moon shape so that the force is distributed across the front pillar efficiently and so that they allow room for an arm to screw the pillar into the floor to mount it. This is done by screwing bolts through the mounting plate, also seen in Figure 84.

The frame also houses the 2 NFC readers (ACM1252U-Z2 NFC). Because NFC signal is obstructed by metal, they are placed behind plastic plates of which the production is outsourced. Pan Oston does this for many of their NFC applications. The NFC reader is screwed on the plastic plate which is mounted to the frame itself by welded studs. Because the NFC reader in the back of the gate is hard to reach, a small door is integrated so that it can be installed. Please refer to the figures below for visual representations.

Figure 84: welded-in plates help distribute any impact forces

Figure 85: NFC reader in front pillar

Figure 86: NFC reader in back pillar

Figure 87: small door to reach the NFC reader

Cover

The cover is the part that closes the frame so that the hardware is protected. It houses all hardware to communicate: the RGB LED strip (Luxendi Neon Flex 60 LED/m), the screen (ELO 0702L) and the speaker (Visaton FR8 3.3 Ohm). It can be seen in Figure 88. This part is also made out of sheet metal and is easily produced by Pan Oston. It has one large radius of 100 mm in the front which Pan Oston does not have the bending hardware for. This is solved by setting multiple smaller angle bends to eventually end up with the bend we need (P. Legebeke, conversation, 30/5/22).

Figure 88: the cover housing the LED, speaker and screen

The screen is mounted to the cover by holes for screws 75 mm apart, corresponding to the VESA norm. The speaker and LED are both mounted to the cover using brackets which themselves are mounted to the cover by use of welded threaded studs. The speaker is mounted to the bracket with screws while the LED is sandwiched between the cover and the bracket so that it is locked in place. These brackets can be seen in Figure **89** for the speaker and Figure **90** for the LED.

Figure 89: speaker mounting bracket

Figure 90: LED bracket made from sheet metal

The cover itself is mounted to the frame using an flap on the bottom of the cover that fits into a slot on the frame (Figure 91), after which it is screwed tight using holes present at the top of the cover as seen in Figure 92.

Figure 91: flap that fits in slot in frame

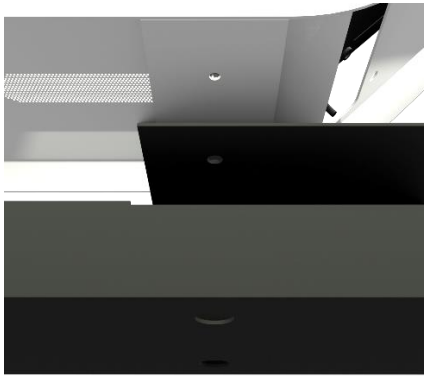


Figure 92: screw holes in cover lining up with those in frame

Arm-pillar

The pillar that houses the arm shown in Figure 93 takes a very similar approach to the widely used Eco gates that can also be seen in Figure 22. It is built up out of 3 shells housing all components, with the middle shelf being able to rotate around its axis so that an arm can be moved. This arm is attached to the arm holder.

A 24V DC brush motor (dunkermotoren GR 45X25 + PLG 42K gearbox, see appendix P for datasheet) delivers rotation in both directions so that the arm can move. Dunkermotoren is the supplier of motors for Eco, which have proven to work very well. This specific motor and gearbox combination is the cheapest that can also deliver at least 14Nm of torque. Since we have two motors, we can deliver roughly 30 Nm of torque assuming a person pushing open the gate pushes both arms equally in force. 30 Nm is the evacuation threshold of norm UNI EN 1125 which we are now in line with.

The rotational force of the motor passes a torque limiter so that the motor is protected from damage if the arm would be blocked. In this case, the torque limiter allows the motor to still rotate even though the arm is blocked.

An electromagnetic brake is applied so that we can make it harder for someone to force open the gate without the motor having to do all the work. This ensures a longer life for the motor. If the brake is on, then friction is created between the brake discs. More torque is now required to force open the gate since this friction has to be overpowered first.

Lastly, an encoder is applied so that we always know the angle the arm is in. This is of course crucial information to be able to understand what is happening with the arm so that we can ensure it is always in the right position.

The brake, torque limiter and encoder can come from any manufacturer. These are parts Pan Oston has not worked with before and therefore they have to be introduced into the company supply chain anyway.

The sheets that give the gate volume and are used for the arms seen in Figure 94 are made out of 10 mm thick frosted PMMA. This is because PMMA does not shatter, unlike glass. It is also easy to laser cut and it weighs less than glass. Because it is frosted, any accidental scratches stand out less. 10 mm provides a lot of stiffness which we need in case people push against the arms. It is also widely available.

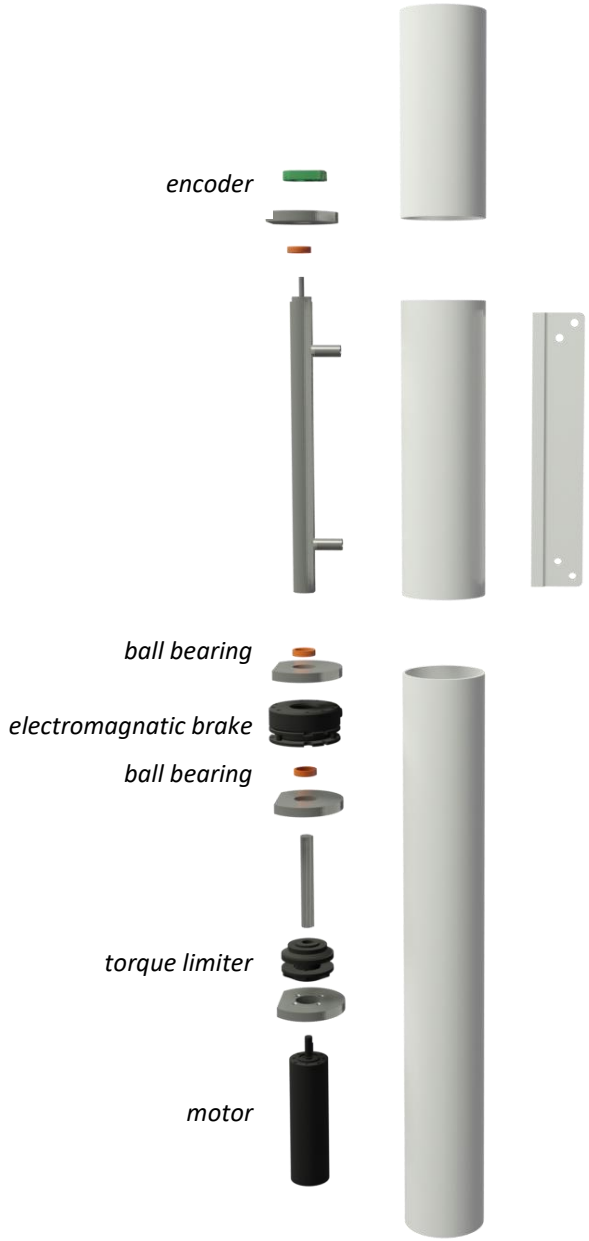


Figure 93: arm-pillar internals

Figure 94: PMMA sheets

Physical model

To be able to touch CLEARGATE, experience it and to test out whether it can actually be made by Pan Oston, a physical model was made as seen in figure Figure 95. This is a simplified model without NFC readers, an integrated speaker, or photocells. It uses mostly the same hardware as the cardboard model shown in Figure 55, being controlled by a Controllino MAXI, motor controllers and multiple ESP32 boards communicating with each other using the ESP-NOW protocol (similar to WiFi).

The left and right frames and covers were laser cut, bent, welded and powder coated by Pan Oston. The end result is of extremely high-quality finish as can be seen to the right. This proves that CLEARGATE can be successfully produced by Pan Oston.

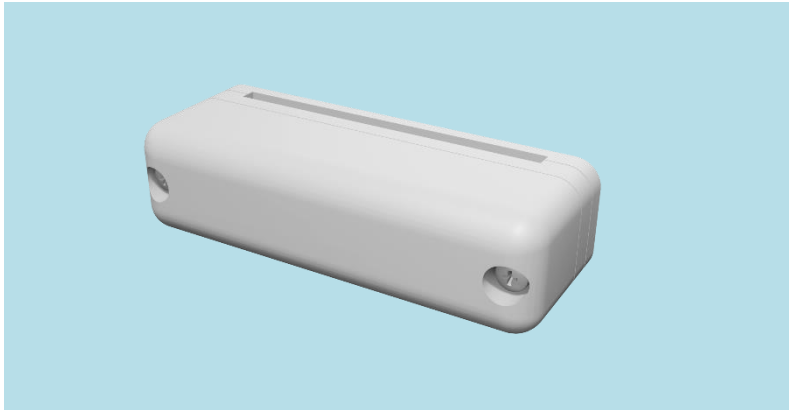
For the sake of time, parts were reused and recycled. The gate uses two spray-painted Eco 4.0 gates with custom-made, laser-cut, hand-sanded PMMA arms. Due to the Eco 4.0 gates having a larger diameter than the arm-pillars in the CLEARGATE design, this model's left and right sides are wider than designed. Foam is used to diffuse the LED light. This works well but it still does not look as good as Luxendi Neon Flex strips.

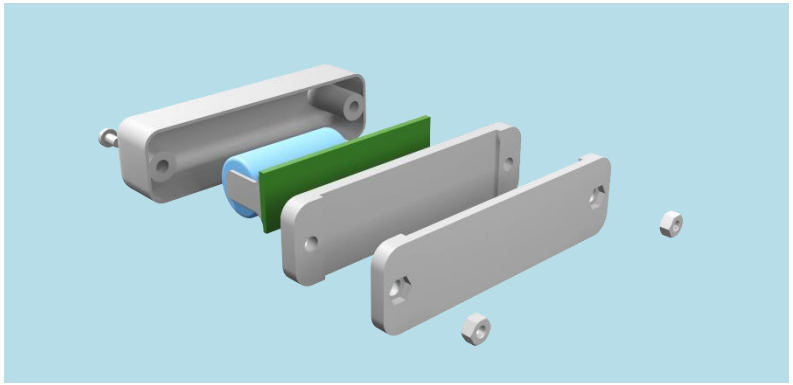
Figure 95: physical model greatly representative of final design

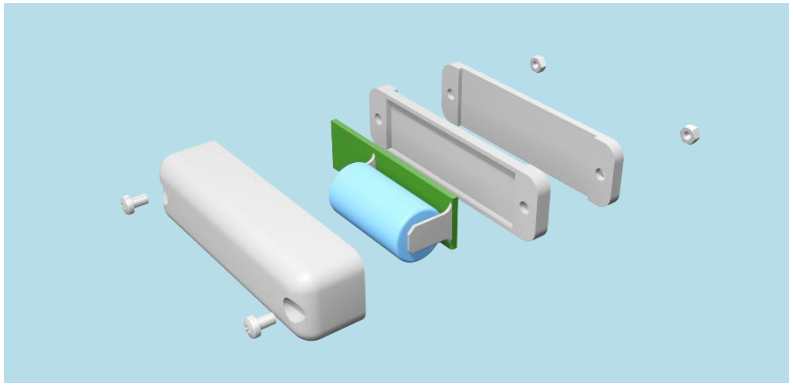
From the model the following knowledge was gained: the flap as seen in Figure **91** works very well since it also acts as a hinge. The frosting of the PMMA should not be too much, otherwise it starts losing its sense of openness. The PMMA panels need to be connected to both the frame and the arm-pillar to provide extra stiffness to the gate. This model is a little too high, a decrease from 1150 mm to 1050 mm would provide a better feeling of openness.

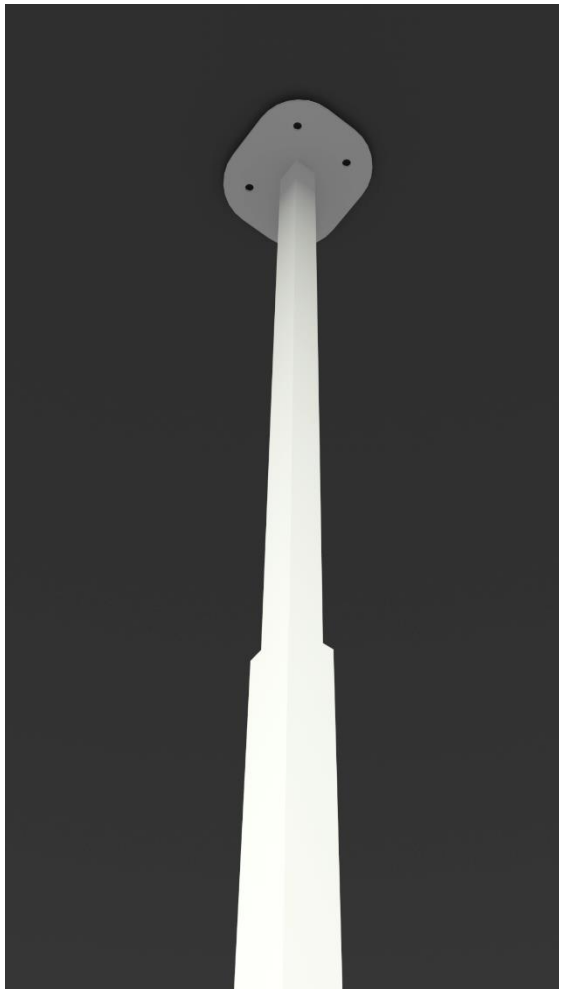
Detail shots of the model can be found below.

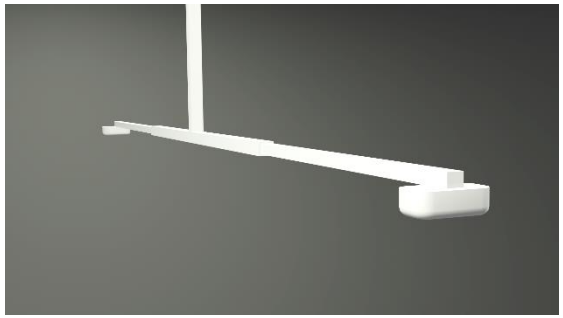
3.2: Final Design: EZ-GO











In the collage on the previous page the final design for the elements of the BLE proximity system can be seen. It is called EZ-GO, because it makes it easy to 'go' and pass the gate. This final design will now be explained. Technical drawings of the BLE beacon attachment can be found in Appendix O.

BLE beacon attachment

Functionality

The BLE beacon attachment exists out of 4 parts: a shell, the BLE beacon, a middle plate, and a back plate. For all prototyping an ESP32 development board was used, however for a final design it is best to design a PCB. The renders shown on the previous page and the printed model shown in figure Figure 97 assume such a PCB is made. It is powered by a 3V CR123A battery. Inspiration regarding dimensions and voltage was taken from the RadBeacon Locator Tent (see figure Figure 96) which has very similar functionality and is widely used by chains such as McDonald's (FCC, 2018). Unlike the RadBeacon, we use a CR123A battery (shown in blue) instead of a CR2477 button cell battery. The CR123A has 400 mAh more capacity and most importantly is small enough so that the beacon can stay under a height of 25 mm. If the attachment is higher than 25 mm the baskets cannot be stacked anymore.

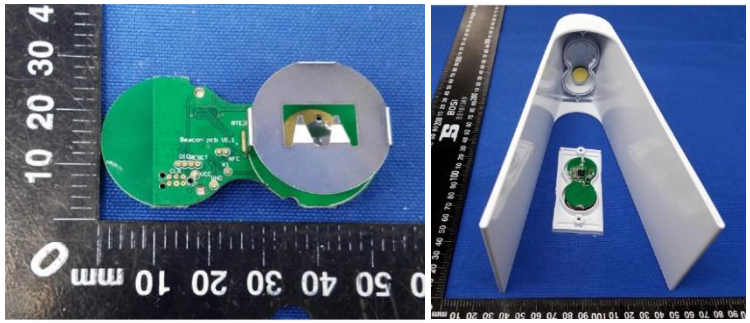


Figure 96: RadBeacon PCB and exterior

The middle and back plate have a rubber pad attached to them. When the attachment is screwed together, a slot exists through which the wiring of a shopping cart is inserted. This way the rubber grips on the wiring, keeping the attachment in place. The shell, middle plate and back plate are held together with 2 screws. This holds the attachment together, but also puts pressure on the wiring of the cart through the rubber pads.

This same system allows it to be attached to a basket, although 2 holes need to be drilled. Attachment to a basket and cart is shown in Figure 97.

Figure 97: attaching the BLE beacon to a basket and cart

Feasibility

The BLE beacon attachment exists out of simple parts that are easily produced by means of injection moulding. They are small in size so the mould needed will be relatively cheap. It is crucial that the attachment is made from plastic, since metal will influence the BLE signal that is being emitted.

It is easily installed on a cart or basket by use of a M3 bolt and nut. If a battery needs to be removed the shell can be screwed off and the battery can be replaced. The assumption is made that the beacon is not tampered with easily since customer do not usually bring screwdrivers with them to the supermarket. This can be made extra secure if special screws like Torx screws are used.

BLE receiver ceiling mount

Functionality

The stereo BLE receivers are easily mounted to the ceiling using a steel plate with 4 screw holes. This is just 1 option, the screw plate could be exchanged for a clamp so that the system can be mounted to other fixtures that are already mounted to the ceiling in the store.

Telescope rods are used so that the height of the BLE receivers and the distance between the 2 receivers can easily be changed. Different stores can have different

ceiling heights and, in this way, optimal distance from the ground can always easily be achieved. The height of the BLE receivers should not be too high since change in signal strength is harder to measure the further away the receiver is, but it should not be too low since this makes it easier for human bodies to block the signal. Taking this into account and based on tests done with ESP32 hardware, a height of 2.2-2.6 meters is best.

These telescope rods also function as cable guidance for any cables that are needed to power the BLE receivers.

Feasibility

This is a very simple construction only existing out of metal rods, screws and a screw plate or another way to fix the system to the ceiling. Pan Oston uses many metal profiles and can easily fabricate this themselves.

3.3: Gate's response to different situations

Like often mentioned before, there are many different situations that can occur for which the gate needs to have a response. Think of a customer being allowed to pass or not, people trying to freeride, people trying to leave without a cart or basket, etcetera. An overview of different situations and how the gate responds will now be given. Please note that the gate can only act upon most of these situations if the gate is combined with EZ-GO, since it needs the information gathered from this system to make decisions accordingly. Please also note that these situations are the same for both configurations of the gate (normally-open or normally-closed), the only difference being the gate having to close or open if it is not already closed or open accordingly.

Situation A: customer has paid and wants to pass the gate

When the customer approaches, the signal of the cart or basket is recognized, and it is checked whether payment was made. If so, the customer is let through and the cart or basket will be again labelled as 'unpaid'. Green animated light will show on the LED strips and a checkmark shows up on the screen.

Situation B: customer has not paid and wants to pass the gate

When the customer approaches, the signal of the cart or basket is recognized and it is checked whether payment was made. If not, the gate stays closed or quickly closes if it was open. Chances are the customer is unaware he/she has not paid, so an animation on the screen shown explaining to the customer that he/she first has to pay and the LEDs light up yellow. If the signal of the cart or basket stays present for more than 10 seconds this probably means the customer is still confused. A 'warning' sound plays, alerting the host that a customer needs help.

Situation C: customer has paid but is with a group and wants to pass the gate together

The customer that carries the basket or pushes the cart is recognized as described in situation A. This customer is let through accordingly. If any people also use the gate within a short timeframe after this customer, it is assumed that these are group members that belong together. The gate will then also let these people pass. People passing the gate without cart or basket are recognized by the photocells placed in the gate. This does mean that all groups are limited to 1 cart or basket, otherwise this second cart or basket is recognized by EZ-GO as another customer who has not paid, causing the gate to close.

If it occurs that a group member is too late to pass the gate together with his group, assistance can be given by the host present in the SCO area.

Situation D: customer wants to pass the gate but does not have a cart or basket

A customer like this is recognized because the photocell at the front of the gate will trigger. The customer is quickly blocked since there is no way to check whether this person has paid or not. A warning sound immediately plays and an animation is shown on the screen, reminding the customer that they may have forgotten their cart or basket. Blocking customers without a cart or basket also stops children from playing around the gate or running through it which would confuse the system.

Situation E: customer is trying to use the gate from the wrong side (backflowing)

When a customer backflows, this is recognized by the photocell in the back of the gate. The gate immediately closes since a customer should not use the exit as an entrance or vice-versa. A warning sound plays, alerting the host of a potentially confused customer and alerting the customer that what he/she is doing is wrong. Yellow light is shown to alert the host.

Situation F: customer is trying to free-ride off of a paying customer by quickly trying to pass the gate after it has let the paying customer through

The gate is always analysing BLE signal around it. If strong BLE signal is received from 2 carts or baskets at the same time but only 1 of them has paid, it most likely means that a customer is trying to free-ride off of a paying customer. The gate will then quickly close. Red light flashes, a warning sound plays and an animation is shown which asks the customer to not free-ride. Due to the light and sound the host is quickly aware of the situation and can judge accordingly.

It is possible that the paying customer will also be blocked by accident, depending on how close the free-rider is following the paying customer. This is less than ideal, but it does have the benefit of putting social pressure on the free-rider, further punishing and demotivating thieves.

Situation G: employee wants to pass the gate

Employees can easily pass the gate from both sides by scanning their NFC chip at one of the NFC readers in the front or back of the gate. This NFC chip could be in their employee card, an NFC tag, keychain, etcetera. These NFC readers also allow the host to easily let a customer through for whatever reason.

Situation H: customer forces open the gate (can be both on purpose or accidentally)

If the gate is forced open then this is recognized by a spike in motor power and the arms not being in a position they should be in. An alarm is immediately played and red flashing light is shown. This alerts all employees around the gate of the situation so that it can be responded to accordingly. Because the gate can also be forced open because of an emergency evacuation, the gate stays open after it has been forced open. The gate is reset by scanning an employee NFC tag at one of the NFC readers.

Situation I: customer forces gate open in emergency evacuation

As explained in situation H, the gate will stay open. In the case of a power outage the motors cannot deliver any resistance and the gate is easily pushed open after which it will stay in whatever position it is pushed.

Situation J: gate is blocked from closing because an obstacle is present

Because of increased motor resistance and the arms not being in the position they should be it is concluded that an obstacle is present. If this obstacles stays present for more than 3 seconds, an alert plays, notifying the host that the gate is being blocked.

3.4: Conclusions

To conclude, a final design is presented for CLEARGATE and EZ-GO. It is shown that both products are feasible through a combination of in-house fabrication and outsourcing. A rough price estimation comes down to €3.891,64 for CLEARGATE which is a respectable price making it viable. For EZ-GO no estimation can be given since it is highly dependent on PCB design and software partner pricing. According to the Pan Oston sales staff, CLEARGATE and EZ-GO provide solutions for current problems at Pan Oston's customers, making it desirable.

4.1: Recommendations

It is highly recommended Pan Oston continues development on both CLEARGATE and EZGO. They have been developed into very respectable products within the timespan of this thesis, but like all products, they leave room for improvement. The following recommendations are made to Pan Oston:

1. The BLE trackers attached to carts and basket continuously send out signal. This means that when BLE receivers are placed not only at SCO's and the gate but also throughout the whole store, it is possible to anonymously track customers. This information can be used for many things, for example if someone has been in the meat & dairy isle for 10 minutes but did not buy any, there is a chance the customer is not scanning this item and thus stealing it. Anonymity is crucial though and using BLE for this application may create a slippery slope with more and more intrusive technology.
2. If only using the BLE signal in the SCO area, it can be considered to make BLE beacons not only send signal but also listen. If they can listen, you can allow them to only start sending out signals as soon as they reach the SCO area. However, this is likely to drain battery faster since they now have to listen for signal on top of sending signal. Alternatively, accelerometers can be integrated into the BLE beacon PCB so that it only sends signal when the cart or basket is being used. When not used and thus being stationary, no movement is registered, and no signal is sent.
3. Mandatory carts and baskets may be a dealbreaker for stores to not use the EZ-GO system or trigger them to still have a barcode scanner next to the EZ-GO system. It is recommended Pan Oston further investigates the possibilities of including people without cart or basket into the system.
4. Ideally the CLEARGATE is connected to the internet, so that its settings and data can be reached via a website or app. This allows the store owner to easily change settings, allows Pan Oston to change settings remotely, but also allows Pan Oston to collect data about all CLEARGATE's that are out there and in turn learning from this data to improve the product.
5. The screen on CLEARGATE can be used for anything. It can show discounts, however this can be perceived as unfriendly since you are leaving the store and just gave the store money. It can also be used to build on a theme in the store, for example showing soccer animations during a soccer championship, or showing many flowers in the summer.
6. Since baskets are stacked, they could be charged while stacked, similar to Figure 52. Whether this is worth it will depend on how often the batteries in the BLE beacons need to be replaced. This system only works for baskets though, carts will need a different solution.
7. It is incredibly important that the host can open the gate remotely. This enables him/her to help customers at the gate while also helping people at a SCO. Pan Oston should make this very clear to any software partner that will eventually develop the software for CLEARGATE (and also EZ-GO).
8. Throughout this thesis no other gates were found within retail that use an always-open approach. Also, no customer control system was found that works using BLE. It is recommended Pan Oston looks into whether these designs can be patented.
9. If it proves costly to run wiring through the ground to connect both sides of the gate, it can be considered to let both sides communicate through WiFi or Bluetooth.

4.2: Discussion

See Appendix H and L for the programs of requirements. They have been scored using the AMPEL method with green meaning success, yellow meaning somewhat success, and red meaning fail. Comments have been placed which explain the ratings if a requirement or wish was scored yellow or red. If we go through both programs of requirements and check the final CLEARGATE and EZ-GO design adhere, we see that most requirements and wishes have been achieved with the occasional yellow and red. The biggest problems are the EZ-GO system not allowing people without cart or basket or things that are dependent on software partner that will eventually create the software for CLEARGATE and EZ-GO, which is outside the scope of this thesis. If Pan Oston further develops EZ-GO so that it allows people without carts or baskets there should be no big problems left.

Pan Oston is company with a mindset regularly found in the production industry: *this is how we have done it so far, and thus how we will keep on doing it*. Outside of the Innovation & Design department there is little room for creative thinking, which caused this thesis project to not always being perceived as useful by Pan Oston staff. Many colleagues did not understand what was being done, and a lot of convincing was done

to show this project is important for Pan Oston. At times when people were asked for advice, they did not really answer and just waved off the project as unimportant. There were times where this was very demotivating. Also, the communication within the company between departments is horrible. Many times, emails were never answered, or employees kept referring to another employee for answers. This caused a lot of time being lost while trying to get information and having to go through multiple people first.

However, the Innovation & Design department was incredibly helpful and knowledgeable. Questions could always be asked, and very clear and complete answers were given every time. This greatly helped this thesis, especially because almost no knowledge regarding this thesis can be found online. This thesis was highly reliant on information present within Pan Oston.

Lastly, since Pan Oston has no prototyping facilities like a 3D printer it was sometimes hard to test out designs. Since there was no way to quickly prototype complex shapes, going through design iterations for the BLE beacon was discouraged and hard to do. In the end it was possible to go through 2 iterations by letting a friend in Delft 3D print.

4.3: Reflection

I am very happy with the results of this project. I worked hard and as a result there was a lot of positive feedback throughout the project, and it was smooth sailing for the most part. I achieved many things I had not expected to achieve. In the end I was able to create a functional physical model that Pan Oston loves and is very much in line of what Pan Oston was looking for. I learned many things such as designing for sheet metal, building big Solidworks assemblies, learned to control motors and LEDs with Controllino, learned to code BLE applications for ESP32 boards and learned how gates work. On top of that I also learned how big production companies work (and how they do not). I further improved my communication and presenting skills, which I had to do a lot of.

Sometimes during this thesis, a less efficient route was taken to be able to learn more things. For example, creating the PMMA sheets for the final model could have been easily bought and laser cut by a third party. Instead, I used PMMA sheets from Pan Oston's trash and laser cut them myself at my previous internship company. I sanded them myself afterwards. It may have taken more time, but I learned about laser cutting different materials and how to achieve evenly sanded surfaces. Also, the sheet metal design in Solidworks could have been done by the Pan Oston engineering department, but I chose to do it myself to learn how to make production-ready sheet metal products. I lost about 3 days to this, but I learned a lot.

Looking at my personal ambitions in the project brief found in Appendix Q, I achieved all 4 points. I learned to use CAD for sheet metal, thought myself new technologies like Controllino and ESP32, was constantly in contact with all kinds of Pan Oston employees and lastly was in touch with different Pan Oston departments and the end user to take into account multiple perspectives.

I am very happy for the guidance I received, both from the TU Delft and Pan Oston itself. They pushed me to go make a physical model which I originally considered not doable within the time left at the time. I am glad they did, because I was able to create a very nice model which I am proud of.

Throughout my bachelor and master I have been moving more and more towards integrated products like mechatronics. This thesis made me even more certain that this is what I find most interesting: physical products with integrated electronics and software. This is something I want to follow up on when finding my first job.

Lastly, I learned that I can be more confident in my abilities. Generally, I am not certain of the quality of my work and underappreciate it. The regular positive feedback in this project and the fact that I achieved more than I expected once again teaches me that there is little reason to doubt my skills and abilities.

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List of people that provided information

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Hofsté, *Product Manager, Pan Oston*

Dikken, *IT Innovation Specialist , Pan Oston*

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[redacted] van der Toom, *Innovation Engineer, Pan Oston*

[redacted] van den Heuvel, *Service Manager, Pan Oston*

[redacted] van der Burg, *Service Coordinator, Pan Oston*

[redacted] Bosch, *Account Manager Netherlands, Pan Oston*

[redacted] IJmker, *Project Manager, Pan Oston*

[redacted] Horstman, *Planner Metal Department, Pan Oston*

[redacted] Hageman, *Engineer, Pan Oston*

[redacted] Strijdveen, *Engineer, Pan Oston*

[redacted] Legebeke, *Engineer, Pan Oston*

[redacted] *Sales, 20face*

[redacted] *, Host, Albert Heijn*

[redacted] *, Host, Jumbo*

[redacted] *, Concept Developer, Albert Heijn*

[redacted]

Appendices

Appendix A: SWOT and VRIO

Resource	Valuable?	Rare?	Inimitable?	Organised?	Comments

Appendix B: Ways of leaving and entering things in other industries

Ways of leaving and entering things

Amazon Go Store
2 way gates with QR code scanner
signage and signals implemented

NS Stations
2 way gates, with QR code scanner and NFC reader
2 variations, one high and one low
signage LEDs implemented, screen inside

Supermarket gates
Gates that open by scanning barcode or by triggered laser
Sometimes used double at entrance

WANZL Casino gate
Detect jumping over, crawling under, or misusing someone else's access

Bouncer
Social pressure, intimidation, prospect of violence

Traditional supermarket checkout counter
Narrow walkthroughs (cant pass without paying)
Social pressure

RFID gates / metaldetector gates
Sometimes very clear, sometimes hidden
Everyone is forced to pass them

Japanese subway gates
Usually always open, close rapidly if you didnt scan ticket
Can work 2 ways
Gigantic number of users per day

Barcelona subway gates
Very quickly retracting
Can work 2 ways

Conductor
No checking at entrance or leaving (in case of station without gates), but checking during trip
Motivated by potential fine (monetary loss)
Social pressure

Hotel door
Reprogrammable RFID tag/card

Moscow subway
Enter, leave and pay by face recognition
Also used in China

Schiphol
Passport control with automatic face recognition
Moving camera + lighting, specific spot for user to stand on

1-way gate
Often used at unmonitored facilities (like public toilets)
Robust

Guest list
Social pressure
Whitelist to check if people are allowed to enter

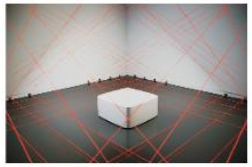
Tourniquet
1 way, robust
Often used at soccer stadiums and event centers

Slagboom
automatic or by card
Very well known and understood concept

Sudden obstacle
To stop crashing cars
Quickly deployable

Drive through gate
Automatic road opening and blocking
Crash proof

WANZL gate
Can open partly if full range is not needed
Available in different glass heights



Security systems
Alarm is triggered when somewhere where he is not allowed to be
Can be made to be invisible or made to be as visible as possible

Appendix C: Host interviews

12/3 [redacted] host and team captain at Albert Heijn

- Very strong focus on hospitality. Hosts are asked to say 'hello' to all customers entering the SCO area. This is because this is customer-friendly but mostly because it makes the customers feel less anonymous, which is thought to lower the chances someone decides to steal something.
- Hosts also do random checks to see whether a customer has scanned everything they have with them. These checks are demanded by the host's terminal (a special phone) or then can initiate themselves if they do not trust the customer. The big downside of checks is that when you are busy with 1 customer, you lose oversight of all other customers. Regularly thiefs make use of this and steal groceries when the host is busy checking someone else.
- If someone is seen stealing, confrontation is NOT allowed by regular employees. Because of safety reasons, only team captains are allowed to intervene and confront. Because of this, thiefs often get away because they are able to escape before a team captain can arrive.
    - Hosts can contact a team captain if they see a regular offender or if they do not trust someone. In this case the team captain will come and confront the customer out of precaution.
- Police only act upon theft if a thief is caught red-handed. Theft seen by cameras after the fact is rarely investigated by police. Albert Heijn rarely presses charges because of a 'customer is king' attitude.
- Entrace gates have alarms. Exit gates at Albert Heijn Diezerpoort do NOT have alarms. This allows thiefs to just walk through the exit gate if they push hard enough. They can also easily free-ride by walking out when a gate opens for another customer. This happens DAILY. The fact that the gate has no alarm and closes very slowly creates high amount of theft.
- Gates are often broken due to employees forcing them open (this exactly matches the Pan Oston service department story)
- 'If our gate would function better, than being a host would be a lot easier. I would have more control over the SCO area.'
-

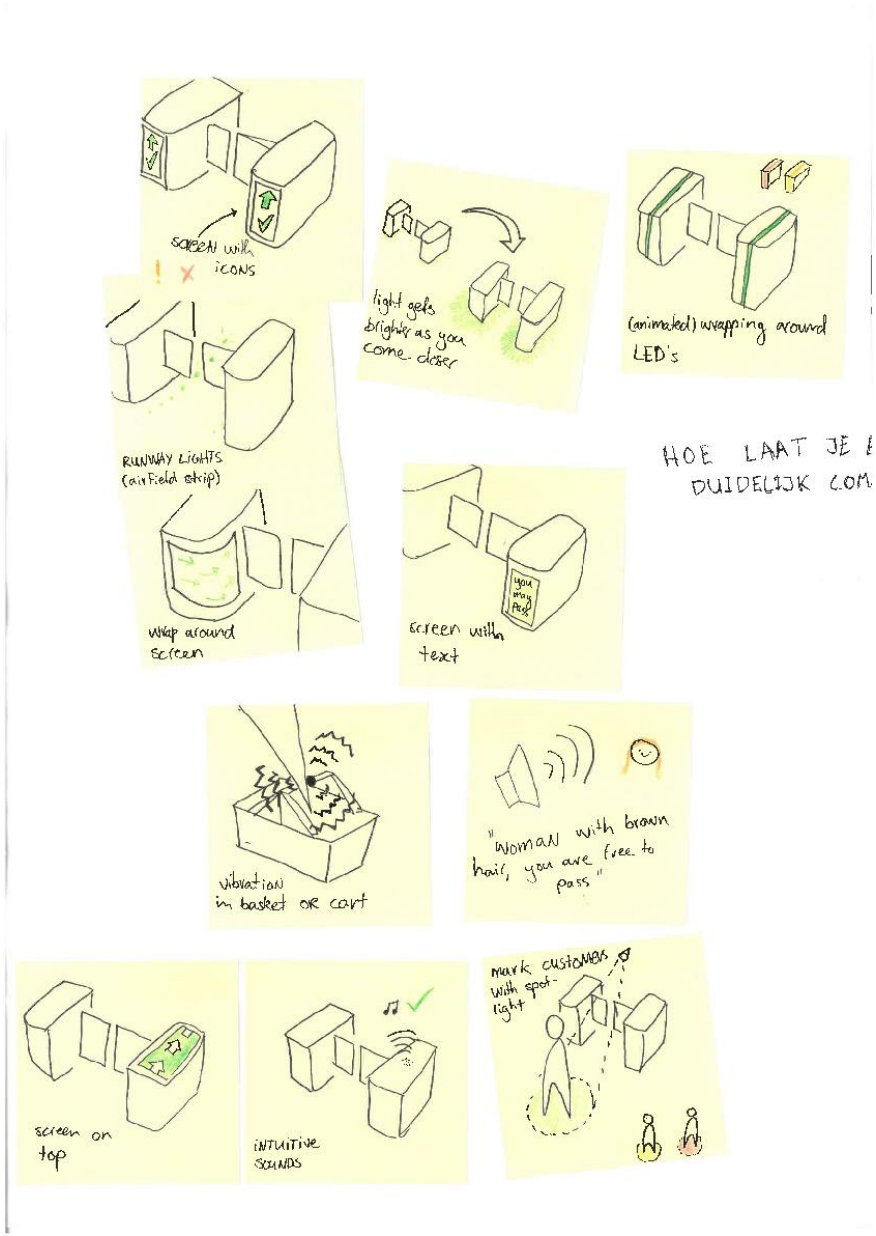
13/3 [redacted] host and team captain at Jumbo [redacted]

- A lot of theft. People regularly put products in their bag instead of their basket. Cheese, washing detergent and meat are stolen the most. Happens daily. Everyday there is at least 1 person you catch red-handed.
- Only 'kaderleden' are allowed to intervene and confront thiefs. These are team captains, managers, and permanent employees with keys to the store.
- Host has a hospitality role, but also does random and prescribed checks, very similar to Albert Heijn. Regular thiefs get a store-ban after being caught 3 times. This is very generous, and is due to a 'customer is king' attitude. This is also why stealing customers who say 'I didn't know', 'I didn't mean to steal' and things like that get the benefit of the doubt, even though regularly it is very clear what someones intentions were.
    - When you are checking someone whether they have scanned everything, all other customers at the SCO area can do what they want. This generates a lot of theft.
- Only girls 18 and older are allowed to be host, since these tend to be more confident than younger girls. Confidence is important for a host because they have to confront people. Usually the good hosts are people with a big mouth. Hosts are almost always girls, but this is simply because men don't want to do it. There is a stigma on men working as cashiers.
- Exit gates have NO alarm. This allows for people to just push through the gate or easily free-ride off of someone else. **This happens approximately every 20 minutes.**
    - Sometimes a bunch of people free-ride when a long queue at the SCO area is created due to someone having issues scanning their receipts. We cant control whether these people actually paid or not.
- Entrance gates are often used to steal. People leave the store through the entrance gates, forcing them open from the wrong side. This triggers alarms but also breaks the gates. A service engineer has to visit the store to reset the gates. Theft through entrance gates is usually done during the day, because the gate opens more often and people can blend into the mass.
- Gates are often pushed open by employees because they need to pass. They have their own QR code to open the gate the right way, but this QR code rarely works.
- People in the city do not care about damage and handle the store's equipment very roughly. People in the countryside are way more careful and have a bigger personal connection with the store and their employees.

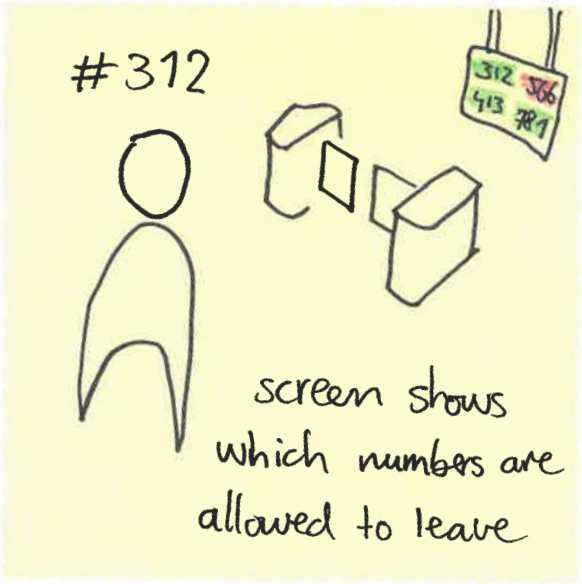
Conclusions

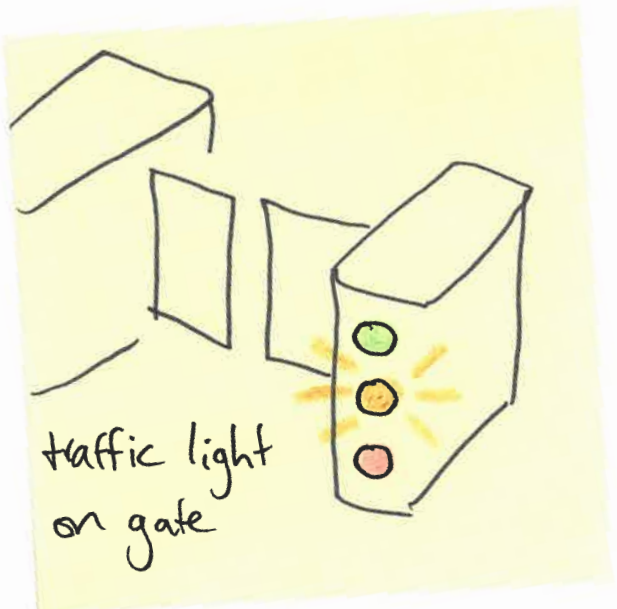
- My gate needs an alarm that communicates the situation to the host, and preferably also to a team captain because only they are allowed to intervene. This could be connected to the employees' terminals
- It is very important that the host quickly and intuitively understands what is happening. My gate can help with this, supporting the host in his/her role.
- An anti-backflow system is requirred so that people cannot leave the store through the entrance gates
- An anti-freeriding system is requirred that triggers an alarm when someone freerides off a paying customer. Preferably the gate closes before the freeriding happens.
- A system is needed which allows employees to open the gate from both sides without needing to force it open.

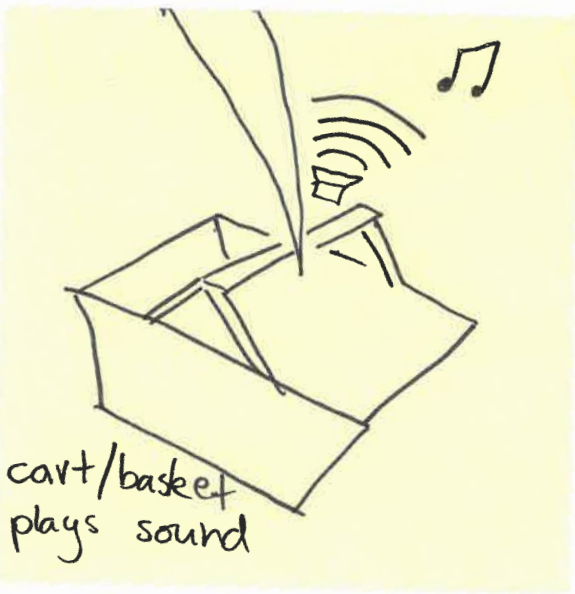
Appendix D: Communication brainstorms

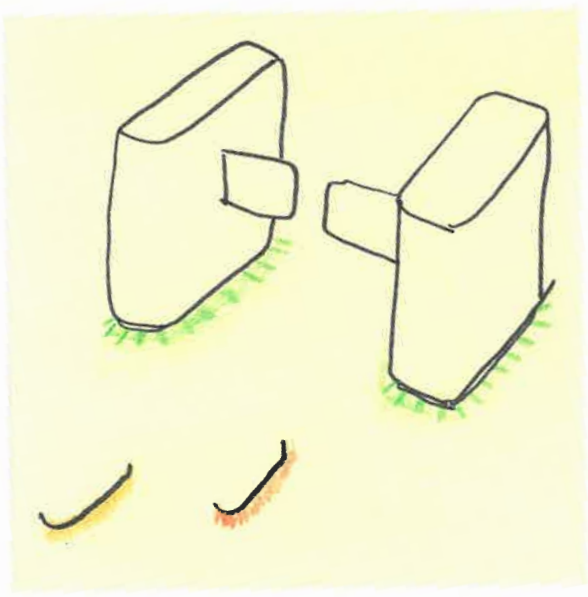


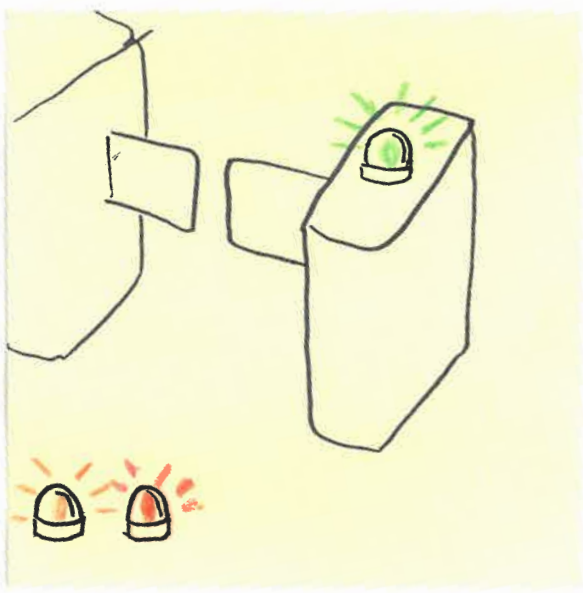
N POORTJE
UNICEREN ?

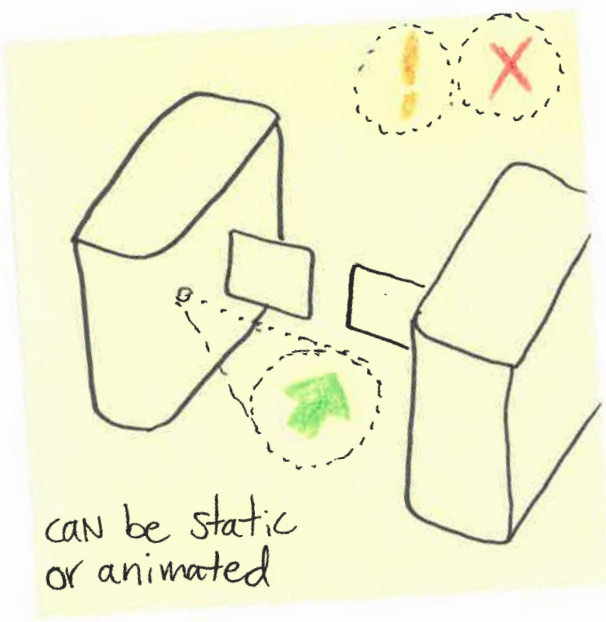


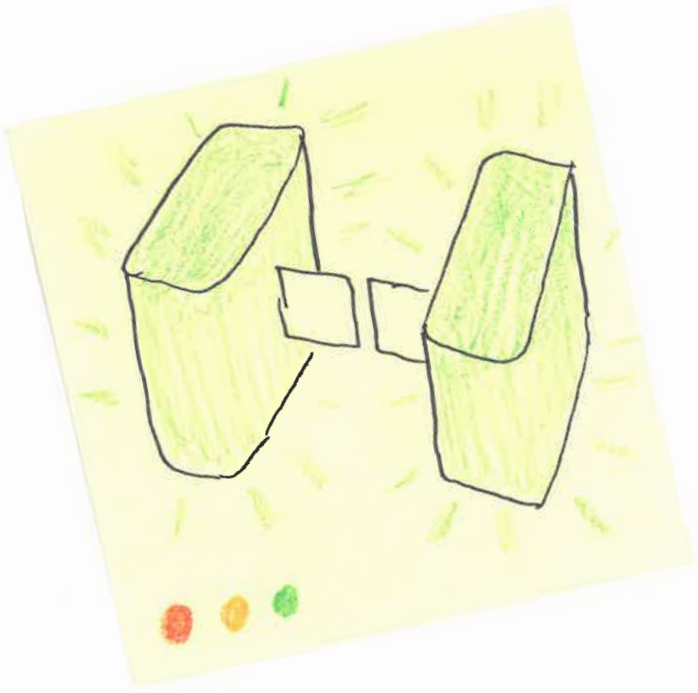


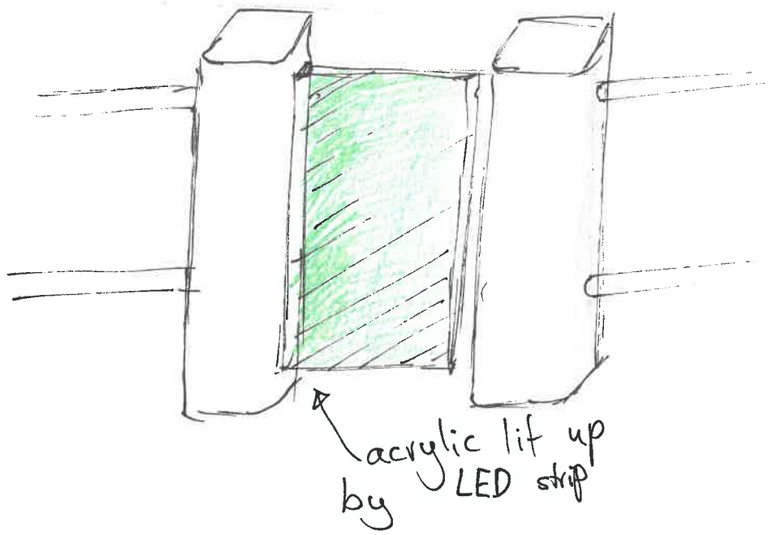


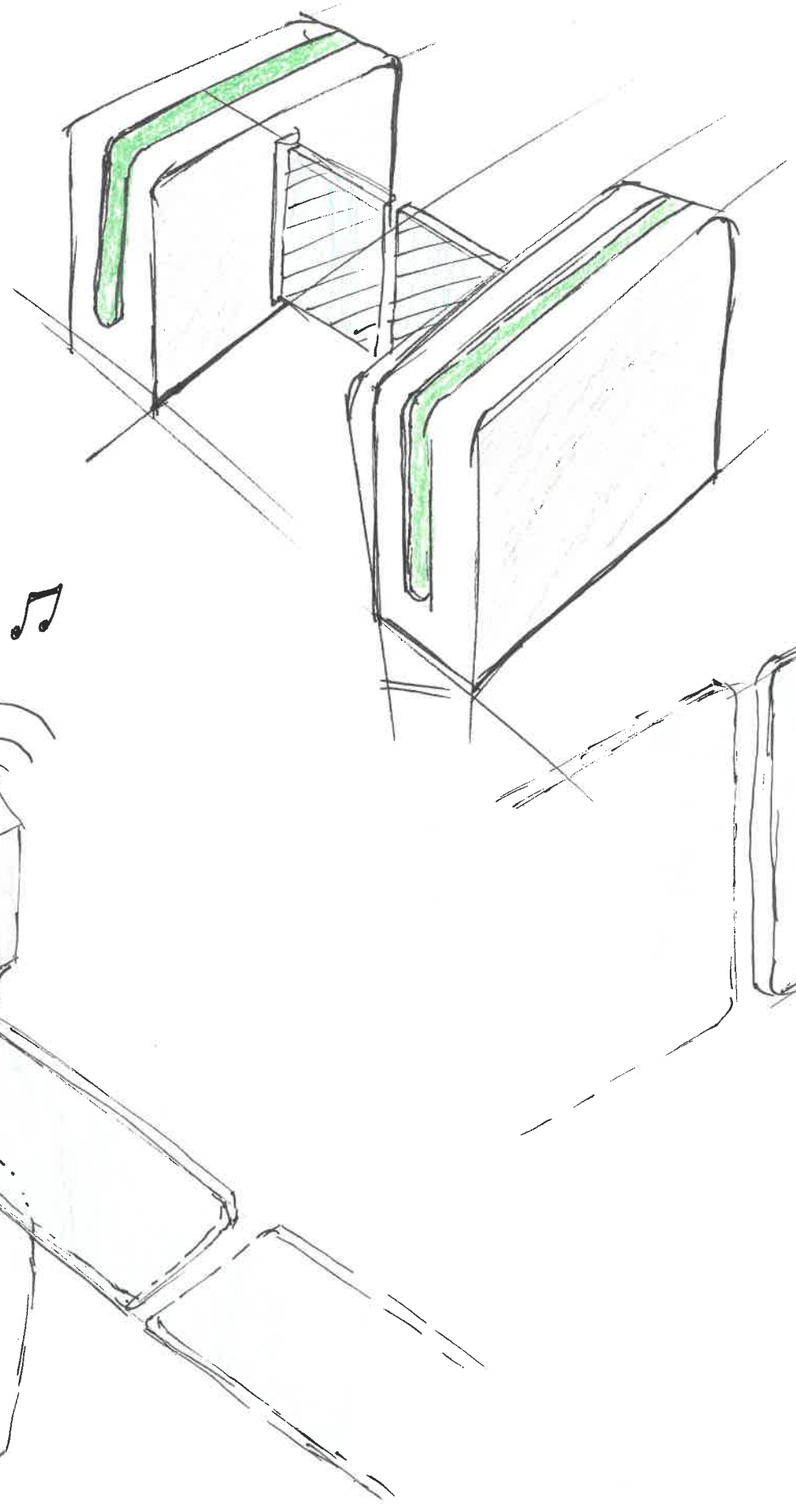


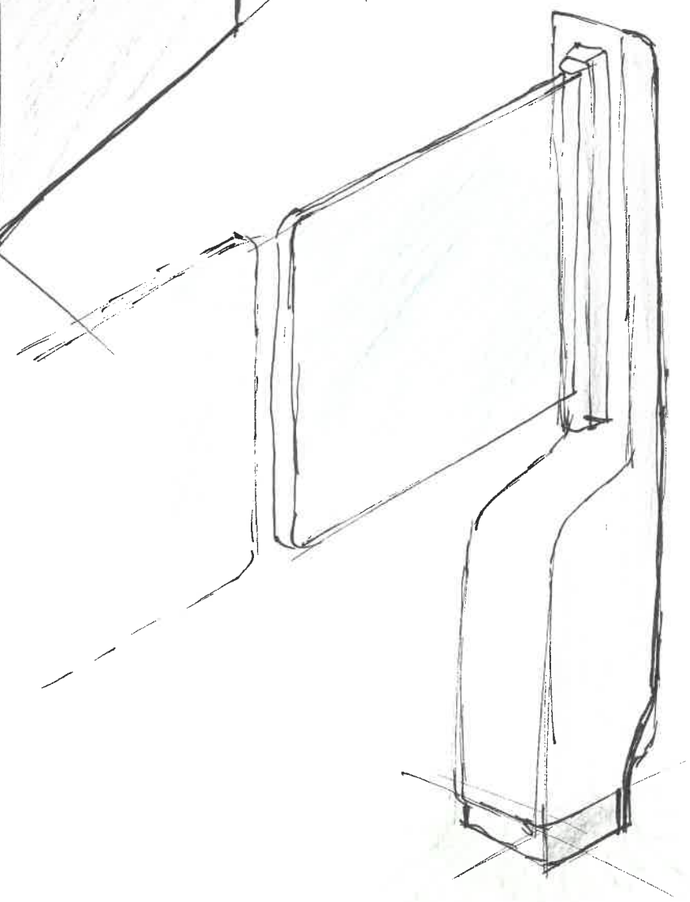


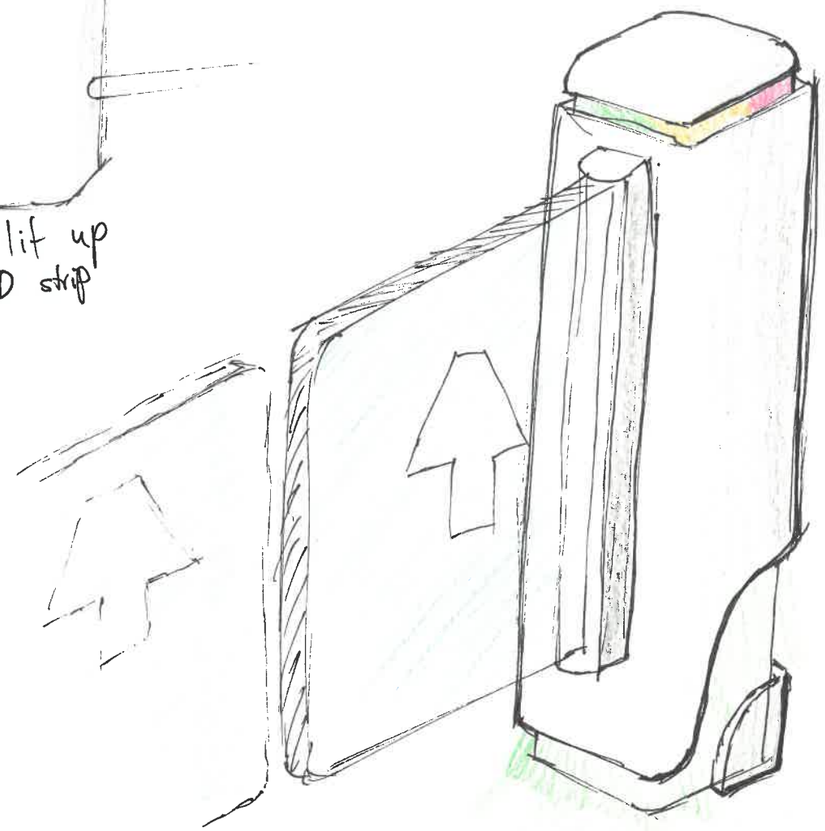


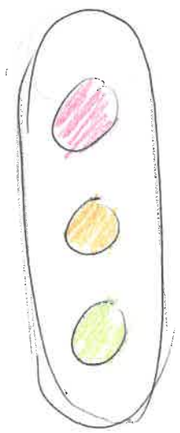



acrylic lit up by LED strip

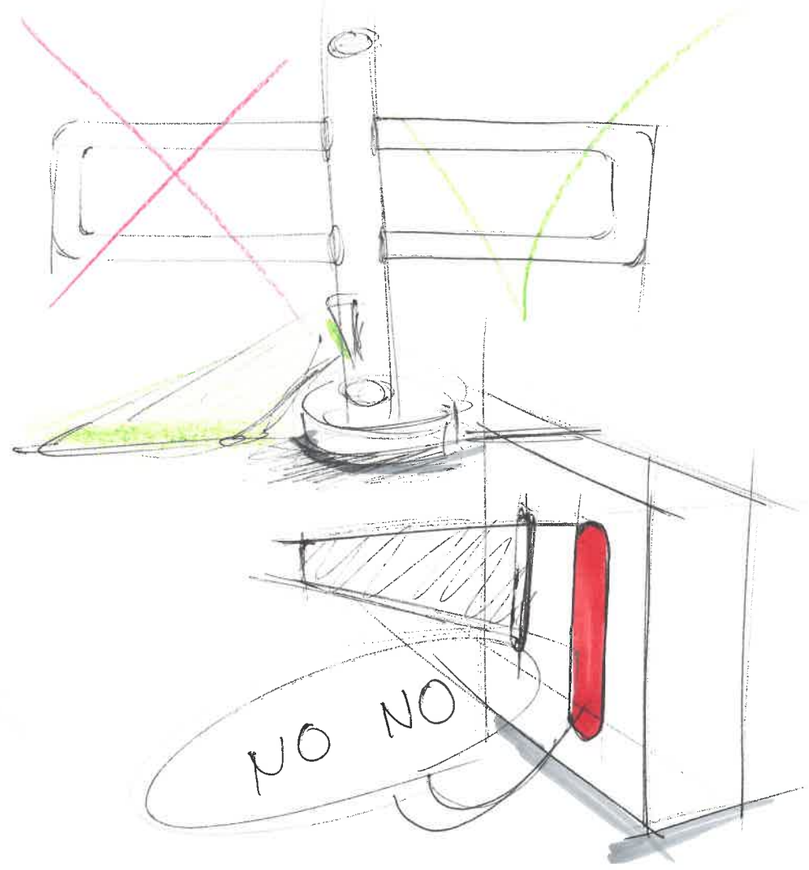


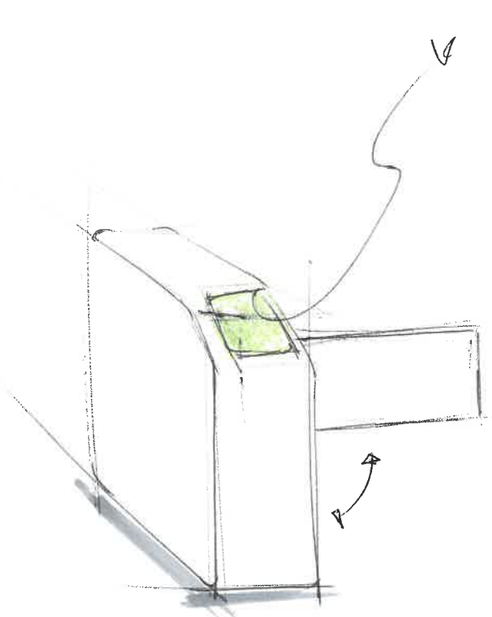






Stoplicht.





kleur + licht
+ tot de volgende keer
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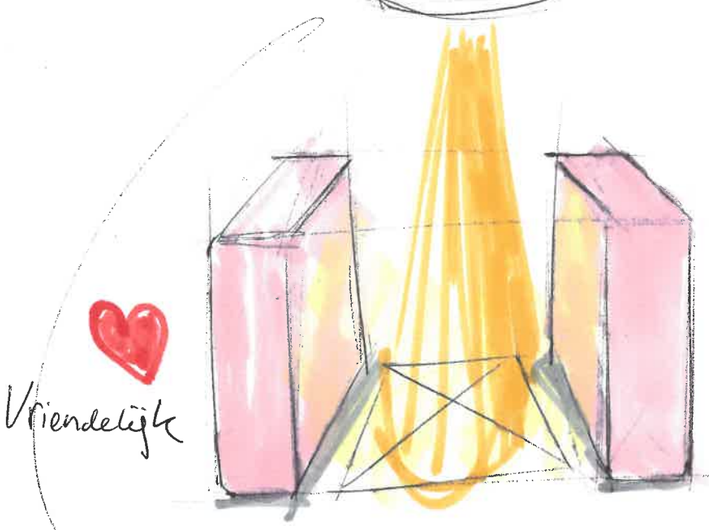


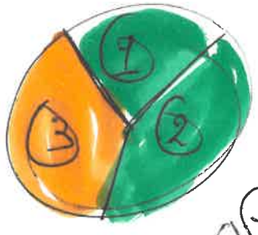
Vriendelijk

AAN = doorgang

UIT/GEDIMPT = geen doorgang.

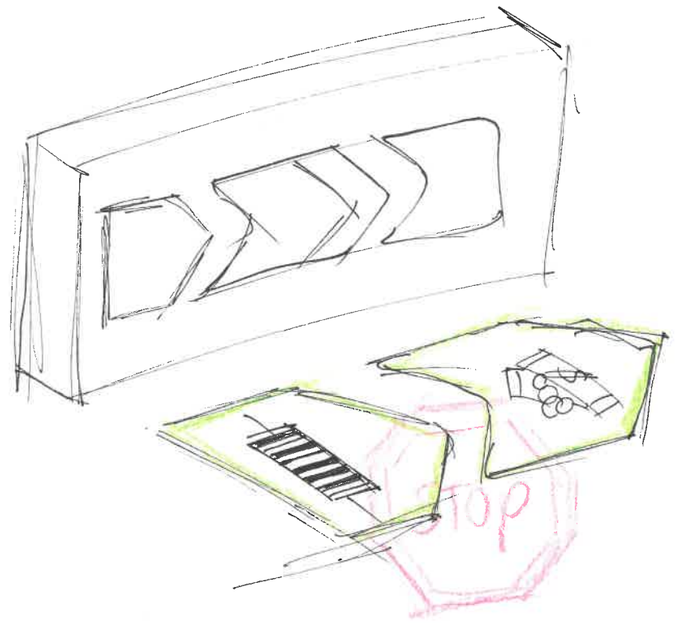
AVATAR

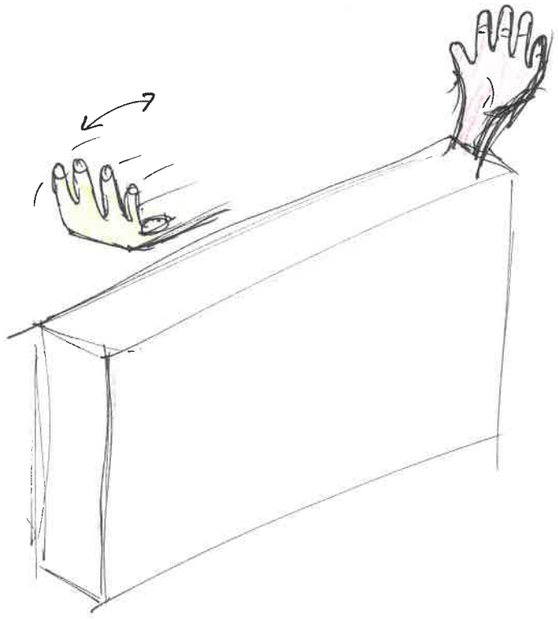
GELUID
=
SNELHEID



PROGRES BAR

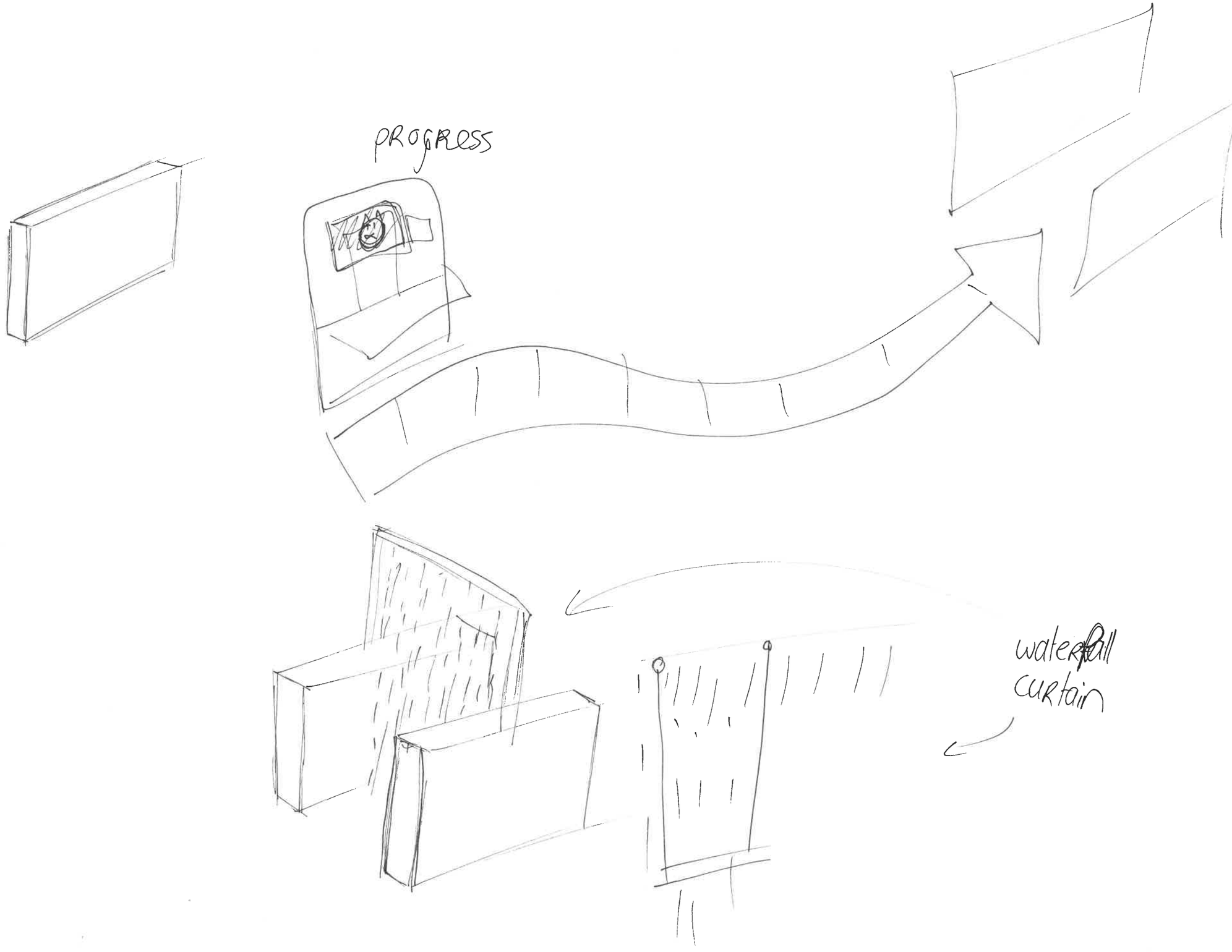
kleurenblinden
oven / slechtzienden





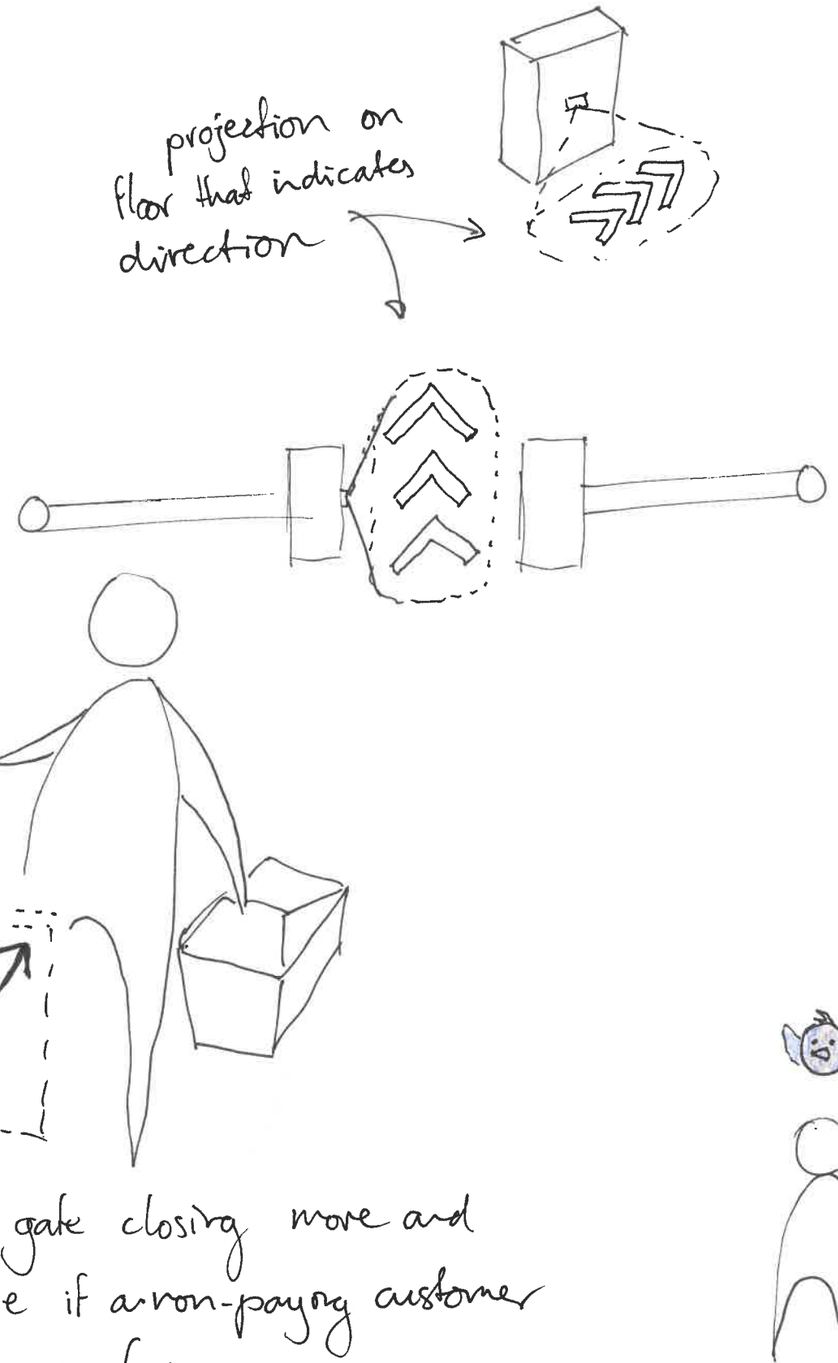
proces stappen tonen

auditieve ondersteuning



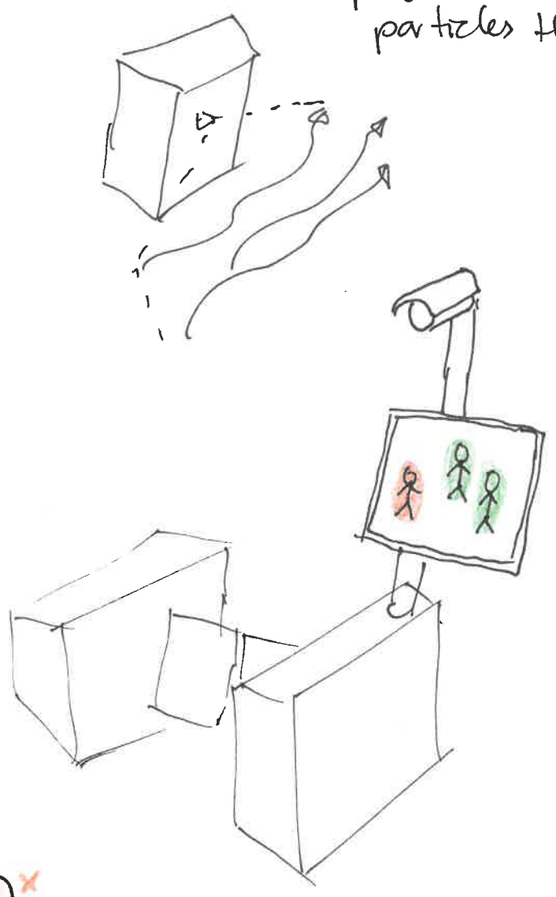
fysieke / digitale avatar

projection on floor that indicates direction



gate closing more and more if a non-paying customer approaches

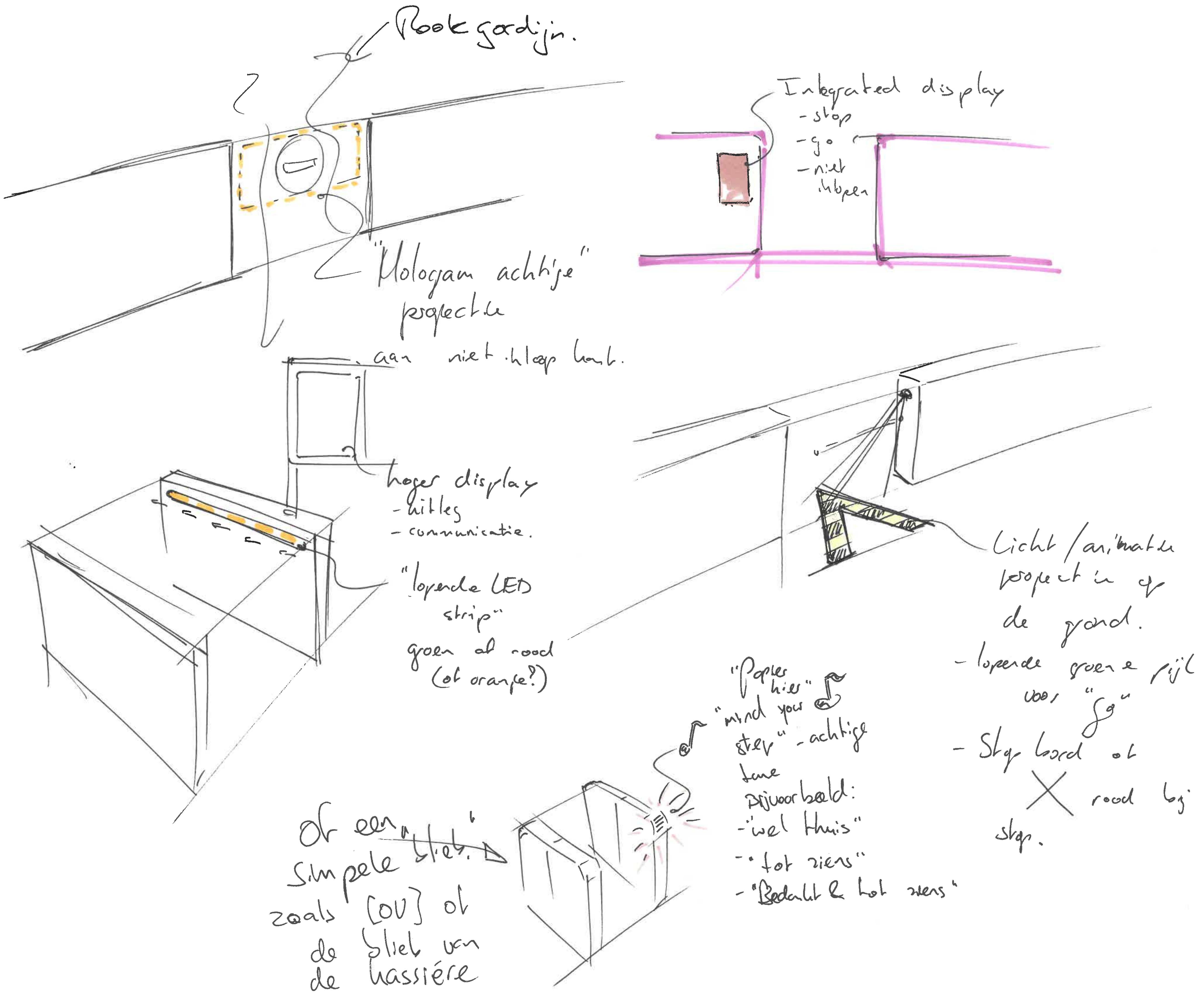
projection on floor showing moving particles that flow in 1 direction

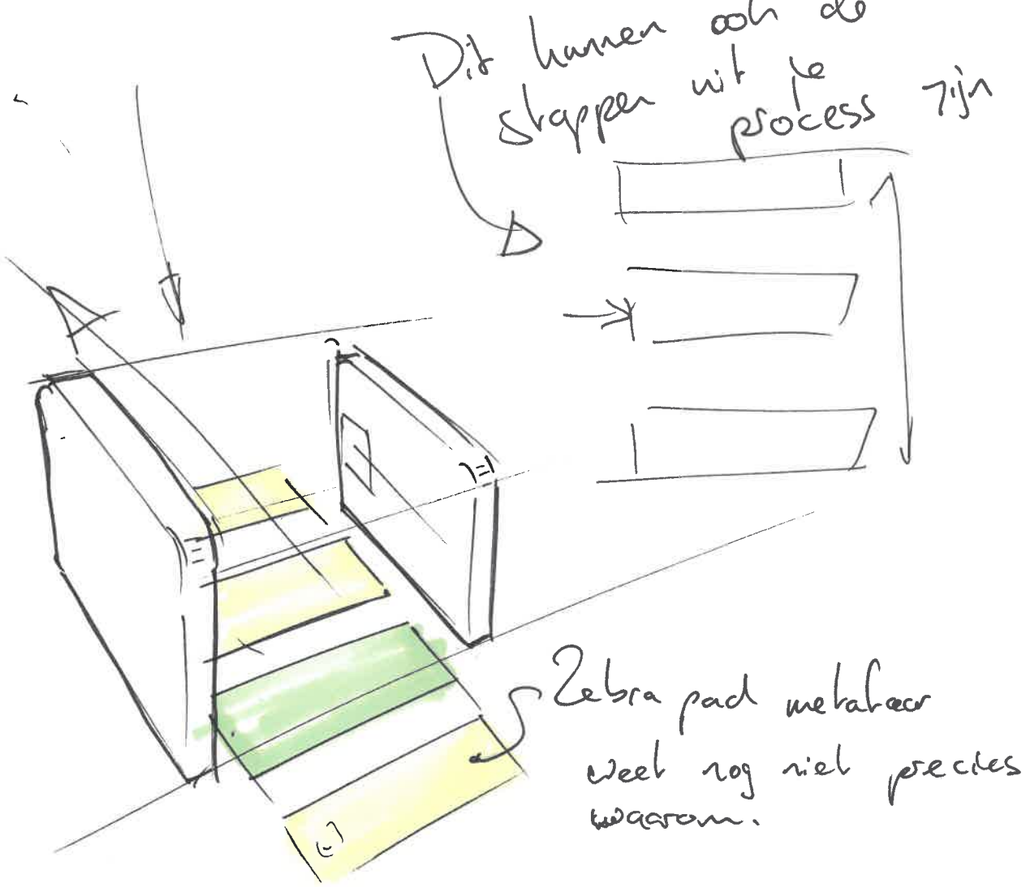


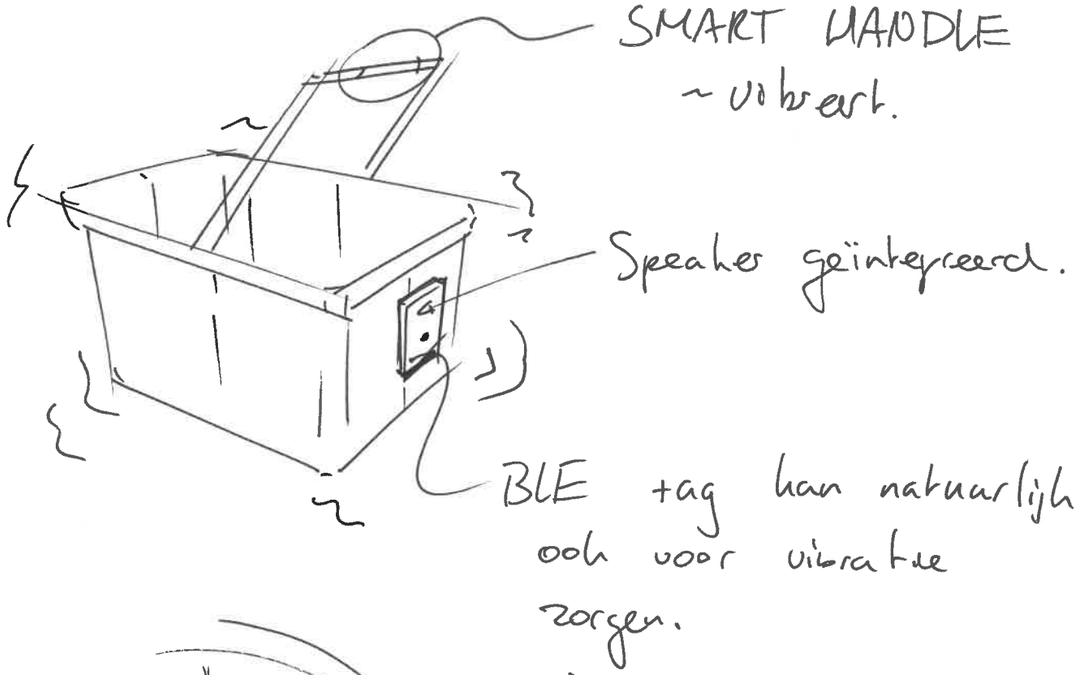
screen showing who is allowed to leave

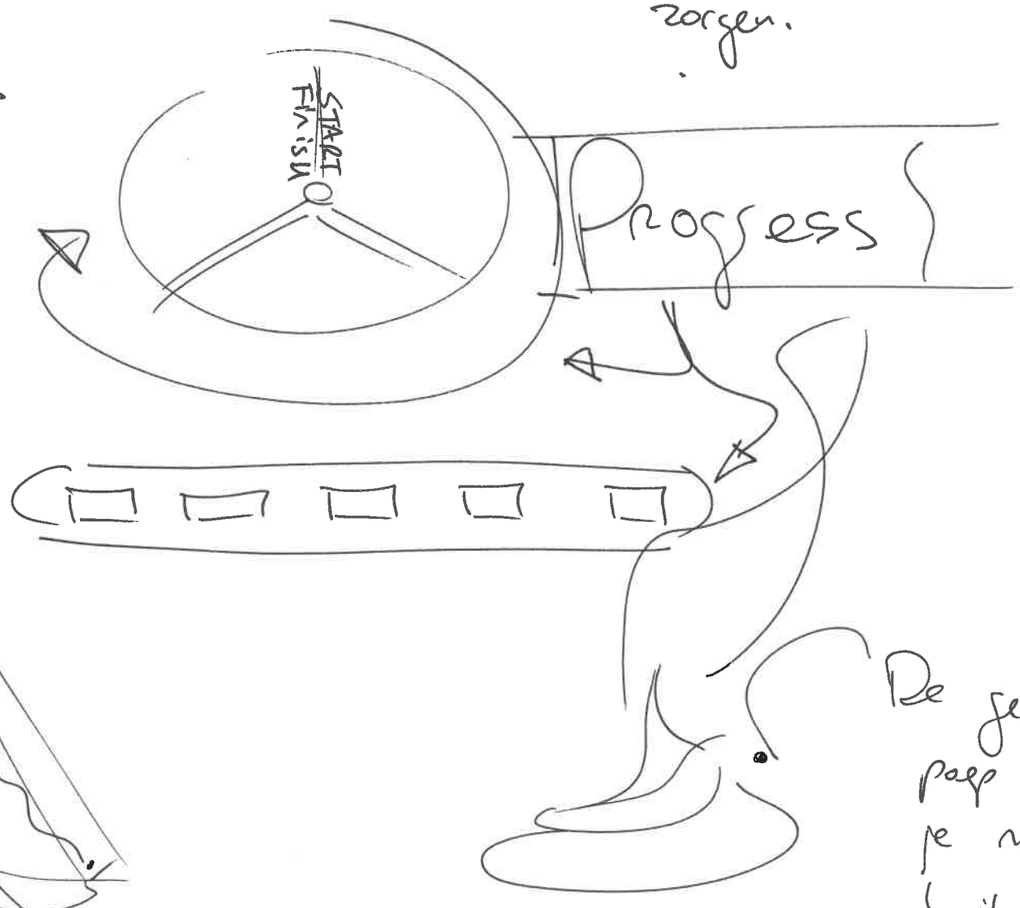
google-does icons (avatar)

- mathetijk schoon te maken

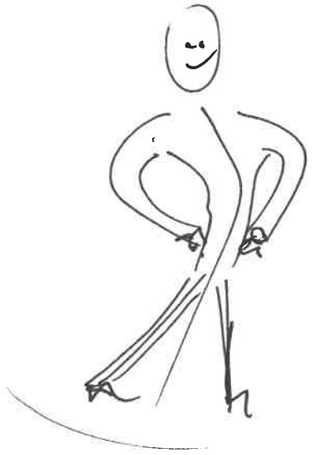

Rook gordijn.
Integrated display
- stop
- go
- niet inlopen
"Hologram achtige" projectie aan niet inloop kant.
hoger display
- titles
- communicatie.
"lopende LED strip" groen of rood (of oranje?)
Licht / animatie projectie op de grond.
- lopende groene pijl voor "go"
- Stop bord of X rood bij stop.
"Papier hier" "mind your step" -achtige tone
bijvoorbeeld:
- "wel thuis"
- "tot ziens"
- "Bedankt & tot ziens"
Of een simpele "bliep." zoals [OV] of bliep van de kassière

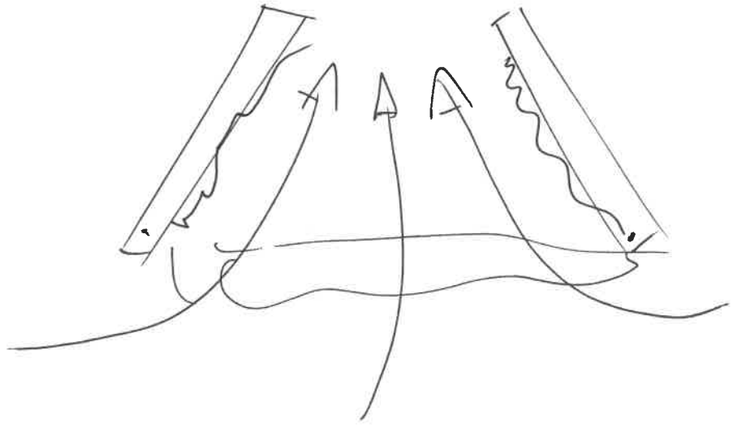






Real life Avatar.





Appendix E: Things to learn from hotels

they take the effort to welcome you and say goodbye, making you feel appreciated

human interaction and personal attention are very important

they unburden you as much as possible, by for example helping with luggage

Sometimes there is entertained to keep your kids busy, allows you to rest (further 'unburdening' you)

Hotels like to make you feel important (usually corresponding with how much you pay)

Payment is done as easily as possible to not have to deal with it, and all purchases/dinners/breakfasts etc. are all charged in 1 go, not seperate

Controlled access to the hotel, security cameras and door locks give a sense of security and comfort

Amenities are provided, which often give a sense of luxury and feel like 'gifts'

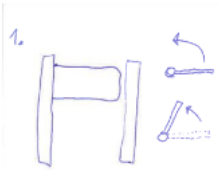
Hotels like to excite you to create a memorable experience. They do this by creating unexpected rooms, beautiful architecture and challenging whats possible.

Hotels get out of your way as much as possible. Once you have checked in, you can leave and enter as you like

Appendix F: Overview of pros and cons of different mechanisms

Different physical barriers

1 arm, pivot

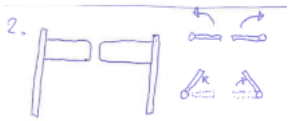


- Very familiar concept
- Arm is very easy to swap and change in size and design
- Only 1 motor is needed
- Width is minimal: multiple gates can be placed next to eachother

- Needs room behind gate to open
- Difficult to open and close quickly

cheaper but slower alternative to option 2

2 arms, pivot



- Can open and close faster than 1 arm
- Arms are easy to swap and change in size and design
- Needs less room behind gate than 1 arm
- Width is minimal: multiple gates can be placed next to eachother
- Can be closed very rapidly to stop thiefs

- Needs room behind gate to open, but less room than 1 arm
- Needs 2 motors

1 arm, slide

- Does not need room in front or behind gate
- Only 1 motor? is needed
- Multiple arm lengths possible
- Customers cannot push this open like they can with a pivotting gate

- Very wide, at least 2 times the width of the arm
- Likely slow
- Harder to implement an evacuation procedure (in case of emergency instinct is to push, not to slide sideways)
- Wide product, can fit less gates next to eachother
- Likely to be damaged more quickly when someone runs into it

cheaper but slower alternative to option 4

2 arms, slide

- Does not need room in front or behind gate
- Multiple arm lengths possible
- Faster than 1 arm
- Customers cannot push this open like they can with a pivotting gate
- Can be closed very rapidly to stop thiefs
- Very wide, at least 2 times the width of the arm
- 2 motors? are needed
- Harder to implement an evacuation procedure (in case of emergency instinct is to push, not to slide sideways)
- Wide product, can fit less gates next to eachother
- Likely to be damaged more quickly when someone runs into it

2 arms, pivot into casing

- Likely to be very fast
- No room needed in front or behind the gate
- Customers cannot push this open like they can with a pivotting gate

- Only suitable for narrow exits
- Needs 2 motors
- No easy changes made to the arms
- Harder to implement an evacuation procedure (in case of emergency instinct is to push, not to slide sideways)

wall, slide into ground

- No room needed in front or behind the gate
- Different widths possible
- Only 1 motor
- Looks cool
- Customers cannot push this open like they can with a pivotting gate

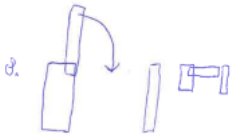
- Need a hole in the ground
- People can step on it, damaging the motors
- Dirt and dust on the floor will get into the system
- Trip hazard
- No evacuation procedure possible

1 arm (slagboom), pivot out of casing

- No room needed in front or behind the gate
- Only 1 motor
- Likely to be fast
- Customers cannot push this open like they can with a pivotting gate

- Maximum width of exit is the height of casing
- Trip hazard
- Possibility of hitting children or kneecaps
- Pinch hazard if arm retracts
- Very limited customizability possibilities for the arm
- Harder to implement an evacuation procedure (in case of emergency instinct is to push forwards, not to push down)
- Strong motor needed due to gravity pulling the arm

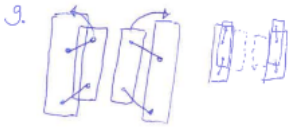
1 arm (slagboom), pivot on top of casing



- No room needed in front or behind the gate
- Only 1 motor
- Likely to be fast
- Familiar concept
- Customers cannot push this open like they can with a pivotting gate

- Possibility of hitting people's heads
- Strong motor needed due to gravity pulling the arm
- Very limited customizability possibilities for the arm
- Harder to implement an evacuation procedure (in case of emergency instinct is to push forwards, not to push upwards)
- Easy to climb under

2 arms, double pivot into casing

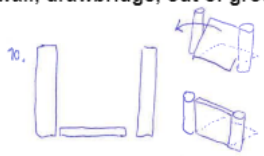


- No room needed in front or behind the gate
- Likely to be fast
- Customers cannot push this open like they can with a pivotting gate
- Can be closed very rapidly to stop thiefs
- 2 motors needed
- Not very suitable for wide exits
- Harder to implement an evacuation procedure (in case of emergency instinct is to push forwards, not to push upwards)

- Pinch hazard

could be argued this is just a form of 2 sliding arms (option 4)

wall, drawbridge, out of ground



- Cool looking
- Varying widths possible

- Very slow
- Pinch hazard
- A lot of room needed behind the gate
- Unnecessarily complex

Appendix G: Pivoting arms vs sliding arms

2 pivoting arms




2 sliding arms




Customer can start walking through the gate before it has fully opened	VS.	Customer has to wait until gate is opened wide enough for him to pass
Feasible within this project's timespan to prototype with	VS.	Necessary to design a mechanism which will take time that is better spent on improving the interaction and communication of the gate
Has minimal width, but rotating arms take up room in front or behind gate	VS.	Uses no room in front and behind gate, but is very wide
Movement of arms feels human, you are either 'welcomed' symbolically or 'let go' symbolically	VS.	Movement of arms have notions of a guilliotine, notions of cutting something
Standard mechanism, limited room for innovation	VS.	Novel mechanism, possibility of creating an innovative image
Less possibilities of getting caught in between arms and better and more intuitive ability to 'defend' yourself by pushing open the arms	VS.	Possibility of feet getting caught between arms if arms close too fast and no natural, instinctive way to 'defend' yourself
Easy to understand how to force it open in case of an emergency	VS.	Confusing how to open it in case of an emergency (instinct is to push, but these arms do not look like they can be pushed open)
Width of exit is usually fixed, cannot be changed after installation		Wide exit possible to let big items through in service situations

Appendix H: Program of Requirements (CLEARGATE)

#	Topic	Demand/ Wish	Requirement	Boundaries	Rationale	AMPEL	Comments	
D 1.1	Performance	D	Product blocks customers that are not allowed to leave	People that have not paid	Increases security, and if there would not be such a function, stealing would be encouraged			
D 1.2		D	Product can function in existing SCO areas		This is where the product will first be applied, as a stepping stone for the 'just-walk-out' stores of the future			
D 1.3		D	The design of the product gives clear feedback about when you are allowed to pass		User experience can be very negative if people are unfairly 'incriminated' by the product, or when they do not understand it			
D 1.4		D	Product can distinguish which people form a group together		So they can be let through together or individually.			
D 1.5		D	The product opens quickly enough, so that a customer can walk through without being blocked by a gate that is still opening		If the gate is still opening, often customers push the gate so that it opens more quickly. This damages the motors, requiring more repairs.			
D 1.6		D	Product has elements that are familiar to the consumer, so that not the whole product is new and unknown		Following Ansoff's matrix, products are less likely to be adopted and accepted if they are very unfamiliar to the user. Change should be introduced incrementaly, so for example the product could have regular gate arms that people are familiar with. Also, people generally have no mercy for products that are hard to understand.			
D 1.7		D	The design is understandable for different languages and cultures	NL, BE, DE, IT, DN	It is likely the product will be placed in NL and DE, so it cannot function on one language: either multiple languages need to be applied or universal language such as lights as sounds need to be applied.			
D 1.8		D	Product can be opened and closed by any system a store can have in place (e.g. camera system, NFC tags, barcode scanners, etc.)		Some stores will have a system that they prefer using which Pan Oston has no control over. In this case the product still has to work, so it should be controllable by many different systems			
D 1.9		D	Product lowers the amount of backflow		By analysing whether someone is using the gate from the wrong side, backflow can be lowered or even prevented.			
D 1.10		D	Product lowers the amount of free-riding thiefs		By analysing how many people are using the exit gate after eachother, free-riding thiefs can be noticed and stopped			
D 1.11		D	Product has an arrangement of alarms for different situations	At least: one for when someone is about to try to leave without paying (warning), one for when someone is forcing the gate and leaving/running away (full-on alarm)	Having a warning alarm allows customers who do not understand the system or made a mistake to correct themselves before the full-on alarm is triggered. This prevents a situation where someone is wrongfully publicly scolded.			
D 1.12		D	Product can be opened from both sides by employees		So that they don't need to force it open. For example a NFC reader can be added that works with employees' tags.			
D 1.13		D	Product supports the host in knowing what is going on in the SCO area	For example: trigger an alarm when gate is pushed, when there is backflow or free-riders	So that the host has more peace of mind and can better fulfill her role as host instead of security guard			
D 1.14		D	SCO host can open the gate remotely from his/her host device		So that people with problems opening the gate can easily be helped. This also allows the host to open the gate for colleagues that need to pass.		No time was spent on this, but given that the gate uses a Raspberry Pi which has wifi this should be very easily implemented, depending on the software on the host's device	
W 1.1		W	Product lets people through that have no products with them				Gate will think it is a person forgetting his/her cart or basket, customer will need to ask assistance from host	
W 2.1	Environment	W	Product's parts that are lasercut are nested in a way that minimizes metal waste		Less metal waste = less demand for new metal = less energy needed for metal fabrication			
D 3.1	Maintenance	D	Components of product are easily reachable and interchangable		Makes service and maintenance a lot easier and faster			
D 3.2		D	Chosen hardware should stilll function if configuration of product is changed		Having little variation in hardware allows for buying in bulk and for easier servicing. For example, if the arm of a gate is made 4 times the size for a different market, it is easiest if the motor that is normally applied can still be applied.			
D 3.3		D	When evacuation mode is triggered, product is able to reset itself		Currently a technician is required to visit the store to reset the gate, costing a lot of unnecessary time and money.			
D 4.1	Production Facilities	D	Product can be fabricated by Pan Oston	Fabricated in factory in Raalte	Fabricating products is how Pan Oston makes money. Fabricating it in Raalte allows for ultimate control, which is needed for a new product that is likely going to be complex.			
D 4.2		D	Product uses Pan Oston's strengths and experience	Use steel, powdercoating, integrated hardware and/or parts supplied by partners	This ensures the product is of high quality and it reflects Pan Oston's strengths. It also automatically means the product fits well with the other products in Pan Oston's portfolio.			
D 4.3		D	Hardware used in the product can be controlled by software written by a third party		A third party will write the software since Pan Oston does not have this knowledge or experience. It should be possible for this third party to do this.			
D 4.4		D	Product can be assembled at Pan Oston instead of in store		Saves time and allows the installation timeframe to be kept more easily			
D 4.5		D	Product uses as few different assembly materials as possible and exists out of as few parts possible		To increase assembly speed		Product requires quite a bit of welding, but installing it in the store is done very quickly because there are few parts to assemble	
D 4.6		D	Product allows Pan Oston to apply their tailor-making skills		So they keep their competititve advantage in this			
D 4.7		D	Product's shell is easily customizable by Pan Oston employees, so that it can be tailor made for different customers.		Making tailor made products is Pan Oston's specialty, and this allows for that. Also, it should fit with SCO's it will be placed next to, which will also be tailormade.			

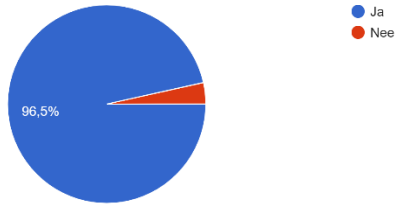
W 4.1		W	Hardware used in the product can be bought from Pan Oston's partners		To further invest in existing relationships, and it easier than to get to know a new partner and have the uncertainties that come with that.		For a lot of parts, yes. However the motor, torque limiter and electronic brake may need new suppliers.	
D 5.1	**Aesthetics**	D	Product is in line with the aesthetic of other Pan Oston products	Fit Pan Oston aesthetic as described in moodboard				
D 5.2		D	Product looks attractive and exciting	Fits attractive and exciting moodboard	Product need to excite and make a store owner proud to own it. Good looks will also excite customers in the store. Therefore product should be attractive.			
D 5.3		D	Product mustn't let the customer feel enclosed or caged		Very often gates are used that have a lot of holes and negative space. This makes the area in the store feel less enclosed, which is a good thing.			
W 5.1		W	Product is stylable and customizable		Stores like to personalize, for example by putting their logo on the product. Stylizing the product would make it fit in the store more.			
W 5.2		W	The design must discourage stealing		Through for example aesthetics the product can perceived as a barrier to steal, as it demands respect and it looks like it knows when you are stealing			
D 6.1	**Product Life Span**	D	Product is built to withstand rough handling in the store	Can withstand being hit by shopping carts, people climbing on/over it, containers ran into it, etc.	Retail stores are a rough environment and often customers are not careful with the store's equipment.			
D 6.2		D	Product discourages children to climb on it		Climbing children cause a lot of damage to current gates			
D 6.3		D	Product allows employees to pass without paying and allows them to use the product from the wrong side		Employees need to be able to move freely throughout the store, and if the product does not allow this they will force the product to, damaging it in the process.			
D 6.4		D	Product lasts at least 7 years	Assuming normal use, no big accidents and no vandalism or sabotage	Makes it cheaper for the store to own and represents Pan Oston's high quality. 7 years is the average lifetime of current gates, so it should at least match that.		No way to know for sure, but given Pan Oston's quality welding and the product's clear communication which should prevent or at least lower damage due to confusion, it has a good chance to last 7 years.	
W 6.1		W	Product is always open and only closes when someone is not allowed to leave		Demands less from the motors, extending their lifetime			
D 7.1	**Ergonomics**	D	Customers should intuitively understand how the product works, without any explanation		Makes sure the experience is seamless, which is the goal of the project. Can for example be done with lighting and sounds.			
D 7.2		D	Product can let all customers through	Children, elderly, wheelchairs, scootmobiles, overweight, handicapped	Retail stores have all kinds of customers, who should all be able to have a seamless experience.			
D 7.3		D	The customer must trust the design by understanding how technology is used to determine whether they are allowed to leave or not		The customer needs to trust the product before he can comfortably make use of it. Therefore, he needs to understand it and feel okay with it.			
D 7.4		D	Product can let all types of customers through: cart, basket, no cart or basket.	Product accounts for different cart measurements, and the width of a person + basket in their hands	Otherwise people cannot leave the store		Cart or basket is mandatory. This compromise has to be made, otherwise biometric technology is required	
D 7.5		D	Access control on the gates itself (for example NFC reader for employees) is easily reachable	Placed roughly where the hand is	So that control is easy, intuitive and quick.			
D 8.1	**Safety**	D	Product can be forced open in critical situations like evacuation		If the product would hinder people trying to flee a dangerous situation, it could endanger the store's customers.			
D 8.2		D	Product should not be able to accidentally injure customers, especially curious children.	Product adheres to CE norm	Serious injuries can cause the product to be recalled. This means no dangerous mechanical parts should be exposed, no wiring should be exposed, audio levels should not be too loud, etc.			
D 9.1	**Install and initiation of use**	D	Product needs to be able to be installed by Pan Oston staff		Will be deliverd and installed together with other PO products			
D 9.2		D	Product can be installed quickly	30 minutes?	Pan Oston has a limited timeframe in which they are requirred to install everything in the store			
D 9.3		D	Software on the product should be able to be tuned by store owner		Things like how long the gates are open, how fast they close (if gates are used), what sound is made, etc. should be able to be set by store owner.		No time spent on in project, this is very much possible but Pan Oston or the software partner will have to do it.	
D 9.4		D	Software on the product is updateable		So that bugs can be fixed, and so that the product can be improved. Especially after first implementation of the product many things will be learned, and most likely things will need to be finetuned.			
W 9.1		W	Product has similar footprint as existing gates		So that it can replace existing gates without being in the way of other elements already placed in the store.		If the reference gate has customer guidance, then yes. If not, then no.	
W 9.2		W	Product should run on power available in the store		If previous products and connection deliverd 12V, then this product should do that too			
D 10.1	**Target product cost**	D	Product cost stays under 14k					
D 11.1	**Transport**	D		1200 mm x 800 mm	So that it can be safely transported		It will stick out 200 mm (which is fine says Pan Oston logistics department)	
D 11.2		D	Product should not be top-heavy, or else the top should be detachable, or else it should fit on a EUR pallet on its side		So that vibrations dont damage the product			
W 11.1		W	Product is not taller than 1400 mm		So that it can fit in a double decker truck			
D 12.1	**Reuse, Recycling**	D	Product can be disposed of by Pan Oston at the end of life		This is how Pan Oston always works. Disposing of the product at the end of life is part of contract the store pays for.			

D 13.1	**Storage**	D	Product can be stored efficiently in case of Forecasted Orders		Sometimes Pan Oston products are fabricated beforehand to be able to deliver on time if big orders are forecasted. In such a case, product needs to be stored			
D 14.1	**Strategy**	D	Product can be used for exiting SCO areas, but also for entering WOT stores	At least with minimal adaptation	This allows Pan Oston to sell to multiple markets with the same product and become more futureproof			
D 14.2		D	Product needs to be able to evolve into a solution for WOT (walk-out-technology) stores, so it evolves with the market		If the product can be evolved into a solution that will be eventually needed for WOT stores, knowledge and experience can be directly appied to these new stores, and retail stores will be already known with the concept			
D 14.3		D	Product is applicable in Pan Oston's customer market: supermarkets and supermarket-like stores such as Action, Big Bazar and Xenos.		These are Pan Oston's customers. However, other markets such as Zara and H&M could become new customers if the products is also applicable in these stores.			
W 14.1		W	Product gives the store an innovative image		New technologies are often exciting, which can have a positive effect on how the store is perceived.			
W 14.2		W	Product can be placed in Pan Oston's showroom		To show potential customers how it works and so that it can inspire			
W 14.3		W	Product allows for extra services to be sold, like knowing how many people leave the store, at what times, remote monitoring of the components, remote software updates, etc.		To create more value for the store and to create a longer stream of revenue for Pan Oston			
D 15.1	**Reliability**	D	Product's internal components like the motherboard and motor should not be reachable without tools		To prevent vandalism and manipulation			
D 15.2		D	Product can withstand accidental spilling of water		So that it still works when someone spills water over it			
D 15.3		D	Product is adaptable to culture and crime rates.		Higher crime rates need more blocking, for example so that baskets cannot be slided under the gate. Audio could also be changed, so that product is perceived less aggressive in cultures where this is not wanted (like Japan)			
W 15.1		W	Product can function without needing a host to oversee it	When product is introduced a host might be necessary because customers are unfamiliar with the product. After a while, host should not be needed	Cuts costs and makes it more futureproof for a future where less staff could be present in the store			

Appendix I: Questionnaire and results

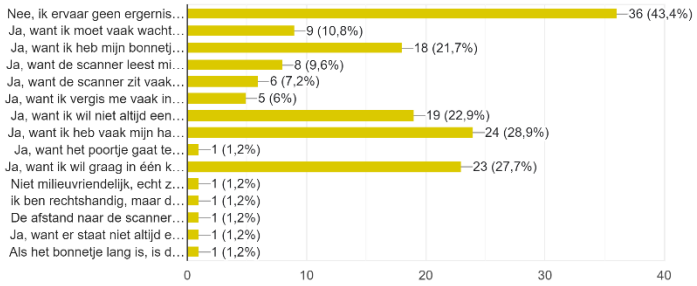
1. Gebruikt u wel eens de zelfscankassa in de supermarkt?

86 antwoorden



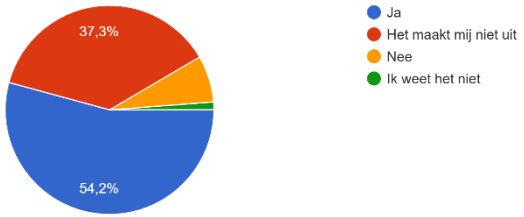
2. Ervaart u ergernissen bij het scannen van uw bonnetje en door het poortje lopen? (meerdere antwoorden mogelijk)

83 antwoorden



3. Zou u na betaling gelijk de winkel uit willen lopen, zonder een bonnetje te moeten scannen?

83 antwoorden



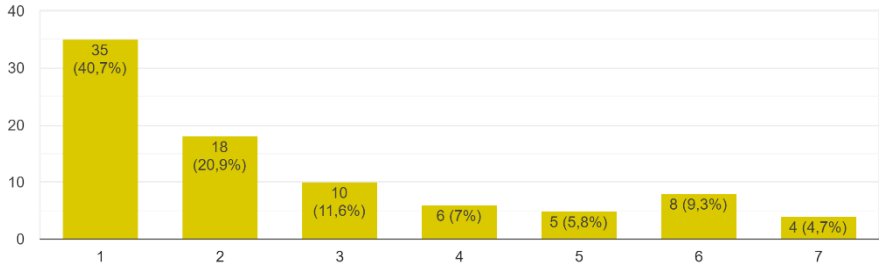
(optioneel) Zou u uw antwoord kort willen toelichten?

Ik heb al betaald waarom moet ik dan nog een handeling verrichten om naar buiten te kunnen.
Bovendien heb je dan vaak je handen vol en is het bonnetje zoek.
Betere flow na transactie geen oponthoud door een extra handeling
Ik vind de handeling niet storend. Grootste argument voor mij is minder papier verbruik.
puur gemak
Ik zoek gemak
bv door een dagcode in de app
Zonde van het papier, gaat daarna rechtstreeks prullenbak in
Sterk afhankelijk van locatie. Bij mijn AH gaan veel mensen naar de normale kassa dus de zelfscan kassa's zijn erg rustig!
Het is niet per se veel moeite, maar vaak erg onhandig. Er is al heel veel controle, en die extra handeling terwijl ik mijn handen vol heb en als moet opschieten voor anderen is de extra handeling zeker een irritatie.
Ja dit zorgt voor een betere doorstroming.
Vind het een kleine moeite, maar ik kan me voorstellen dat er wel manieren zijn om deze stap over te slaan en toch een soort check kan inbouwen.
Gewoon omdat ik aan mijn verplichtingen heb voldoen door mijn boodschappen af te rekenen.
Een extra handeling zou daarom niet meer nodig zijn. Een controle zou tijdens de afrekenprocedure moeten gebeuren en niet nog een keer bij het poortje. Het zegt ook niets over wat ik afgerekend heb. Ik begrijp echter wel dat de winkel enige controle wil hebben over de personen die op die plek het winkelgedeelte/betaalplein willen verlaten.
Het is een kleine moeite om even het bonnetje te scannen
Ik snap de overweging van de supermarkt of ik alles heb gescand en het is minimale moeite
Een extra bonnetje is overbodig als je het niet nakijk
handen vol
Als het process vloeiender verloopt zou ik natuurlijk blij zijn. Dit zorgt voor gemak en minder ergernis. Aan de andere kant kijk ik natuurlijk een beetje naar mijn privacy en maak ik mij soms wel een beetje zorgen over de impact die AI-tracking-systemen daarop hebben.
De tijdwinst die je hebt behaald met de zelfscan kassa wordt teniet gedaan door het “ gedoe” rondom een kassabon om een poortje te openen.
Zonder de extra stap van mijn bonnetje moeten scannen kan ik sneller doorlopen en hoef ik het bonnetje niet in mijn hand te houden.
Ik houd niet van Camera's en dat alles wordt vastgelegd
Na betaling ben ik eigenaar en wil ik in principe geen belemmering meer tegenkomen.
De hoofdreden van het bonnetje scannen zal waarschijnlijk voor veiligheid zijn en administratie voor het bedrijf. Die twee aspecten verlies je dan
De scanner bij de Hornbach is vooral onhandig, bij Ah werkt die wel altijd.
Ik denk dat voor het milieu een korte bon (3cm) beter is dan de productie en verbruik van de apparatuur die nodig is voor automatische poortjes.
Het zou een stuk sneller en efficiënter zijn, en daarnaast ook stress schelen
Het scannen van een bonnetje is geen enorme ergernis, maar ik zou zeker open staan voor een oplossing waarbij deze stap wordt weg genomen
Dat is natuurlijk wel prettiger maar ik stoor me niet enorm aan het poortje.
Het scannen van een bonnetje ervaar ik niet als storend. Maar als het seamless kan, altijd goed! Groet BBO
Zelfscan ergernissen wegen niet op tegen kassa ergernissen
Dan zou ik het gevoel hebben dat ik iets niet goed doe. Ik heb bevestiging nodig dat ik mag gaan, zoals bij de AH op het station in Zwolle met een voice-over en groen licht.

Het is een simpele handeling. Zo de winkel uitlopen voegt iets toe, maar is geen significate verbetering.
Dat bonnetje is een heel ouderwets middel na een hippe zelfscankassa
Ik ga naar de zelfscanner voor het gemak, kan super snel zonder interactie zelf alles regelen maar wordt daarna weer opgehouden en ik wil geen bonnetje!!
Dat zou de meest naadloze ervaring zijn.
Ik ondervind geen hinder van het scannen.

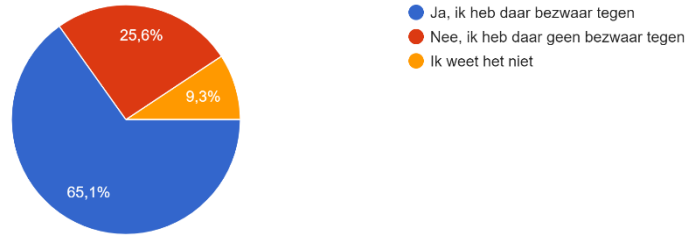
4.1 Hoe zou u zich voelen in een winkel waar GEPERSONALISEERDE gezichtsherkenning wordt toegepast?

86 antwoorden



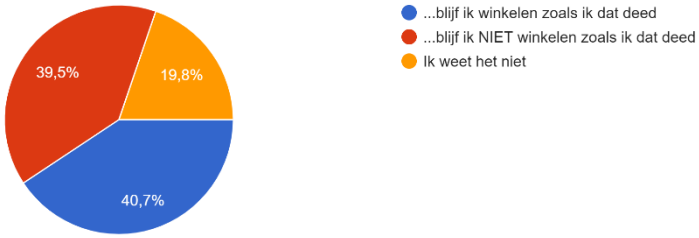
4.2 Heeft u er bezwaar tegen als uw supermarkt GEPERSONALISEERDE gezichtsherkenning toepast?

86 antwoorden



4.3 Wanneer mijn supermarkt GEPERSONALISEERDE gezichtsherkenning zou gebruiken, dan...

86 antwoorden

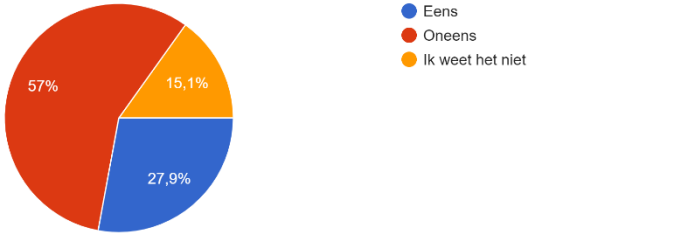


4.4 Als u anders zou gaan winkelen, wat zou u veranderen?

86 antwoorden

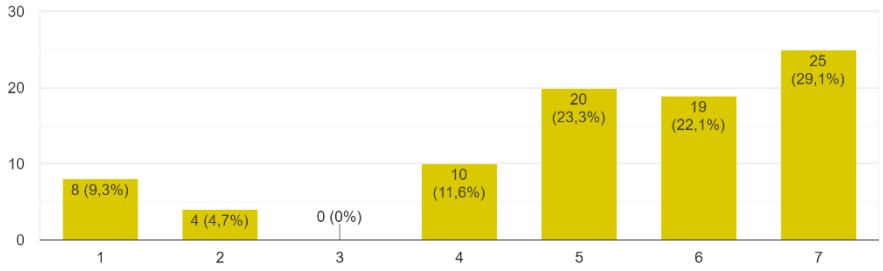
4.5 Als GEPERSONALISEERDE gezichtsherkenning er voor zorgt dat ik na betaling gelijk de winkel kan verlaten zonder mijn bonnetje te moeten scann...n vind ik het gebruik van deze technologie prima

86 antwoorden



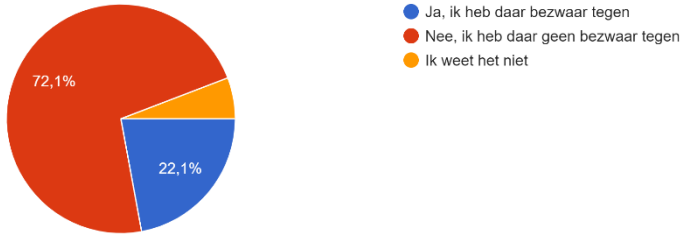
5.1 Hoe zou u zich voelen in een winkel waar ANONIEME gezichtsherkenning wordt toegepast?

86 antwoorden



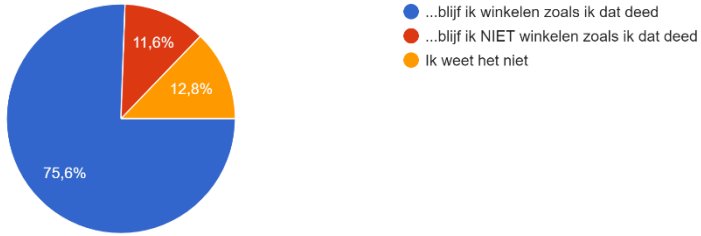
5.2 Heeft u er bezwaar tegen als uw supermarkt ANONIEME gezichtsherkenning toepast?

86 antwoorden



5.3 Wanneer mijn supermarkt ANONIEME gezichtsherkenning zou gebruiken, dan...

86 antwoorden



5.4 Als u anders zou gaan winkelen, wat zou u veranderen?

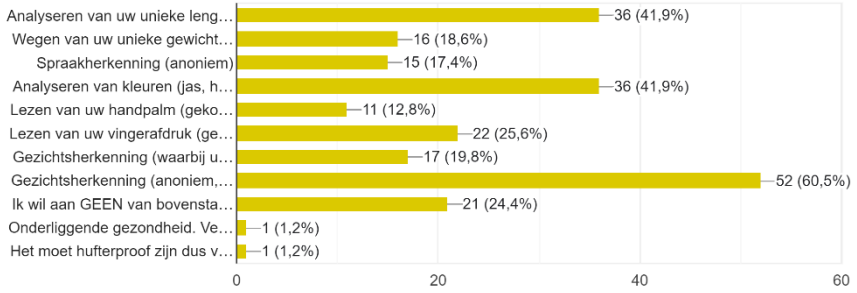
86 antwoorden

5.5 Als ANONIEME gezichtsherkenning er voor zorgt dat ik na betaling gelijk de winkel kan verlaten zonder mijn bonnetje te moeten scannen, dan vind ik het gebruik van deze technologie prima

86 antwoorden

6. Aan welke technologieën bent u bereid mee te werken? (meerdere antwoorden mogelijk)

86 antwoorden

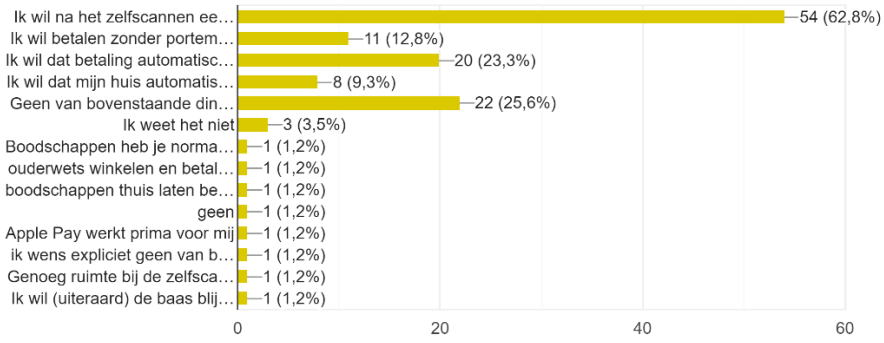


7. (optioneel) Als u zich zorgen maakt over genoemde technologieën, kunt u noemen waar u zich zorgen over maakt?

Privacy
Ik wil niet dat mijn koopgedrag wordt gebruikt om aanbiedingen enz te sturen.
Misbruik.
Ik vind het geen fijn idee dat er persoonlijke data van mij wordt gebruikt zonder dat ik daar toestemming voor geef.
Beveiliging
Waar ik mij het meest druk om maakt is het beïnvloeden van de consument. Data/technologieën zoals hierboven worden genoemd, hebben als doel mij als consument te analyseren en vervolgens wordt dit gebruikt om mij te beïnvloeden. Een heel simpel voorbeeld: mannen tussen 1,80-2,00 zijn meestal gevoeliger voor drank, dus er komt allemaal Heineken op onze ooghoogte. En zo zijn er nog veel meer en ook veel extremere zaken. We worden aan alle kanten al beïnvloed, zie de analyses van Hariri. Ik heb hier bezwaar tegen en zie dit als begin van de ondergang van de vrije geest. Dat klinkt wellicht overdreven, maar zo zie ik het oprecht. Ik maak hierin dus echt een onderscheid tussen: wat is voor mij praktisch en wat heeft voor mij geen toegevoegde waarde: mijn gezicht anoniem herkennen zorgt ervoor dat ik direct door kan lopen of mijn telefoon kan ontgrendelen. Mijn gewicht of mijn kleur jas herkennen heeft voor mij geen toegevoegde waarde (ook al zullen de grote bedrijven zeggen dat het allemaal ten gunste is van de klantbeleving), maar draait het gewoon om omzetverhoging voor de grote bedrijven.
Al die commerciele shit
De supermarkt weet al genoeg over mijn consumentengedrag middels de bonuskaart. Gezichtsherkenning lijkt me niet nodig.
Data is nooit echt anoniem en kan ten alletijde, bedoelt of niet, tegen je worden gebruikt als een bedrijf of overheid het uitkomt. Ik ben tegen volledige gedrags analyse van mensen.
Het blijkt vaak dat bedrijven moeite hebben met het waarborgen en niet misbruiken van persoonsgegevens, dan wel het onzorgvuldig omspringen met dergelijke persoonsgegevens. Daarnaast is de stap van anoniem naar gepersonaliseerd klein als tracking hardware eenmaal in gebruik is genomen.
Ik wil niet dat mijn lichamelijke/persoonlijke kenmerken gebruikt wordt door winkels voor individuele herkenning, een pasje gebruiken is beter al zit daar ook haken en ogen aanvast.
Opslag van (anonieme) camerabeelden. Zijn deze bijvoorbeeld terug te kijken door het winkelpersoneel en adhv terug te redeneren naar wat iemand gekocht heeft?
1. Kleuren, ik vind het van belang dat dit niet gaat kijken naar huidskleur o.i.d. 2. Ik vind heel veel technologieën heel interessant, maar wel eng. Ze weten al zo veel van mij/ mensen algemeen, ik kan nog niet wennen aan het idee van meer nogal persoonlijke gegevens delen (ookal zullen ze toch al wel alles weten)
Met name de veiligheid van de data
nee
risico op potentiele datalekken; risico op achterdeurtjes waardoor de fabrikant van de technologie kan meekijken; waar heeft de winkel deze informatie überhaupt voor nodig?
Data wordt ergens opgeslagen, hoe veilig is dat en waar wordt de data allemaal voor gebruikt
Chinese datachappies
dat de data op verkeerde plekken terecht komt door hacks of vrijwillig delen tbv Big data
Privacy
delen/verkopen van privacy gevoelige gegevens met derden
Ik vind niet dat een supermarkt toegang zou moeten hebben tot zulke persoonlijke gegevens, hoe geanonimiseerd dan ook.
Privacy van de verzamelde data
Het begint met het anoniem vastleggen maar wat is de volgende stap? Net als bij qr code, die gaat ook niet meer weg vermoed ik
privacy
Ik houd er niet van om mijn persoonlijke eigenschappen te moeten gebruiken als identificatie in de openbare ruimte, zeker niet als een commercieel bedrijf die gegevens ophaalt. Bij persoonlijke apparaten als smartphones vind ik het niet erg omdat ik daar meer controle over heb en het gebruik voor beveiliging. Het opgeven van privacy voor een niet-essentiele functie als afrekenen vind ik de veiligheidsrisico's niet waard.
Data Analyses op gedrag/patroon daarop volgend bv uitsluiting van verzekeringen etc door slechte gewoontes
Privacy, ongewenste opslag van data en ongewenste mail, hoewel je dit meestal wel zelf kunt sturen.
Al deze technologieen kunnen worden gebruikt voor de uitrol van een technocratische surveillance staat. Wat technologisch kan hoeft niet altijd. Zeker in de winkel is de toegevoegde waarde minimaal.
Privacy is belangrijk en dit is weer een stap in het belemmeren van de privacy.
Wetgeving
Ik maak mij geen zorgen, maar ik zie niet in wat voor meerwaarde een winkelketen met die specifieke gegevens zou moeten. Deze technologie wordt ook gebruikt voor bankgegevens en om inloggevens te verifieren. Zou het dan handig/eerlijk zijn als mensen verplicht worden om dit te gebruiken als ze dat eigenlijk niet willen? Overigens denk ik dat dit vooral voor de rechtse politiek een hekelpunt wordt. Ik zie ook in vraag 8 dat het huis automatisch weet wat ik nodig heb..daar word ik ook niet heel enthousiast van, dan weten producten en diensten meer van mij dan ik van mijzelf weet.
Ik heb gene behoefte aan gepersonaliseerde reclame dus alleen anoniem is voor mij een optie
Waar blijft het gewone leven?
Angst dat je in de gaten gehouden wordt.
De beveiliging van mijn persoonlijke data
Dat het escaleert
Complexiteit van de technologie is 1, maar bijv zou je de situatie kunnen krijgen dat er personen overeenkomen op basis van de eerste 4.
Dat deze gegevens in verkeerde handen vallen
Grote ondernemingen handelen per definitie in de kern niet in het belang van de klant maar in het belang van winstmaximalisatie. Dat is dan ook de grootste reden voor het inzetten van technologie en moet daarom bij voorbaat gewantrouwd worden. Daarnaast zijn er natuurlijk praktische bezwaren, zoals: ik ben voor menselijk contact bij het winkelen; veel grote ondernemingen hebben laten zien niet heel nauwkeurig met privacy om te gaan.
Mijn privé
Gebruik van privacygevoelige informatie door derden, bijvoorbeeld het verkopen van deze data door deze supermarktketen.
Ook mogelijke diefstal van opgeslagen persoonlijke informatie vind ik geen fijn idee
Ik zou mij zorgen maken over het opbouwen van een persoonlijk profiel waarbij mijn aankoopgedrag wordt geanalyseerd en aan mij gerichte reclame wordt voorgeschoteld. Ik wil niet op deze manier bewust of onbewust beinvloed worden.
Ik vind het bezwaarlijk dat bedrijven zoveel persoonlijke informatie tot hun beschikking hebben. Ze hebben nu misschien geen kwade bedoelingen, maar het is misbruikgevoelig. En misschien kan het ook in verkeerde handen vallen voor cyberaanvallen.
Tech is helemaal niet nodig. Je kan de klant ook volgen bij binnenkomst. Is ook anoniem. (Zie onze oplossing voor de WOT store)
Wat heeft een winkel aan je persoonlijke gegevens? Dat lijkt mij niet echt normaal dat zij je vingerafdruk, handpalm of gezichtsherkenning incl. Gegevens hebben.
Privacy gevoeligheid van zeer specifieke gegevens
De vrijheid om niet opgemerkt te worden is in het geding. Het is niet eens rationeel maar psychisch beklemmend dat je in dergelijke semipublieke ruimtes gevolgd wordt.

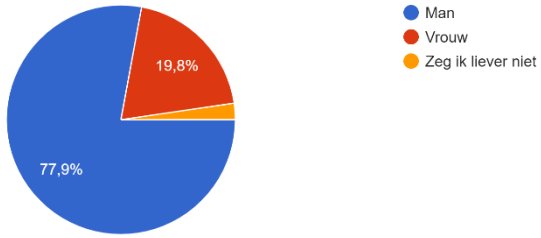
8. Welke van de volgende voordelen zou u graag in uw supermarkt willen zien? (meerdere antwoorden mogelijk)

86 antwoorden



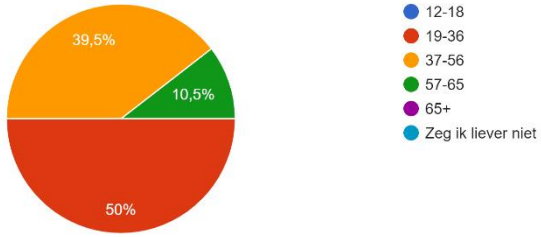
Wat is uw geslacht?

86 antwoorden



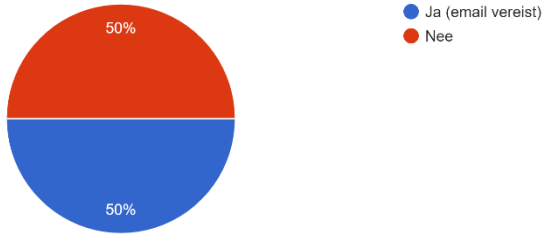
Wat is uw leeftijd?

86 antwoorden



Staat u open om meer vragen te beantwoorden in de toekomst?

86 antwoorden



Appendix J: Biometric vs. Non-biometric

Biometrisch of niet-biometrisch?

Biometrisch




- Very robust technology, can work really well
- Can recognize people, and thus can recognize frequent thiefs
- Installation can be as simple as placing a camera
- Generated data can be used for multiple purposes
- Many existing solutions available

- Heavily under legislation by GDPR and AVG
- Permission from customer needed before technology can be used on them
- For existing stores, a tradition not-seamless option with barcode scanner will still need to be available, as not all customers will give permission for using biometric technology on them
- Negative public opinion due to high amount of privacy scandals and data leaks
- Growing public awareness of the dangers of biometric tech, making the public support for these technologies unstable
- Data protection is often not taken seriously enough
- Growing concern about hardware producers spying on people using their products, especially Chinese hardware producers
- Expensive

Niet biometrisch



- No problems with GDPR and AVG legislation
- No permission needed from customers, can function in background and if needed even without them knowing
- Sustainable solution due to it not being influenced by growing public concern regarding privacy and data protection
- Fully anonymous (although if stores REALLY want to they can probably find ways to link the anonymous data to a loyalty card)
- If realtime location can be analyzed, data can be generated about how customers walk through the store without using camera's
- More possibilities for Pan Oston to play a part in fabrication of the system

- Most likely more hardware needed than when using biometric technology (RFID scanners, BLE beacons and locators, etc.)
- Less existing solutions available (although this can also create competitive advantage)
- Radio signals can be disrupted by all the metal, people and groceries in the store
- Adaptations to carts and baskets might be necessary
- Possibly a need for removeable batteries, generating waste
- Can be difficult to determine which RFID tag/beacon etc. belongs to which SCO

Criteria	Weight	Rationale
Public acceptance How comfortable are customers using it?	2.5	If customers do not feel comfortable, they do not use the system. If the system is not used, it serves no function and the system does not work. This is most important
Seamlessness Can it create a seamless shopping experience?	2.0	The system is only a success if it adds added value. The goal of this system is to make the shopping experience more seamless. Without reaching this goal, the system has no use.
Robustness How reliable is it?	2.0	Customers hate when technology doens't work and when their trip to the store is made unnecessarily complicated. Even more importantly, the system should work to prevent theft and wrongful incrimination.
Safety How safe is people their data?	1.5	Raising public awareness regarding privacy and data protection demands that companies respect their customers' data. If this is not respected and the data leaks or is misused, the store will receive a storm of negative PR which is the nightmare of any supermarket chain (source: Martijn Termaten, sales director)
Ease of application How easy is it to apply?	1.0	To make the system applicable in as many stores as possible and to save installation costs, the system needs to be easy to apply.
Competitive advantage Can Pan Oston gain an advantage with it?	1.0	To provide a business case for Pan Oston it is important there is money to be made. This is however not the biggest priority, because the main goal is being able to provide a system that can be sold together with the gate (on which Pan Oston makes the most money)
Cost How much does it cost?	1.0	Especially in retail costs are always cut and kept to a minimum. The lower the price, the more likely a store is to try out the system.
Legislation How does current or future legislation affect it?	0.5	A system work best if can function without legislation limiting it.
Sustainability How futureproof is it?	0.5	A business case is only viable if it can withstand the test of time. With changing public opinion and changing legislation, the system should be able to function. However, this is not top priority because retail hardware generally has a short life, usually 10 years maximum.

Biometric		
Score (1-10)	**Total**	**Rationale**
3	**7.5**	As shown in the questionnaire, people do not like it when technology analyzes them, especially not in a supermarket. They are slightly OK with it if it happens anonymous, but full support or the public will never be reached.
6	**12**	Identification of customers can be done from a distance so that the gate can open automatically quickly enough. However, customers will need to give permission before using the system. This adds an annoying step, making it less seamless.
8	**16**	Modern AI algorithms are trained extraordinarily well and perform great
3	**4.5**	Many data leaks over recent years have damaged the public's trust. Even governmental organisations like GGD leak very privacy-sensitive data. Biometric technologies generally need to save your data. Even if it is anonymized, it is never 100% anonymous.
7	**7**	Many hardware already exists and there are many plug and play options. For facial recognition only a few cameras would need to be installed and the system would be functional.
3	**3**	There is not much for Pan Oston to add, since biometric technologies tend to be plug-and-play systems that Pan Oston has no part in regarding fabricating or assembling.
4	**4**	Not a lot of hardware is needed, but depending on the technology provider there are costs to run their software or to use the data analysis tools. High detail AI-enabled cameras can also be very expensive (source: Morrisons, ECR Loss Prevention).
4	**2**	The GDPR and AVG legislations put a lot of pressure on how biometric technology should be applied. Due to public concern and regularly occuring privacy scandals these legislations could be made more strict
5	**2.5**	It is very suitable for continued reliability with software updates, but the fact that you are analyzing people's bodies does not change. If public opinion towards biometric technology becomes more critical, the system will lose its support
Total	**58.5**	

Not biometric		
Score (1-10)	**Total**	**Rationale**
8	**20**	No part of the body is being analyzed. All tracking is done anonymously. If the product works like it should and automatically opens a gate when a paying customer approaches, then the system is easy to use and there is little reason as to why people would not feel comfortable.
7	**14**	System can function in the background without the user having to do anything. However, because most likely hardware will need to be integrated in shopping carts and baskets, a new strategy for handing in baskets is needed because currently baskets are handed in before using the exit gate.
6	**12**	Reliability is dependent on how well signals are being sent and received. Bluetooth and RFID signals can be disturbed by the high amount of metal, fluids and other devices present in the store. There is a chance that this causes unpredictability, making the system less reliable.
8	**12**	The data being recorded are generic things such as location in the store and direction of movement. No data about someone's body or other details are being saved. This is not a perfect 10, since there are ways to link the anonymous data to a loyalty card. However, even if this happens, the store has little data compared to what data biometric technology would generate.
4	**4**	More hardware is needed than with biometric technology: you need signals senders and signal receivers. They need to be placed strategically (for signal coverage, flow of people, etc.), requiring a specific strategy for each store since every store is different.
5	**5**	Pan Oston can play a role in fabrication and/or assembly of signal senders and receivers. For example, Pan Oston could facilitate the placing of signal senders into carts and baskets if such an approach is taken.
4	**4**	More hardware is needed, increasing the cost. However, it is likely that less complicated algorithms and hardware is needed than when biometric technology is used, decreasing the cost. But less solutions already exist, so more development costs are required.
10	**5**	Bluetooth and RFID are non-intrusive technologies and they pose no health, safety or privacy risk. Besides obvious quality and safety checks like CE, FCC and RoHS, these technologies are not affected by legislation.
6	**3**	Introduction of more and more smart products in the supermarket could generate more signal traffic in the store, possibly disrupting the system. Besides this, it is very futureproof as it is not affected by legislation or public opinion.
Total	**79**	

Appendix K: BLE vs. RFID

Advantages and disadvantages of BLE and RFID

- RFID tags are cheap
- RFID tags require no battery (except for Active RFID)
- Widely used proven technology
- RFID tags are very small and easy to integrate
- Possibilities of letting customer take a tag with them and re-use it, creating possibilities for no-cart-or-basket shoppers

- Only presence detection is possible
- If RFID tags are integrated in carts and baskets, detection is impossible if customers place their cart or basket in an unexpected position or orientation
- Detection at SCO's only possible when standing exactly in/under RFID reader hardware
- 1 RFID reader necessary for each SCO + gate
- Signal is easily interrupted by metal, fluids and humans
- RFID tags require big, expensive hardware to be read (like that 'gate' you walk through when entering any clothing store)
- Difficult to make a representative PoC with hobby-grade electronics

- Broadcast on 3 radio wave channels, making it so that it does not obstruct 1 specific channel and makes it harder for its signal to be lost in other signals
- 3 possible levels of tracking: real-time location, proximity detection, presence detection
- Possibilities to let the system work with smartphones
- Feasible and relativelyt easy to prototype with/for

- Beacons are relatively large
- Beacons have batteries (will last 0.5-2 years most likely)
- Nowadays there are many devices everywhere that send out Bluetooth signal, which could pose a threat to the interpretability of the BLE beacons' signal readability
- Signal interrupted by metal or objects that emit strong radio frequencies

Appendix L: Program of Requirements (EZ-GO)

#	Topic	Demand/ Wish	Requirement	Boundaries	Rationale	AMPEL	Comments	
D 1.1	Performance	D	System removes steps in the current process of leaving the SCO area	At least: system needs to enable a customer to leave a SCO area without scanning a barcode, ticket, etc.	Makes the store more seamless, which is the goal of the project.			
D 1.2		D	system can function in existing SCO areas		This is where the system will first be applied, as a stepping stone for the 'just-walk-out' stores of the future			
D 1.3		D	system can distinguish which people form a group together		So they can be let through together without the gate closing prematurely		Does come with the compromise that groups can only have 1 cart or basket per group	
D 1.4		D	The system gives an 'opening' command quickly enough, so that a customer can exit the store without being blocked by a gate that is still opening		If the gate is still opening, often customers push the gate so that it opens more quickly. This damages the motors, requiring more repairs. It also creates frustration for the customer.			
D 1.5		D	System needs to be able to communicate with SCO's		So that it is known which SCO's are paid and which are not.		Development done by Pan Oston	
D 1.6		D	System is not limited to working with Pan Oston gates and can function with any gate		So that it can also be applied to Pan Oston customers who want the seamless shopping experience but want to use different gates			
D 1.7		D	Most of the customers feel comfortable with the technology the system uses, and for people who do not feel comfortable the system has an alternative available	At least 70% of users feel comfortable	If consumers do not feel comfortable, system will not be used, no shop will want it and the system would fail.			
D 1.8		D	System does not add more steps to the checking out and leaving a SCO area procedure		So that maximum seamlessness is maintained			
D 1.9		D	System does not use biometric tracking technologies		Opinions about biometric tracking technologies are very mixed. A group of people will not want to use the system, creating a situation where not all customers are offered the same shopping experience.			
W 1.1		W	Seamless experience is available for all 3 types of customers	1. No cart or basket, 2. Basket, 3. Cart	Most likely it is the hardest to apply the seamless shopping experience to customers without a cart or basket. In this case this group can be excluded for the introduction of the system, but of course ideally you want to include all customers.		Cart or basket is mandatory	
W 1.2		W	All customers feel comfortable using the system		If this is the case, the system can fully applied so that a seamless exit without receipt is the only option, creating a seamless experience for everyone without making people uncomfortable. Also not a single barcodescanner is necessary anymore, saving costs.			
D 2.1	Environment	D	System must lower the amount of receipts needed		Less receipts is less paper needed, which if applied on a large scale contributes to less paper waste			
W 2.1		W	system does not use disposable batteries		Disposable batteries create waste and pollution		Further development is possible where baskets are charged when stacked	
D 3.1	Maintenance	D	Software on the system is updateable		So that bugs can be fixed, and so that the system can be improved. Especially after first implementation of the system many things will be learned, and most likely things will need to be finetuned.			
W 3.1		D	Components of system are easily reachable and interchangable, and if necessary batteries should be able to be changed easily		Makes service and maintenance a lot easier and faster. This ensures the system can stay online and functional.			
D 4.1	Production Facilities	D	System can be produced by a (new) partner of Pan Oston		Pan Oston has no experience with producing electronic products, only with assembling them. This is why they need a partner that can do this.			
D 4.2		D	Hardware used in the system can be controlled by software written by a third party		A third party will write the software since Pan Oston does not have this knowledge or experience. It should be possible for this third party to do this.			
W 4.1		W	Hardware used in the system can be bought from Pan Oston's partners	Even better: creator of the software also delivers the hardware	To further invest in existing relationships, and it easier than to get to know a new partner and have the uncertainties that come with that.			
W 4.2		W	System is fabricated and/or assembled by Pan Oston		This makes use of Pan Oston's strengths in fabrication and assembly and ensures that Pan Oston plays a part in producing the system. If all they do is outsource, it is very easy for a competitor or even the partner itself to start selling the system or a comparable system without Pan Oston getting a cut.			
W 4.3		W	System can be fabricated by existing Pan Oston partner		Using existing partners gives more security because you know how trustworthy they are.			
W 5.1	Aesthetics	W	System is recognizable, making it clear when you are able to use the seamless shopping experience.		For example in the case a tracker of some sorts is attached to a cart or basket, it is good for the people to notice this so that they know their cart or basket is 'seamless enabled'. This can make it easier for people to understand and recognize why the gate is opening automatically.			
D 6.1	Product Life Span	D	system uses low energy		So that less stress is put on electronic components, and so that batteries last longer (if used)			
D 7.1	Ergonomics	D	System can work with all kinds of customers	Children, elderly, wheelchairs, scootmobiles, overweight, handicapped	Retail stores have all kinds of customers, who should all be able to have a seamless experience.			

D 7.2	**Ergonomics**	D	The system must work in the background, but customers should understand what is happening so that they can comfortable enjoy the seamless experience		Customers will only trust the system if they (roughly) understand how the system works. This is why transparency is important. This also makes the system more predictable which can prevent frustration.			
D 8.1	**Safety**	D	System has cyber protection layers	For example: passwords, only able to be accessed locally	So that people with wrong intentions cannot easily access the system and open the gate without permission		No time spent on in project, is up to software developer	
D 8.2		D	system should not be able to accidentally injure customers, especially curious children.	system adheres to CE norm	Serious injuries can cause the system to be recalled. This means no dangerous mechanical parts should be exposed, no wiring should be exposed, audio levels should not be too loud, etc.			
D 9.1	**Install and initiation of use**	D	system needs to be able to be installed by Pan Oston staff		Will be deliverd and installed together with other PO products			
D 9.2		D	system can be installed quickly	30 minutes?	Pan Oston has a limited timeframe in which they are requirred to install everything in the store			
W 9.1		W	system should run on power available in the store		If previous systems and connection delivered 12V, then this system should do that too			
D 10.1	**Transport**	D	system is packaged securely		So that no parts are damaged during shipping			
D 11.1	**Standards, rules and Regulations**	D	Technologies applied comply with privacy legislation	GDPR, AVG	Otherwise big fines can be applied			
D 12.1	**Strategy**	D	System can be easily sold and installed together with Pan Oston gate		So that they enhance eachother's sales.			
D 12.2		D	system is applicable in Pan Oston's customer market: supermarkets and supermarket-like stores such as Action, Big Bazar and Xenos.		These are Pan Oston's customers. However, other markets such as Zara and H&M could become new customers if the system is also applicable in these stores.			
W 12.1		W	system gives the store an innovative image		New technologies are often exciting, which can have a positive effect on how the store is perceived.			
W 12.2		W	system can be placed in Pan Oston's showroom		To show potential customers how it works and so that it can inspire			
W 12.3		W	system should use software from exclusive partners		Because if the partnership is exclusive, it creates competitive advantage		Outside my power	
W 12.4		W	system allows for extra services to be sold, like knowing how many people leave the store, at what times, remote monitoring of the components, remote software updates, etc.		To create more value for the store and to create a longer stream of revenue for Pan Oston			
D 13.1	**Reliability**	D	system's internal components like the motherboard and motor should not be reachable without tools		To prevent vandalism and manipulation			
D 13.2		D	system can withstand accidental spilling of water		So that it still works when someone spills water over it			
D 13.3		D	System can function even though there being a lot of metal present in the store		Metal can interfere with certain signals			

Appendix M: User test questionnaires

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Wat vindt u het duidelijkst?

~~*Lichten links (grote vlak)*~~ *Lichten rechts (dunne lijn)* *Projector*

Waarom?

Projector word je qua zichtsveld op gewezen als poortje dicht is
Lichten rechts meer op ooghoogte

Wat denkt u dat geluid + GROEN licht betekent?

Doorgaan, je hebt betaald

Wat denkt u dat geluid + ORANJE licht betekent?

Fout in het systeem

Wat denkt u dat geluid + ROOD licht betekent?

Fout, je hebt iets niet gedaan namelijk betalen. (gebruiker fout)

Zou het poortje even goed werken zonder geluid? Waarom wel/niet?

Met geluid beter, opvallend voor host.
Misschien alleen bij foutieve situaties

Zou u iets toevoegen of wijzigen?

Ander geluid bij fout, maar geen idee wat...

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Wat vindt u het duidelijkst?

Lichten links (grote vlak) *Lichten rechts (dunne lijn)* *Projector*

Waarom?

Projector, hoeft niet na te denken, voelt natuurlijk, je kijkt al voor het poortje, en ziet dan doorheen de projectie

Wat denkt u dat geluid + GROEN licht betekent?

Betaling correct, mag doorlopen

Wat denkt u dat geluid + ORANJE licht betekent?

Controleren of storing

Wat denkt u dat geluid + ROOD licht betekent?

Betaling mislukt of storing

Zou het poortje even goed werken zonder geluid? Waarom wel/~~niet~~?

Omdat het poortje open is en visueel

Zou u iets toevoegen of wijzigen?

Projector is heel duidelijk

Wat vindt u het duidelijkst?

Lichten links (grote vlak) *Lichten rechts (dunne lijn)* *Projector*

Waarom?

Duidelijker zichtbaar, omdat de lamp ook bovenkant zichtbaar is

Wat denkt u dat geluid + GROEN licht betekent?

je kunt doorlopen

Wat denkt u dat geluid + ORANJE licht betekent?

stop - er is iets waardoor je niet door de poort kunt

Wat denkt u dat geluid + ROOD licht betekent?

stop - geen doorgang

Zou het poortje even goed werken zonder geluid? Waarom wel/niet?

ja, kleur rood/groen duidelijk

Zou u iets toevoegen of wijzigen?

/

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Wat vindt u het duidelijkst?

Lichten links (grote vlak) *Lichten rechts (dunne lijn)* *Projector*

Waarom?

Projector omdat de symbolen al meer vertellen dan alleen een kleur.
opvallendst is dunne lijn

Wat denkt u dat geluid + GROEN licht betekent?

ik heb betaald en mag doorlopen

Wat denkt u dat geluid + ORANJE licht betekent?

betaling mislukt

Wat denkt u dat geluid + ROOD licht betekent?

ik maak zelf een fout of steel iets

Zou het poortje even goed werken zonder geluid? Waarom wel/niet?

Ja kleuren geven genoeg aan.

Zou u iets toevoegen of wijzigen?

Scherm met symbolen

Wat vindt u het duidelijkst?

Lichten links (grote vlak) *Lichten rechts (dunne lijn)* *Projector*

Waarom?

LED rechts meer opvallend en chic
projector meerwaarde voor extra info en gewoon gaaf

Wat denkt u dat geluid + GROEN licht betekent?

Doorgaan

Wat denkt u dat geluid + ORANJE licht betekent?

Pas op / Even wachten / wat minder duidelijk

Wat denkt u dat geluid + ROOD licht betekent?

Stop, iets fout gedaan

Zou het poortje even goed werken zonder geluid? Waarom wel/niet?

Ja, mits de lampen opvallend genoeg zijn
Bij rood geluid wel meerwaarde voor anderen

Zou u iets toevoegen of wijzigen?

n.v.t.

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Wat vindt u het duidelijkst?

Lichten links (grote vlak) | *Lichten rechts (dunne lijn)* | *Projector*

Waarom?

zichtbaarheid

Wat denkt u dat geluid + GROEN licht betekent?

goed, je mag doorlopen

Wat denkt u dat geluid + ORANJE licht betekent?

er is iets niet in orde

Wat denkt u dat geluid + ROOD licht betekent?

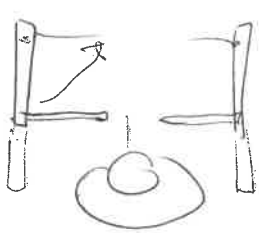
verboden, je hebt echt wat fout gedaan

Zou het poortje even goed werken zonder geluid? Waarom wel/niet?

Ook wel, bij fout wel. extra waarschuwing

Zou u iets toevoegen of wijzigen?

* lampen al subtiel aan
* beamer → pijlen ook terug laten lopen
* geluid luider
*



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Wat vindt u het duidelijkst?

Lichten links (grote vlak) *Lichten rechts (dunne lijn)* *Projector*

Waarom?

subtiel, toch duidelijk door beweging

Wat denkt u dat geluid + GROEN licht betekent?

alles goed
klant mag door

Wat denkt u dat geluid + ORANJE licht betekent?

weet in niet proces

Wat denkt u dat geluid + ROOD licht betekent?

niet betaald

Zou het poortje even goed werken zonder geluid? Waarom ~~wel~~/niet?

geluid draagt bij aan signalering
bij groen overbodig

Zou u iets toevoegen of wijzigen?

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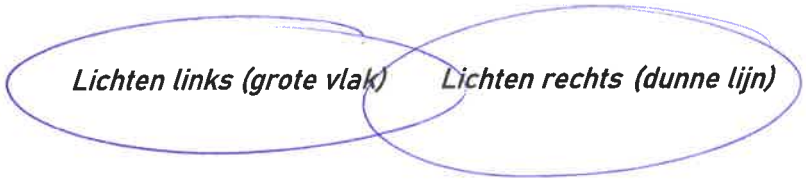
Wat vindt u het duidelijkst?



Waarom?

* grote vlak valt goed op
* omdat ik rechts georiënteerd ben, is lijn rechts ook duidelijk.

Wat denkt u dat geluid + GROEN licht betekent?

doorlopen! Alles is goed. Poortje werkt goed.

Wat denkt u dat geluid + ORANJE licht betekent?

Er is een storing in het poortje. Als het kan loop ik door want ik heb betaald.

Wat denkt u dat geluid + ROOD licht betekent?

Er is een storing in het poortje. Ik moet "hulp hebben".

Zou het poortje even goed werken zonder geluid? Waarom wel/niet?

Als het poortje dicht blijft is geluid wel handig. Een cassière in de buurt kant vast op het geluid af.

Zou u iets toevoegen of wijzigen?

Prima zo!

Wat vindt u het duidelijkst?

~~Lichten links (grote vlak)~~ Lichten rechts (dunne lijn) Projector

Waarom?

projector → zelfde blikveld
lichten rechts → ook voor host zichtbaar

Wat denkt u dat geluid + GROEN licht betekent?

doorlopen

Wat denkt u dat geluid + ORANJE licht betekent?

system ERROR

Wat denkt u dat geluid + ROOD licht betekent?

jij bent een dief! je hebt iets fout gedaan!

Zou het poortje even goed werken zonder geluid? Waarom wel/niet?

nee, draagt bij aan positieve gevoel. Eigenlijk versterkt het alle boodschappen die het poortje uitdraagt

Zou u iets toevoegen of wijzigen?

–

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Wat vindt u het duidelijkst?

Lichten links (grote vlak) *Lichten rechts (dunne lijn)* *Projector*

Waarom?

Lichten rechts communiceren snel dat er iets is → projector geeft vervolgens uitleg / bevestiging hoe of wat.

Lichten links is mij te heftig

Wat denkt u dat geluid + GROEN licht betekent?

Ik mag doorlopen en alles is goed

Wat denkt u dat geluid + ORANJE licht betekent?

Er is iets aan de hand maar ik weet niet wat

Wat denkt u dat geluid + ROOD licht betekent?

stop er is iets mis of niet goed

Zou het poortje even goed werken zonder geluid? Waarom wel/niet?

Ja dat denk ik wel, geluid maakt de beleving voor mij wel dop completer (wel subtiel toe passen)

Zou u iets toevoegen of wijzigen?

+ Knipperen → frequentie vs snelheid niet te snel
+ Vooral groene verlichting aan en uit in fasen, niet vol aan en uit
+ projector het liefst met 1 logo communiceren less is more

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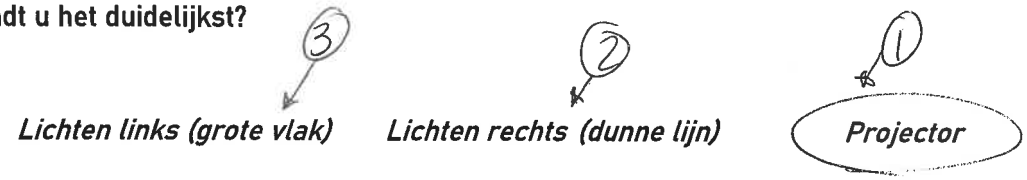
Wat vindt u het duidelijkst?



Waarom?

Dit valt het meeste op en ik denk dat dit het best zichtbaar is omdat je altijd kijkt waar je loopt

Wat denkt u dat geluid + GROEN licht betekent?

je mag doorlopen

Wat denkt u dat geluid + ORANJE licht betekent?

stoppen

Wat denkt u dat geluid + ROOD licht betekent?

stoppen + controle o.i.d.

Zou het poortje even goed werken zonder geluid? Waarom wel/niet?

Alleen als het goe heel duidelijk zichtbaar is te Hard geluid vind ik niet klantvriendelijk

Zou u iets toevoegen of wijzigen?

Nee, alleen moet de poort Ruim op tijd sluiten.

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Wat vindt u het duidelijkst?

2 1

Lichten links (grote vlak) *Lichten rechts (dunne lijn)* *Projector*

combi is super

Waarom? valt op geeft gelijk het gevoel wat past bij de situatie

Wat denkt u dat geluid + GROEN licht betekent?

Doorlopen

Wat denkt u dat geluid + ORANJE licht betekent?

storing

Wat denkt u dat geluid + ROOD licht betekent?

stop Niet betreden

Zou het poortje even goed werken zonder geluid? Waarom wel/niet?

voor mij wel of het geluid moet helderder/ scheller

Zou u iets toevoegen of wijzigen?

- projector ~~uit~~ verlichting verder naar voren
- verlichte poort beugels

Wat vindt u het duidelijkst?

Lichten links (grote vlak) *Lichten rechts (dunne lijn)* *Projector*

Waarom? Verwachting Rechts

Wat denkt u dat geluid + GROEN licht betekent?

Alles oke

Wat denkt u dat geluid + ORANJE licht betekent?

problemen kant help

Wat denkt u dat geluid + ROOD licht betekent?

Stop!

Zou het poortje even goed werken zonder geluid? Waarom wel/niet?

Wel. overbodig

Zou u iets toevoegen of wijzigen?

Info Scherm

Wat vindt u het duidelijkst?

Lichten links (grote vlak) [*Lichten rechts (dunne lijn)*] *Projector*

Waarom?
Lichten rechts, vanwege het flikkeren van het licht

Wat denkt u dat geluid + GROEN licht betekent?
Doorlopen en alles is goed

Wat denkt u dat geluid + ORANJE licht betekent?
Attentie, maar niet stoppen

Wat denkt u dat geluid + ROOD licht betekent?
Stop, maar mag dwingender

Zou het poortje even goed werken zonder geluid? Waarom wel/niet?
Ja, omdat groen/geel/rood licht al duidelijk is voor mij

Zou u iets toevoegen of wijzigen?
Rood geluid dwingender
Projectie op de grond is extra

Wat vindt u het duidelijkst?

Lichten links (grote vlak) *Lichten rechts (dunne lijn)* *Projector*

Waarom?

wel aan beide kanten. , markeert de weg naar buiten.

Wat denkt u dat geluid + GROEN licht betekent?

geluid bij groen heeft geen toegevoegde waarde.

Wat denkt u dat geluid + ORANJE licht betekent?

zeg mij niets geluid en oranje licht niet.

Wat denkt u dat geluid + ROOD licht betekent?

bij rood mag geluid wel agressiever. moet demotiverend werken om het weer te doen zonder betalen.

Zou het poortje even goed werken zonder geluid? Waarom wel/niet?

groen wel / rood verstrekt het geluid.

Zou u iets toevoegen of wijzigen?

Wat vindt u het duidelijkst?

Lichten links (grote vlak) *Lichten rechts (dunne lijn)* *Projector*

Waarom?

Op goede hoogte een vriendelijke vorm van Communicatie

Wat denkt u dat geluid + GROEN licht betekent?

Dat alles goed is afgerond

Wat denkt u dat geluid + ORANJE licht betekent?

Er is iets aan de hand maar ik weet niet wat

Wat denkt u dat geluid + ROOD licht betekent?

Ik heb niet betaald en probeer weg te gaan!!

Zou het poortje even goed werken zonder geluid? Waarom wel/niet?

in de groene en gele modus voegt het niet veel toe in de rode modus wel → mensen gaan naar je kijken

Zou u iets toevoegen of wijzigen?

Wat vindt u het duidelijkst?

Lichten links (grote vlak) *Lichten rechts (dunne lijn)* *Projector*

Waarom?

Zichtbaarder en in het zichtveld, dus vóór je neus en het oppervlak is groter.

Wat denkt u dat geluid + GROEN licht betekent?

goed gekeurd, je mag doorlopen

Wat denkt u dat geluid + ORANJE licht betekent?

Er is iets aan de hand maar onduidelijk wat

Wat denkt u dat geluid + ROOD licht betekent?

stop, niet doorlopen de deur iets fout

Zou het poortje even goed werken zonder geluid? Waarom wel/niet?

Nee, geluid voegt urgentie toe voor mij en duidelijkheid.

Zou u iets toevoegen of wijzigen?

Nee

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Wat vindt u het duidelijkst?

Lichten links (grote vlak) (*Lichten rechts (dunne lijn)*) *Projector*

Waarom?

Geeft richting en boodschap van fietsverlichting

Wat denkt u dat geluid + GROEN licht betekent?

Go, maar met aanzetting, want klinkt toch alsof je eerst van iemand op "ok" geklikt moet worden

Wat denkt u dat geluid + ORANJE licht betekent?

Stop, maar oranje is overbodig (net niet duidelijk)

Wat denkt u dat geluid + ROOD licht betekent?

STOP!

Zou het poortje even goed werken zonder geluid? Waarom wel/niet?

Ja, geluid leidt af

Zou u iets toevoegen of wijzigen?

Geen geluid

Appendix N: Price estimation

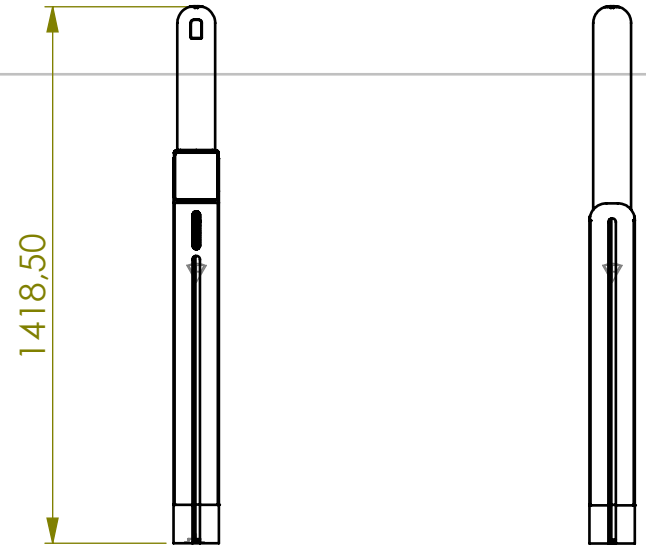
Benaming	CLEARGATE		Productieserie	2	stuks	per onderdeel
Materiaalkosten		**bruto hoeveelheid/product**	**eenheid**	**prijs/eenheid**	**bedrag**	
halffabrikaat	Zincor 1.25 mm	12,3	kg	€ 1,90	€ 23,37	
halffabrikaat	materiaal B	0	m	€ 0,00	€ 0,00	
				totaal materiaalkosten	**€ 23,37**	**€ 23,37**
Bewerkingskosten	**capaciteit [stuks/u]**	**machineuren**	**machine-uurtarief**	**machine-kosten**		
lasersnijder	4	0,50	€ 50,00	€ 25,00		
kantbank	2	1,00	€ 10,00	€ 10,00		
lassen	0,5	4,00	€ 10,00	€ 40,00		
poedercoaten	10	0,20	€ 10,00	€ 2,00		
				totaal machinekosten	**€ 77,00**	
machines als bovenstaand	**mens/machine-bezetting**	**arbeidsuren**	**mensuurtarief**	**arbeidskosten**		
lasersnijder	1	0,50	€ 0,00	€ 0,00		
kantbank	1	0,20	€ 50,00	€ 10,00		
lassen	1	4,00	€ 50,00	€ 200,00		
poedercoaten	1	0,20	€ 50,00	€ 10,00		
				totaal arbeidskosten	**€ 220,00**	
				totaal bewerkingskosten	**€ 297,00**	**€ 148,50**
Instelkosten serie	**insteltijd [u]**	**uurtarief insteller**	**mach.uurtarief**	**kosten**	**per product**	
lasersnijder	0,1	€ 50,00	€ 50,00	€ 10,00	**€ 5,00**	**€ 5,00**
Gereedschapskosten	**aanschafprijs**	**standtijd [stuks]**	**restwaarde**	**prijs/eenheid**		
matrijs A	€ -	25.000	€ 0,00	€ 0,00		
montagemal B	€ -	25.000	€ 0,00	€ 0,00		
subtotalen	€ -		€ 0,00			
gemiddelde waarde	€ -					
kapitaalrente	0,0%	rentekosten	€ 0,00	€ 0,00		
				totaal gereedschapskosten	**€ 0,00**	**€ 0,00**
Algemene toeslagen						
uitval-factor*	1,0%	*afgekeurde producten, zie Kals voor percentages			**subtotaal**	**€ 176,87**
overheadfactor**	15,0%	** algemene toeslag voor productiefaciliteiten				
totaal	**16,0%**					**€ 28,30**
		K_{Fi} voor interne calculatie:		**Productiekostprijs CLEARGATE**		**€ 205,17**

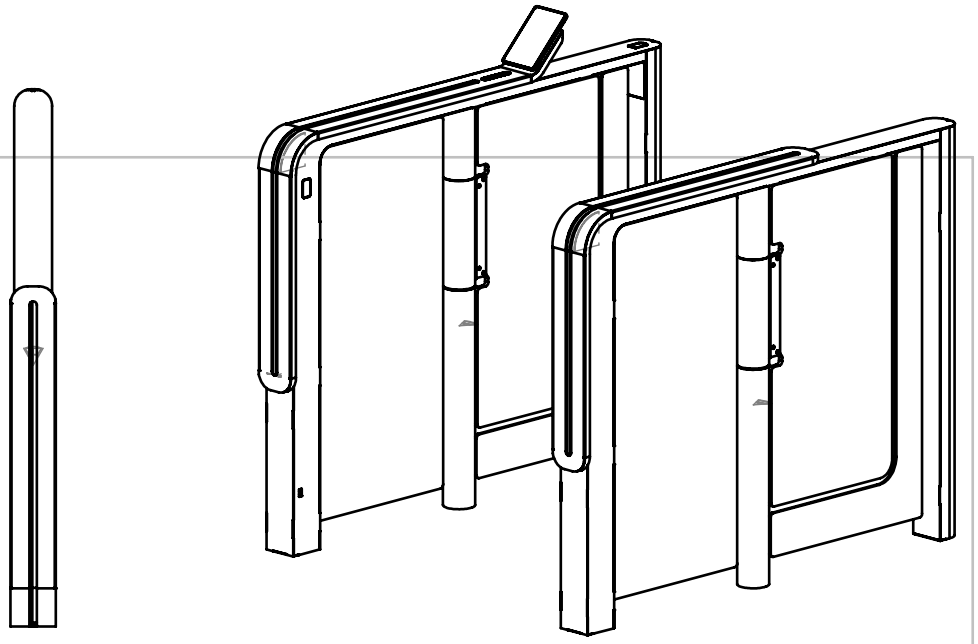
Opbouw van de fabricagekostprijs van een compleet product (vgl. Kals)

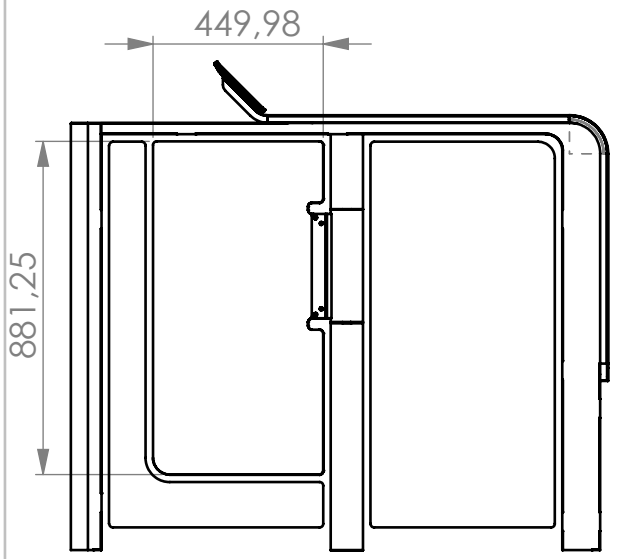
Product	CLEARGATE					
						prijs per product
In-huis te vervaardigen	**prijs/stuk**	**stuks/product**	**prijs per product**			
CLEARGATE	€ 205,17	2	€ 410,34			
		1	€ 0,00			
			€ 410,34		**totaal vervaardiging**	**€ 410,34**
Inkopen	**prijs/eenheid**	**eenheid**	**eenheid/product**	**prijs per product**		
motor	€ 240,000	st	2	€ 480,00		
scherm	€ 150,000	st	1	€ 150,00		
LED strip	€ 30,000	st	2	€ 60,00		
torque limiter	€ 40,000	st	2	€ 80,00		
electromagnetische rem	€ 40,000	st	2	€ 80,00		
Raspberry Pi	€ 40,000	st	1	€ 40,00		
speaker	€ 10,000	st	1	€ 10,00		
soundboard	€ 5,000	st	1	€ 5,00		
PanIO board	€ 100,000	st	1	€ 100,00		
fotocel	€ 5,000	st	2	€ 10,00		
NFC reader	€ 5,000	st	2	€ 10,00		
arm pillar shell	€ 20,000	st	6	€ 120,00		
NFC dekplaat	€ 20,000	st	2	€ 40,00		
arm pillar staven	€ 40,000	st	2	€ 80,00		
encoder	€ 20,000	st	2	€ 40,00		
bekabeling	€ 2,000	st	30	€ 60,00		
PMMA platen	€ 30,000	st	6	€ 180,00		
				€ 1.545,00	**totaal inkoop**	**€ 1.545,00**
Assemblagekosten		**assemblageserie**	2			
	capaciteit [stuks/u]	**machineuren**	**uurtarief**			
montagestation	1	2,00	€ 0,00	€ 0,00		
verpakken	4	0,50	€ 0,00	€ 0,00		
				totaal machinekosten	**€ 0,00**	
machines als	**mens/machine-**	**arbeidsuren**	**uurtarief**	**arbeidskosten**		
montagestation	1	2,00	€ 50,00	€ 100,00		
verpakken	1	0,50	€ 50,00	€ 25,00		
				totaal arbeidskosten	**€ 125,00**	
				totaal assemblagekosten	**€ 125,00**	**€ 62,50**
K_{ft} Productiekostprijs geassembleerd product voor interne calculatie:				**Productiekostprijs CLEARGATE**		**€ 2.017,84**

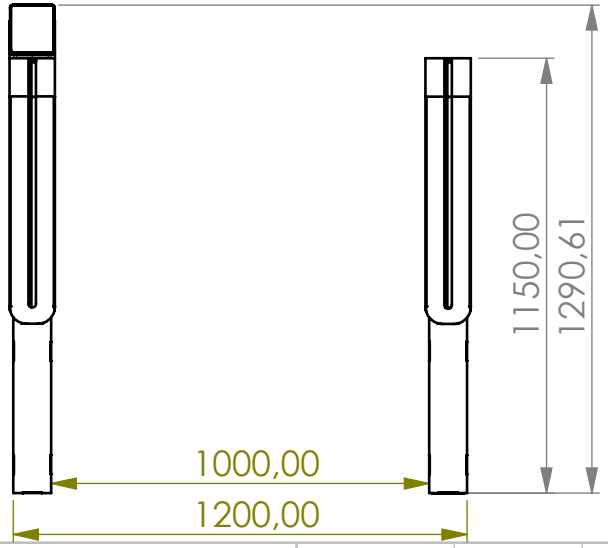
	Voorbeeldberekening voor de winkelprijs op basis van de fabricagekostprijs (bron: Erik Thomassen).		
K_{Ft}	Productiekostprijs geassembleerd product voor interne calculatie:	**CLEARGATE**	**€ 2.017,84**
F_{OB}	Overheadfactor voor algemene bedrijfskosten*	15%	
F_{OV}	Overheadfactor voor verkoopkosten	5%	
F_W	Winstfactor (onvoorziene kosten worden a.h.w. uit de winst betaald)	10%	
	Totaalfactor = product van (elk van deze factoren+1) min 1	32,8%	**€ 662,36**
K_V	Verkoopprijs af-fabriek (moet je betalen als je product bij de fabriek zelf ophaalt)		**€ 2.680,19**
	Marge tussenhandel (bijvoorbeeld: importeur, groothandel, leverancier, distributeur)	0,0%	**€ 0,00**
	Groothandelsverkoopprijs		**€ 2.680,19**
	Marge detailhandel (winkel) is zeer branche- en aanbiedingsafhankelijk, ligt tussen 25% voor een webshop en 300% voor een servicegerichte detaillist in een mooi pand op een A-locatie. Strategie met oog op o.a. concurrentie en voorraad bepaalt de marge.	0,0%	**€ 0,00**
	Netto verkoopprijs (exclusief BTW)		**€ 2.680,19**
	Foutmarge	20,0%	**€ 3.216,23**
	BTW (= Belasting op de toegevoegde waarde, = omzetbelasting)**	21,0%	**€ 3.891,64**
	Verkoopadviesprijs, normale winkelprijs		**€ 3.891,64**

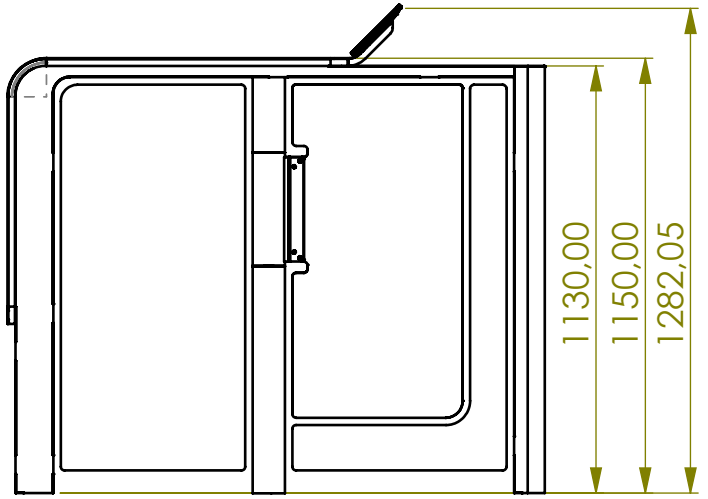
Appendix O: Technical drawings
CLEARGATE and EZ-GO





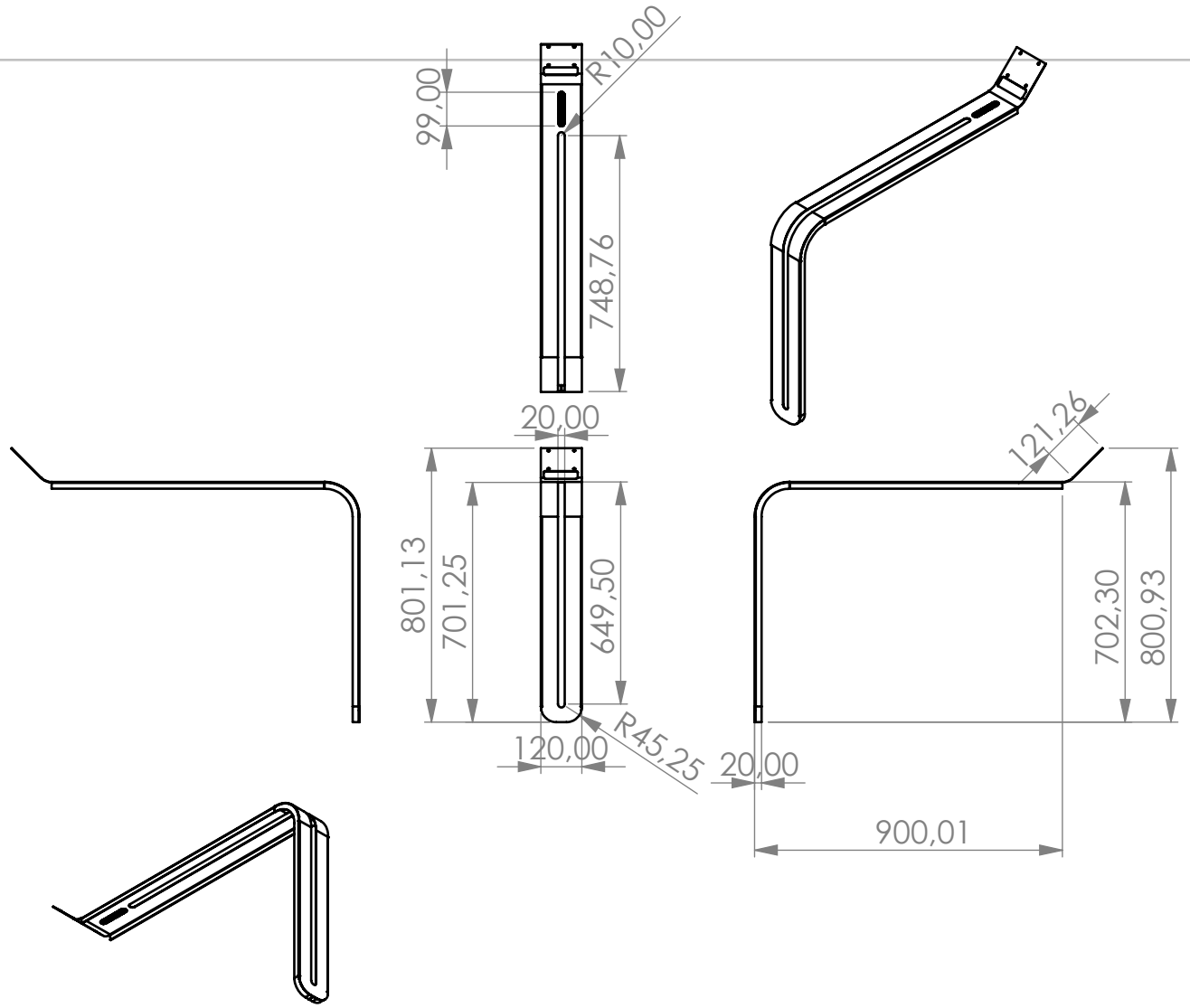






C:\Users\jesse\Desktop\Pan Oston\SW Eind\

TU Delft Delft University of Technology	name CLEARGATE		units mm	scale 1:20	quantity <<nr>>	date 23-6-2022	remark <<remarks>>
		material			mass gr	
		author <<names & student numbers>>		group <<group>>	format A4	drawing no. <<drawing no.>>



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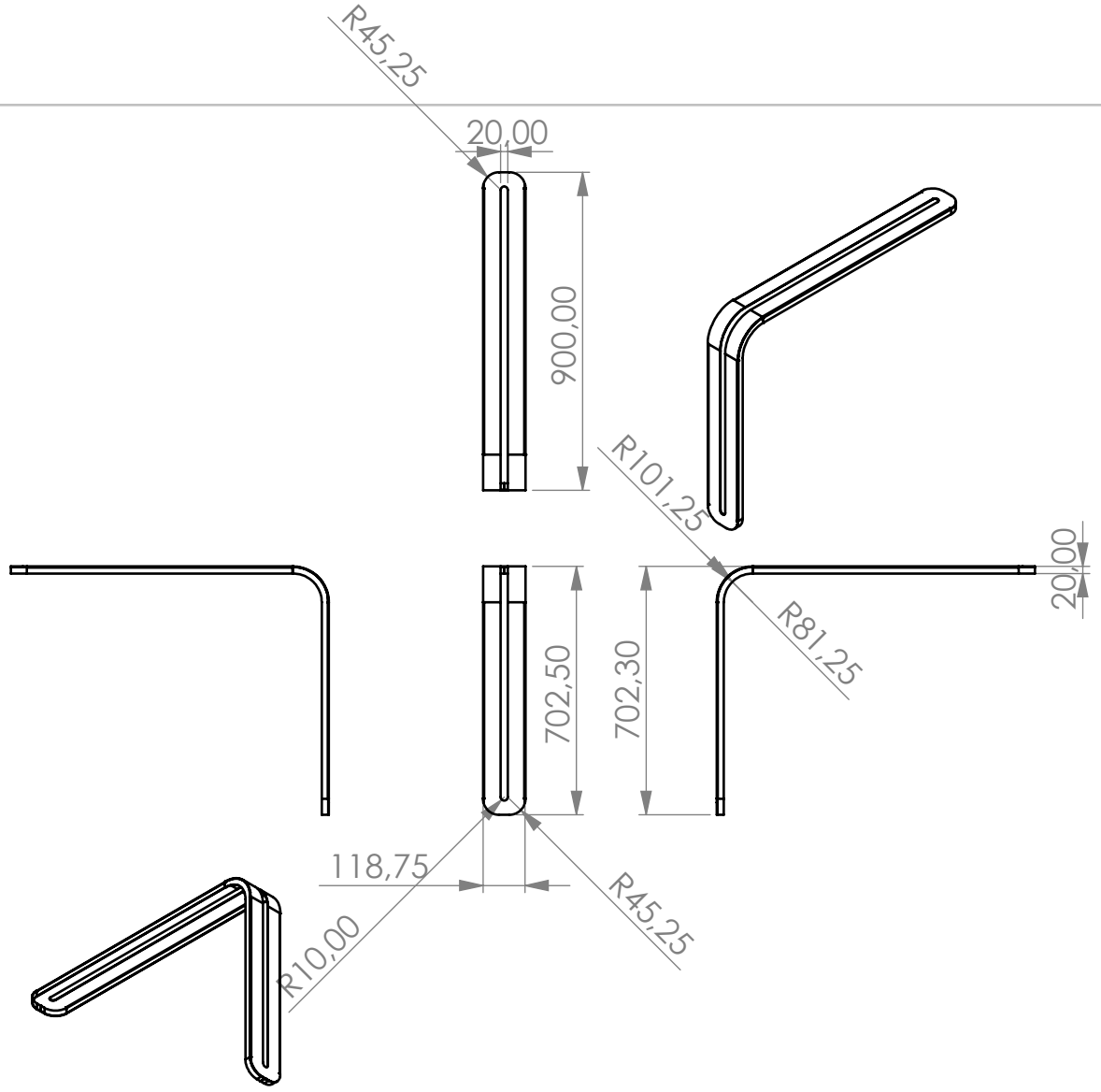
TU Delft Delft University of Technology	name Cover left	units mm	scale 1:20	quantity <<nr>>	date 23-6-2022
		material Zincor (DC01+ZE25/25)		mass gr	remark <<remarks>>
		author <<names & student numbers>>	group <<group>>	format A4	drawing no. <<drawing no.>>



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TU Delft Delft University of Technology	name Cover right	units mm	scale 1:20	quantity <<nr>>	date 23-6-2022	remark <<remarks>>
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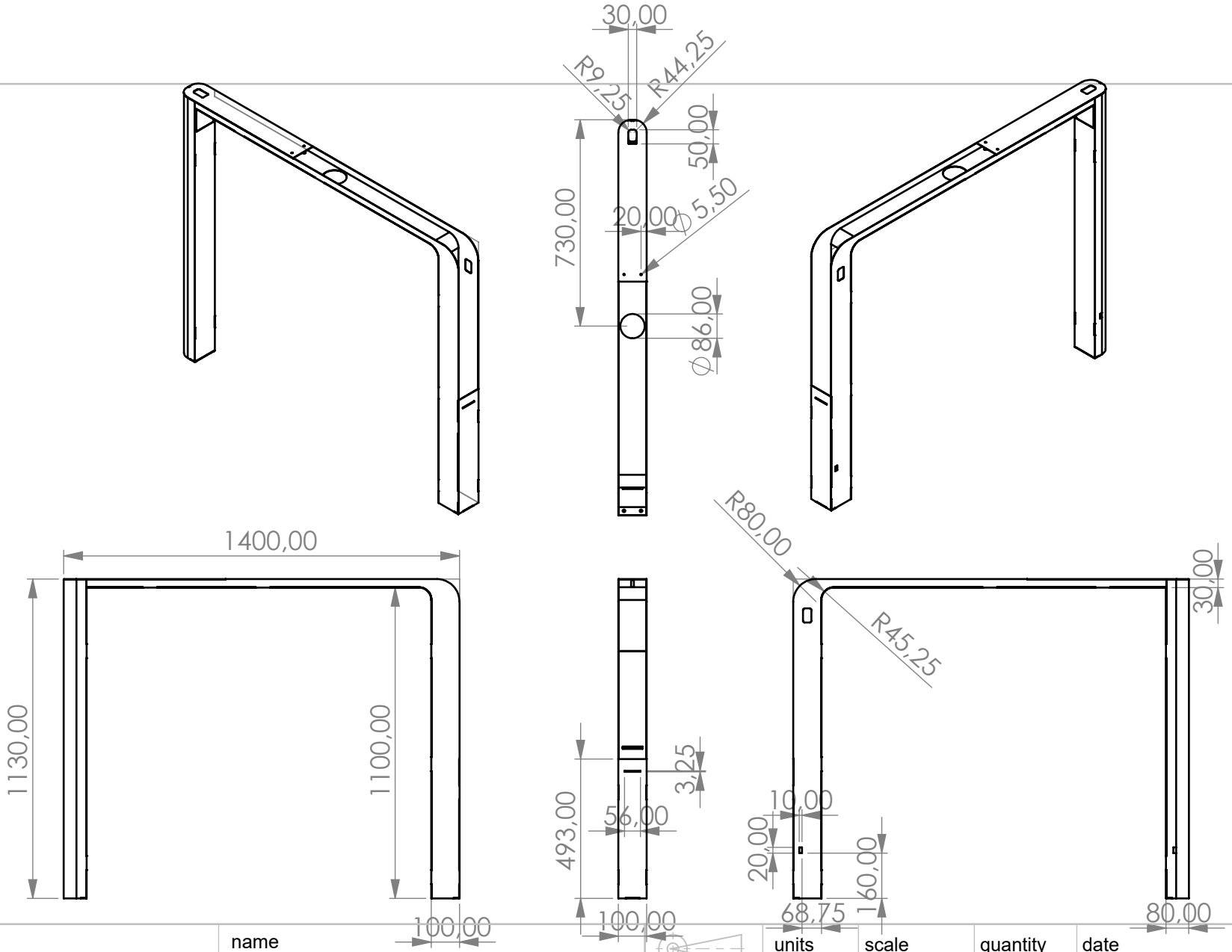

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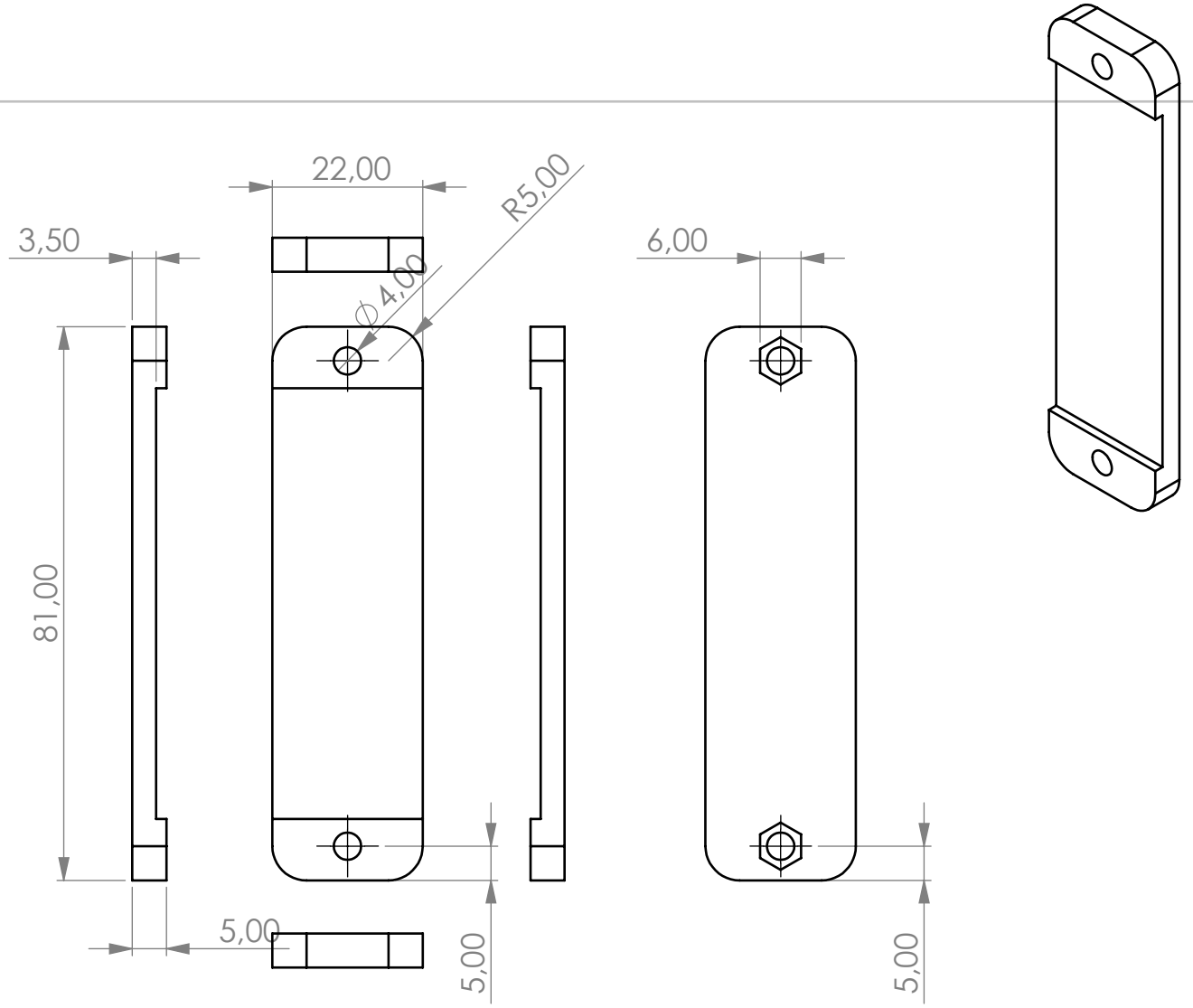
			material			mass gr	
		author <<names & student numbers>>		group <<group>>	format A4	drawing no. <<drawing no.>>	

Frame



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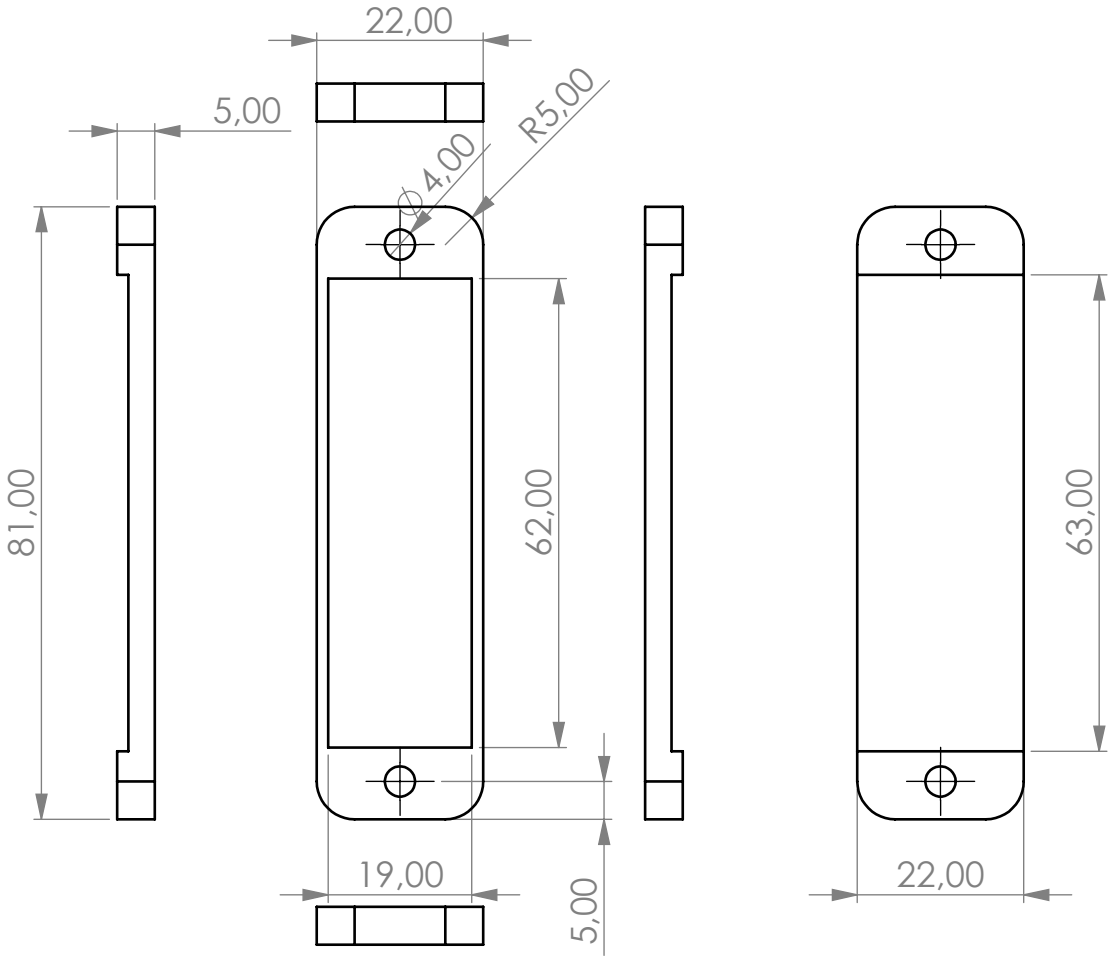
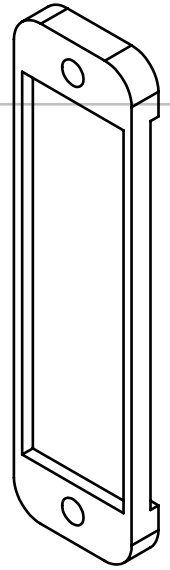
TU Delft Delft University of Technology	name BLE Beacon bottom		units mm	scale 1:1	quantity <<nr>>	date 23-6-2022	remark <<remarks>>
		material				mass gr	
		author <<names & student numbers>>		group <<group>>	format A4	drawing no. <<drawing no.>>	





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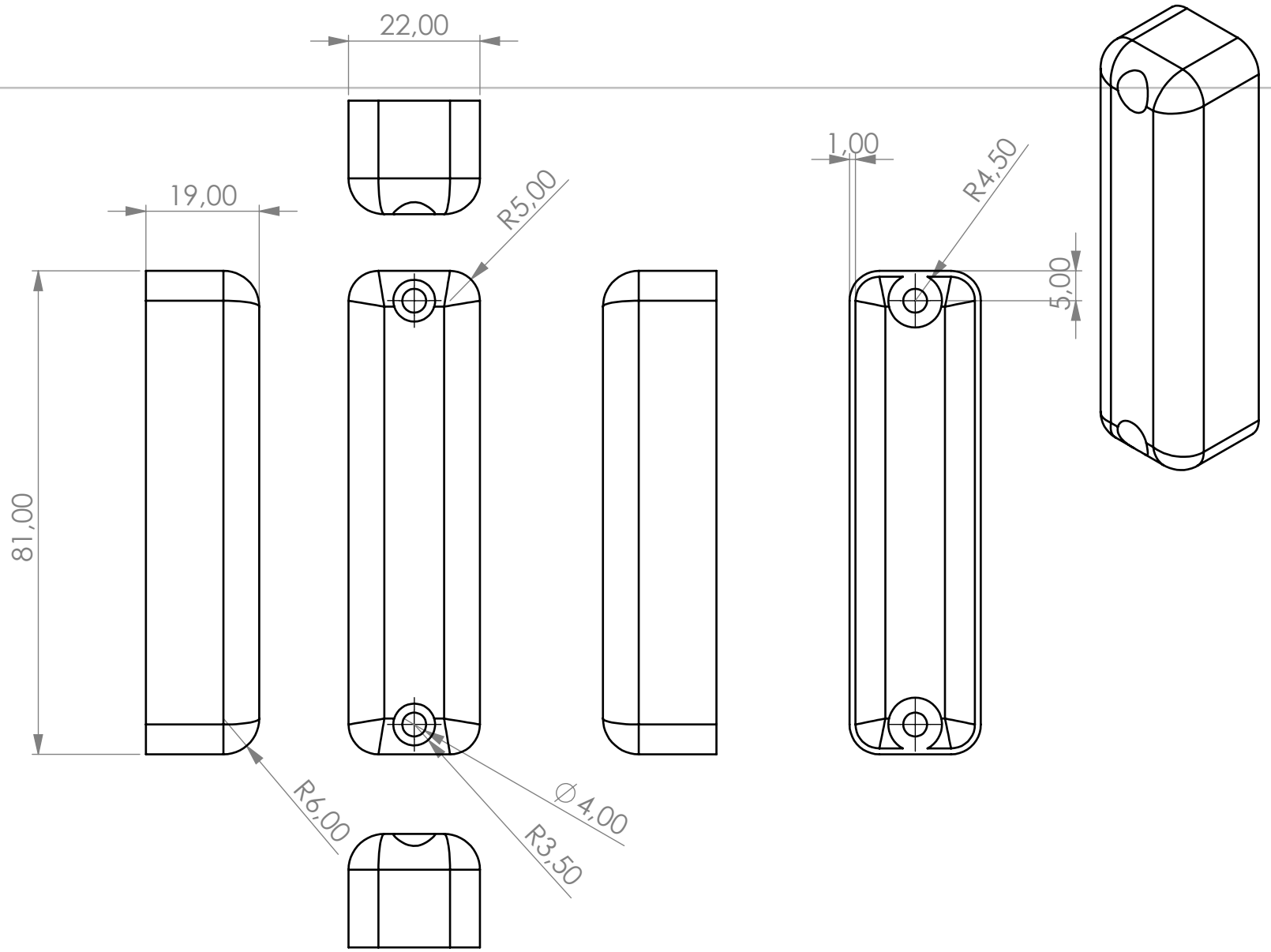
TU Delft Delft University of Technology	name	units mm	scale 1:1	quantity <<nr>>	date 23-6-2022
	BLE Beacon middle	material		mass gr	remark <<remarks>>
		author <<names & student numbers>>	group <<group>>	format A4	drawing no. <<drawing no.>>



TU Delft
Delft University of Technology

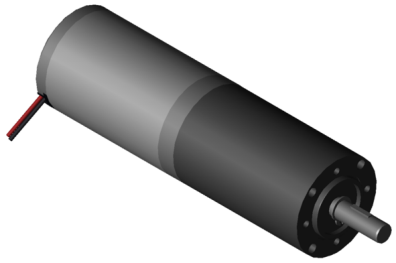
name

BLE Beacon top

	units mm	scale 1:1	quantity <<nr>>	date 23-6-2022	remark <<remarks>>
material				mass gr	
author <<names & student numbers>>			group <<group>>	format A4	drawing no. <<drawing no.>>

Appendix P: Motor datasheet

50271

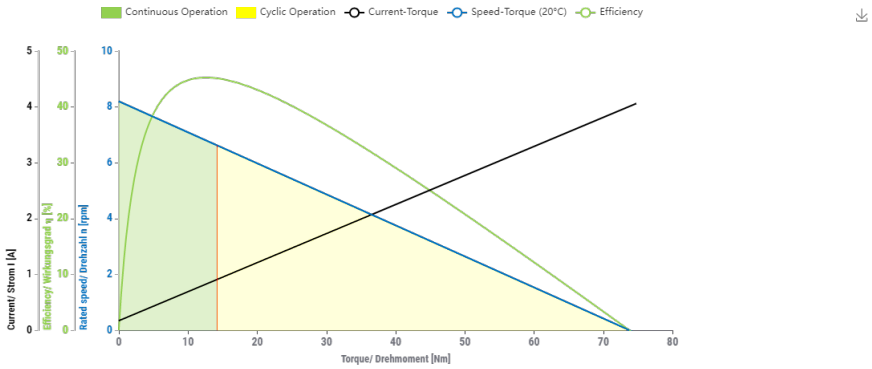


GR 42X25	8842705065
PLG 42K	8885801829

Motor-Gearbox Combination	
Nominal Speed	7,03 1/min
Nominal Torque	14,2 Nm
Nominal torque limited by gearbox	3 Nm
No load Speed	8,2 1/min
Maximum torque limited by gearbox	74,75 Nm
Stall Torque	74,75 Nm
Torque Constant	19,21 Nm/A
Damping constant	8994,16 Nm/rpm
Output Diameter	8 mm
Output Shaft Length	25 mm
UL Mark	J
Protection class excluding shaft	IP50
Weight	0,64 kg

Motor	
Preferred series	S
Standard product	J
Nominal Power	14,3 W
Nominal Motor Voltage	24 V
Nominal Speed	3600 1/min
Nominal Torque	0,038 Nm
Nominal Current	0,86 A
Stall Torque	0,2 Nm
No Load Speed	4200 1/min
Torque Constant	0,05 Nm/A
Damping constant	0,05 Nm/rpm
Connection	LI
Suppression	2L 3C
Direction of rotation	CW
Front Shaft Diameter	3 mm
Front Shaft Length	12 mm
Flange	F
Rotor Inertia	71 gcm²
Protection class	IP50
Protection class capability	IP50
Motor Weight	0,39 kg

Gearbox	
Preferred series	S
Standard product	J
Reduction	512
Nominal Output Torque	3 Nm
Number of Stages	3
Efficiency	73
Output Shaft Diameter	8 mm
Output Shaft Length	25 mm
Protection class	IP50
Gearbox Weight	0,25 kg



Please note that this is only an excerpt from the specification. The values displayed for the entire drive are theoretical values, the characteristic curve is an approximation. The complete product specifications, measured motor characteristics and notes on design are available on request.

Please note! In this combination, the nominal motor torque * ratio * efficiency can be higher than the nominal gearbox torque. This is possible for intermittent operation under defined conditions, but may lead to reduced life time. Our sales department will be happy to advise you further.

Appendix Q: Personal Project Brief

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT

Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy".
Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

APPROVAL PROJECT BRIEF
To be filled in by the chair of the supervisory team.

Initials & Name J. Kamp Student number 4599039

Title of Project Improving frictionless shopping using seamless customer access control

Improving frictionless shopping using seamless customer access control — project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 07 - 02 - 2022 — 24 - 06 - 2022 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

The goal of this project is to improve the shopping experience in retail stores so that it is more frictionless, by creating a physical product that allows for access control. A product like this can also help battle shoplifting in retail stores like Albert Heijn and Action, and at the same time create an addition to Pan Oston's product portfolio that allows them to stay relevant in a future where traditional cash registers and even self-check-out registers are slowly but surely being replaced by autonomous stores like Amazon Go (https://youtu.be/NrmMk1Myrxc).

This project tries to create a physical product that functions as a stepping-stone towards Pan Oston playing a role in Amazon Go-like stores. It does this by focusing on already widely applied self-check-out squares such as seen in figure 1. These squares use gates (as shown in figure 2) that require the user to scan their ticket before they can leave. This adds extra steps and creates friction in the shopping experience. By creating a product with less friction for the customer, customer experience can be improved. Such a product is an important step for Pan Oston in making products that are ready for the future of retail where autonomous technologies and/or products will play a significant role, thus improving Pan Oston's product portfolio and allowing them to stay relevant for longer.

The stakeholders in this project are:
- Pan Oston
  - o Wants to create a future-ready product that still allows them to do what they are good at: building physical products with their knowledge of steel and together with purchased parts like plastics, wood and electronic components assembling this into a product
  - o Wants to help retail stores create a frictionless shopping experience, decreasing theft in the process. Doing this, Pan Oston hopes to become more attractive than competitors
- Retail stores
  - o Want to offer cost savings and a more customer friendly way of checking out
- Customers
  - o Want a shopping experience that is as seamless and frictionless as possible
- Software suppliers

The (for now foreseen) opportunities in this project are:
- Pan Oston has great knowledge and experience of making well-functioning, long lasting physical products
- Self-checkout solutions are on the rise, creating a need for autonomous permission to leave and enter the store
- Theft is a very big and relevant problem for retail stores, and Pan Oston's customers are willing to provide information to help battle this problem

The (for now foreseen) threats of this project are:
- Pan Oston's products come without software since usually Pan Oston customers want to apply their own software on Pan Oston's products. This is why Pan Oston has no experience with software. Thus, for the software part of this project, collaboration with a partner or using open source technology is necessary. The threat is Pan Oston's dependency on these third parties or open source technology.

space available for images / figures on next page

introduction (continued): space for images

image / figure 1: Self-check-out square

image / figure 2: Barcode scanning gates

Initials & Name _____ Student number _____

Title of Project _____

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

Current self-check-out squares can be left by scanning a barcode printed on your receipt (figure 2). This system adds steps the customer has to do before he/she can leave the store, creating friction in the shopping experience.

It is important that the product is not intrusive so it keeps a good user experience and prevents congestion. Research has to be done to find and decide on technologies that allow for the frictionless leaving of the store as previously described. Part of this will be sourcing technologies that check whether a customer has paid or not, as this is a functionality crucial for deciding whether someone can leave or not. If the used technology has to comply with current or upcoming privacy/ethics legislation, research has to be done on how this legislation can be respected. User research has to be done to determine who will use the system and what their needs are. It will also need to be determined how the applied technologies can be used so that the user remains feeling comfortable and safe.

Lastly, the product has to fit the capabilities of Pan Oston and their production facilities, but can make use of third parties Pan Oston works with. The product has to distinguish Pan Oston from their competitors. This can be done on quickness of the system, flowthrough, customer experience, implementation, service and/or design.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

I will research, design and create a physical product that autonomously lets people leave a retail store if they are allowed to do so. I will do this with help of Pan Oston's knowledge of physical products, Pan Oston's employees and partners that have knowledge of Industry 4.0 technology and of course my own interests and knowledge. I will deliver a Proof of Concept that can be validated by Pan Oston's customers.

I will do this by first getting to know Pan Oston and their exact demands and wishes, after which I will do research upon which I will build my design. This research regards possible methods and technologies that can be applied, possible ways you can determine someone has paid or not, the users' demands and wishes (regarding ease of use but also privacy), legislation, products of Pan Oston's competitors. User experience is key and researching how people experience the current gate has to be done. I hope to achieve this final product by building prototypes as soon as possible so that I can learn from experience rather than theory, and go through as many iterations as needed to deliver a Proof of Concept

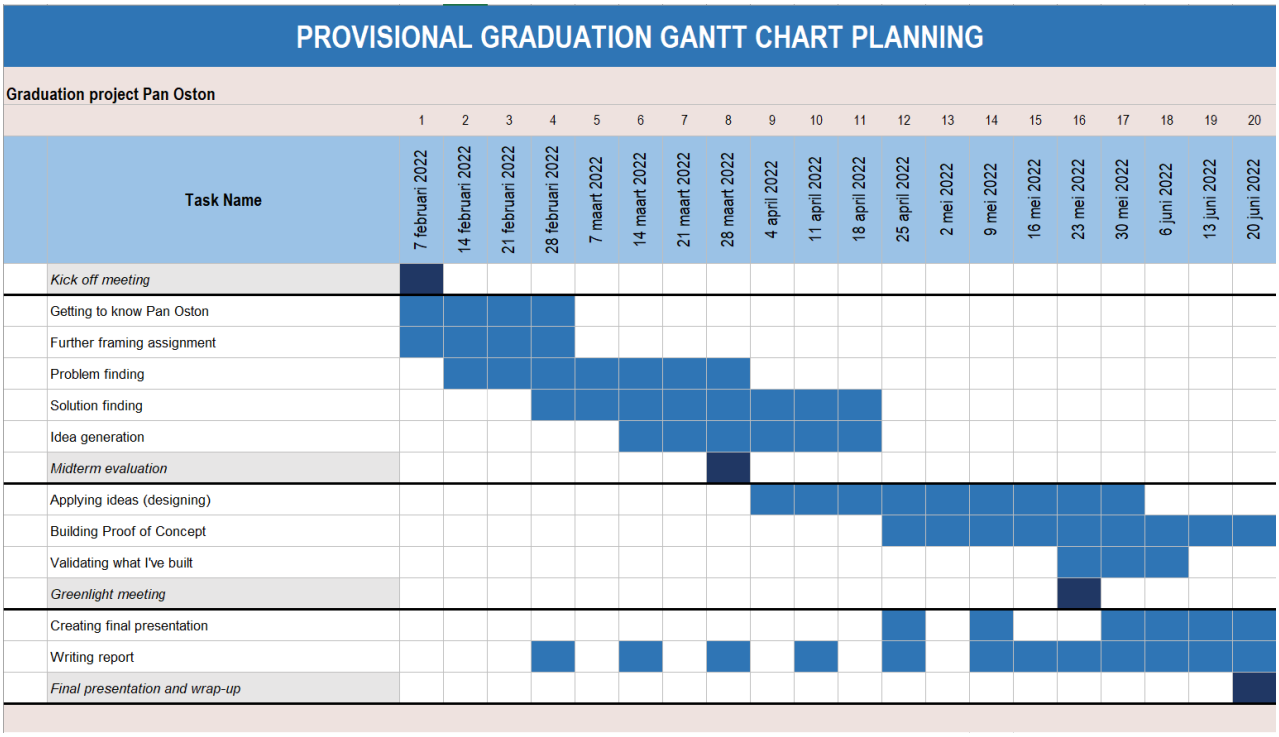
Initials & Name _____ Student number _____

Title of Project _____

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 7 - 2 - 2022 24 - 6 - 2022 end date



I start by getting to know Pan Oston and further framing the assignment. These 2 activities will go hand-in-hand and will build the foundation of this project, as it is essential for me to understand who Pan Oston is and what they want from this project to be able to deliver a satisfactory Proof of Concept. Part of framing the assignment is finding the problems that need to be solved, which I will be doing until roughly week 8. This means doing user interviews in retail stores, analyzing the products that are currently being used in stores, etc. Parallel to this I will find and think of solutions that solve the problems I come across. This will give me a good overview of what problems there are and where the opportunities are to be able to solve these problems. I will do this from week 6 on in 'idea generation', where I design solutions that solve the problems I've found. From week 9 on, after the midterm evaluation, I will combine these ideas into a product. I will do this until week 18, since I am convinced it is better to spend my time on building the product in such a late stage of the project. Parallel to designing the product, I will start building it from week 12 on. It is important for me to start building early, so that I can learn from and fix any problems I come across. When my prototype is ready to be validated (I planned from week 16 on), I want to validate it with end-users and change the product if necessary.

I will start writing my report and making my final presentation early, so that I do not get surprised with an enormous workload in the end.

I will not take a break. This is because if I added an extra week to my planning and my graduation would be extended by another 4 weeks (due to whatever reason) I would not be able to go on my holiday which is already booked.

Initials & Name _____ Student number _____

Title of Project _____

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

I set up this project as I am looking for a project that allows me to create a physical product with integrated technology. I wanted to do this assignment at a company to learn more about how products are designed in practice, and to gain more experience in the product design work field.

I want to prove and learn the following competences:

1. Apply CAD modelling to be able to prototype and create a working product. I would like to use this for 3D printing for quick prototyping, but also for sheet material (steel) as this is what Pan Oston mostly works with
2. Getting in contact with departments within Pan Oston and companies outside Pan Oston for researching technologies applicable and suitable for this project and Pan Oston specifically. I find that communicating with others for gaining information to solve my problems is something I am good at and want to keep practicing.
3. Quickly learning how to apply a technology I am not familiar with, so that I can use it in my project. I want to prove I am able to go outside of my comfort zone and still make it work.
4. Be in control of a project so that all stakeholders are taken into account and all demands are met, while keeping check of the original problem statement and assignment

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.

Initials & Name _____ Student number _____

Title of Project _____