MIDP Design Specification with Justification

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Abstract

The report summarises the exploratory work completed in semester 1 resulting in a final concept and a design specification. Firstly, the DPP project was investigated to understand the why it was needed and the aspects that this project should target. Then a technology audit was completed to access how different technologies could perform when conveying data between the user and a DPP, where RFID seemed the best. Stakeholders for the project were interviewed after to generate user requirements and ensure that the concepts catered to their needs. Some of these needs being: ease of use, visual feedback, and consistency. Next an opportunity was found within the design space that led to a design specification being created. This design specification allowed concepts to be generated that were then compared and a final concept, RFID Black Box, was chosen to be taken forward to the prototyping stage.

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AI	Artificial Intelligence
DPP	Digital Product Passport
RFID	Radio-Frequency Identifier
QR	Quick Response

1 INTRODUCTION

This project titled, Digital Product Passports, was broad with many potential design paths. This report delves into the decisions that were made leading to a final chosen concept and design direction.

Firstly, it was important to gain an understanding of Digital Product Passports (DPPs), why they are needed and how they are used. It was discovered that DPPs are part of a wider European Union (EU) Green initiative to transition to a circular economy by 2050 (European Parliament, 2023b). The aim by 2050 is to have a DPP for most products to reduce waste created, the brown section of Figure 1, and provide economic benefits for all stakeholders.

Figure 1: The EU circular economy model (European Parliament, 2023a).

Digital Product Passports are needed due to the large volumes of waste generated by people replacing products rather than repairing (Yale Sustainability, 2021). By making it part of legislation it encourages all stakeholders to participate and reduce products that reach landfill. Currently however, due to them being a new concept, there is minimal understanding on how the DPPs might work and how data will be conveyed.

The DPP has already been implemented for some of the worse polluting product groups such as batteries and textiles. The EU wants to expand this to other products so a focus for the project was chosen being electronics as E-Waste is the largest growing waste stream in the world (Forti et. al., 2020). Many of the materials used in electronics are not only rare but also toxic, both of which are reasons they should be recovered to the greatest extent possible (World Health Organisation, 2023).

The project aim therefore is to develop of novel method for communicating the information contained within a Digital Product Passport, with a focus on electronics.

2 Exploratory Work

2.1 Technology Audit

The first piece of exploratory work completed was an audit of potential technologies that could be used to convey the data stored in a DPP.

Before the technology audit, investigation into how the DPP was applied to batteries was conducted. This helped identify the types and volume of data that need to be incorporated into a DPP to make it functional. During this investigation other, less complex, product waste reduction strategies were discovered such as the Product Circularity Data Sheets used in Luxembourg (Luxembourg Government, 2023). According to papers published on the viability of these, they were too simple and didn’t provide enough functionality to make a difference to the amounts of products going to landfill (Mulhall et al., 2022).

The technologies reviewed in the technology audit were SmartTags, Artificial Intelligence (AI) Image Recognition, Radio-Frequency Identifier (RFID) tags and Icons / Labelling. Some of these technologies were tested first hand while others were reviewed using data collected by other researchers on their functionality in scenarios like that of DPPs. This review of technologies allowed for the identification of some important characteristics that should be considered. For example, the structure of the data would need to be flexible as the use of a product could change. This ruled out choices such as labelling as these cannot be changed once they are created.

The technologies that showed promise were the SmartTags, RFID and AI image recognition. AI recognition was the least reliable, but it is evolving exponentially so within a couple of years could be the perfect choice for the DPP application (Wu et al., 2023).

The benefit of SmartTags was the fact that a user, without the need for any technology, could tell that there had been a change to the state of the product. RFID was promising as it was able to store data offline as well as requiring minimal retrofitting to existing supply chains.

2.1.1 Technology concepts

To ensure that all the concepting was not left until the end some rough ideas and concepts were produced, Figure 2, demonstrating how different technologies could be used.

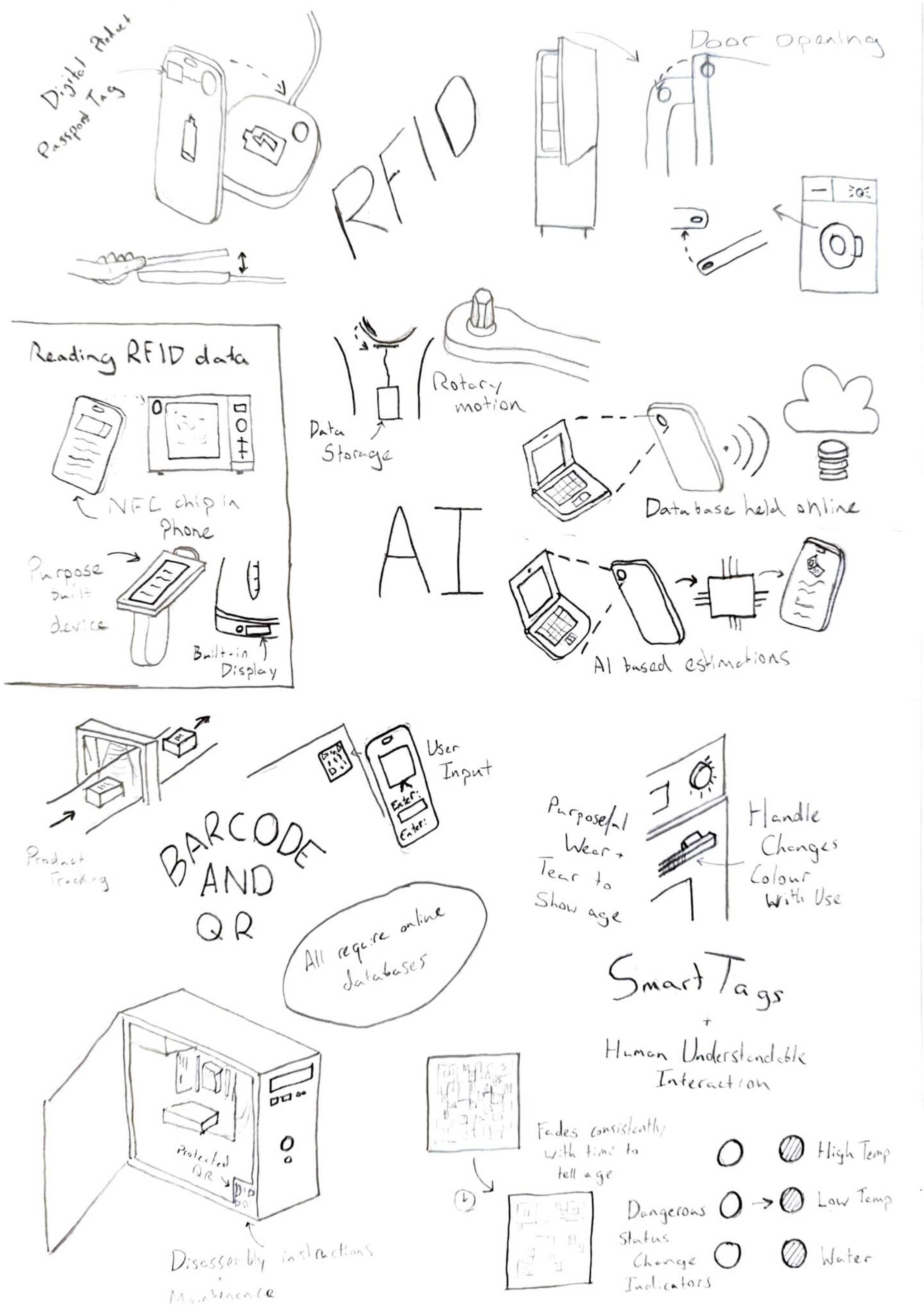


Figure 2: Rough concepts of technologies being used for DPPs.

2.2 User Needs Research

Next it was important to gain the opinion of stakeholders to develop a list of user requirements. This was done through expert interviews. To ensure that all stakeholders from across a products lifecycle were consulted, an identification tool called SCOPIS was used (Fritz et al., 2018). This was used as it is designed to generate stakeholders from across a product's supply chain. The groups of stakeholders identified were:

- Sustainability Engineers
- Product Life Cycle and Circularity Experts
- Manufacturing Engineers
- Recycling Contractors and E-Waste Experts
- Supply Chain and Logistics Experts
- Product Users

These groups were interviewed on technologies they found easy to use, important factors in implementing circular solutions and how they preferred to collect and store data. These interviews assisted in generating requirements and constraining the DPP. The main takeaways from the interviews were:

- Ease of Use – Almost all interviewees felt an important factor in the function of a passport is how easy it is to use. While regulations can ensure that manufacturers are using the passport as intended, the use phase of the product is up to the user. Therefore, making the DPP easy to learn and use is likely to be more effective in enhancing recycling and reuse.

- Adherence to legislation – One point mentioned by a manufacturing engineer was that they feel the implementation of a DPP should not affect any existing product or manufacturing regulations. Also, while the concept should adhere to EU DPP and Circularity legislation it should also not increase the production costs of the product massively as this would disincentive companies from adopting the passport.

- Visual Feedback – Many interviewees stated that the products they find easy to use are the ones that let them know what they are doing. This highlights that visual feedback and visual elements are key and should be incorporated as part of the DPP concept.

- Consistency – Additionally most interviewees mentioned that they like how across similar products, such as kitchen appliances, the interactions are simple and consistent. This is especially applicable in the case of DPPs as the intention is for them to be used across a wide variety of products. The passport concept should therefore function in a common way across all products.

- Narrow the focus – A product life cycle expert recommended that the project scope be narrowed from electronics. He stated that previously when regulations regarding electronics were implemented, high impact products were tackled first. This approach was implemented with a subgroup of electronics chosen being large electronic devices containing mechanical components.

2.2.1 Backpedalling on Barcodes

Many of the interviewees liked the idea of using barcodes and Quick Response (QR) codes, something which was decided against in the project brief. The reasons they stated were familiarity and the fact that contemporary supply chains typically use these technologies. There is still the issue of maintaining an online database for these codes to link to, however they were reconsidered and included in the initial round of concepting.

2.3 Picking a Path

After the exploratory work, the design space was still very broad. While constraints and needs had been identified, a design direction had not. To quantifiably identify potential paths an opportunity lollipop was used, Figure 3, which bases the opportunities on insights gained from the research already completed.

Figure 3: An opportunity lollipop containing the research and insights gained during exploratory work into DPPs.

From this an opportunity was chosen being “To create a simple and easy to use passport for everybody to use that only targets certain products.” This was based on many of the surrounding insights. The identification of an opportunity allowed the project to progress in a focused way.

2.4 GENERATING GUIDANCE

Following on from the identified opportunity, guidelines for the passport were created to aid the concept generation. This was done though a 635 ideation where 3 ideas are jotted down in 5 minutes and is repeated 6 times. A “How might we” question based on the design opportunity was used as a prompt to create these guidelines in Figure 4.

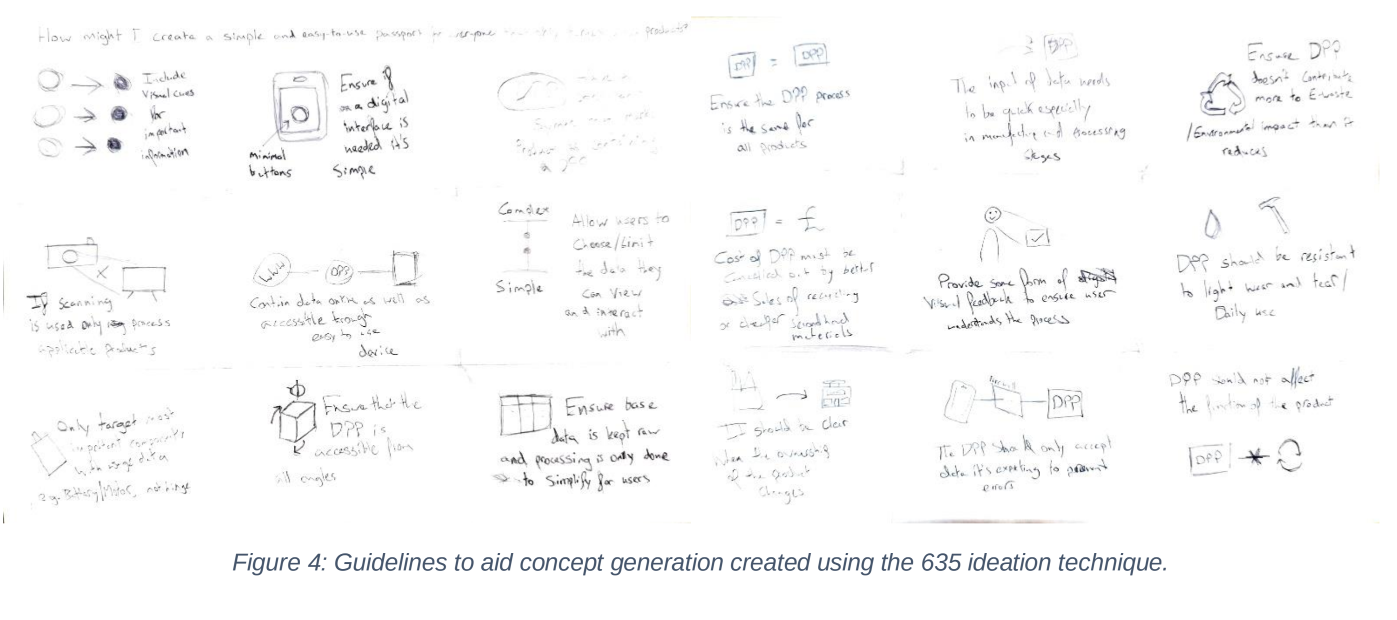


Figure 4: Guidelines to aid concept generation created using the 635 ideation technique.

3 SPECIFICATION

With exploratory work and research completed leading to many insights a cohesive design specification was created, Table 1, that would provide a basis for the generation of concepts alongside a prototype and the project as a whole moving forward.

In order to allow for quantification of some of the specification points, the sub-category of electronics that has been chosen needed to be defined. Therefore, for this project, the focus will be on products between toasters and washing machines in terms of their complexity and size.

Table 1: Design Specification

Category	No.	Description	Quantification	Source	Wish / Demand	Weight
Functionality	1	Technology used should be viable	Technology chosen should be capable of holding 1kb of data	Mini Study 1	D	
	2	Passport concept should be easy to learn	Users should be able to understand how to use the product after one example	Mini Study 2	W	M
	3	Passport concept should be easy to use	Users should be able to complete their interaction with the passport within 10 seconds	Mini Study 2	D	
	4	Concept should have visual feedback elements	Passport should contain a digital or analogue output that users can understand	Mini Study 2	W	M
	5	Concept should be able to identify the correct products	Passport should have a way of letting the user know which product is associated with it	Concept Presentation	D	
	6	Passport concept should only allow each stakeholder to access or edit their data	There should be a form of locking or protection for data that only certain users should have access to	Mini Study 2	D	
	7	Concept should make it clear who is in ownership of the passport at any given time		Mini Study 1	W	L
	8	Concept should be able to have data written to it quickly	The transfer of data to or from the passport should take no longer than 1 seconds	Mini Study 2	W	H
	9	Passport Concept should only accept data in the forms it's expecting	Passport should have a blocker that only allows certain forms or pieces of data to be input	Concept Presentation	D	
	10	Passport Concept should prioritise the more polluting and complex components within electronics	Components containing rare and toxic metals and chemicals should be targeted	Concept Presentation	W	M
	11	Passport concept should automatically collect data about critical components	The prioritised components should have their usage and condition tracked every 6 hours or each use	Research	D	
	12	Concept should allow for manual entry where needed		Mini Study 2	W	L
	13	Passport concept should use a technology that allows for flexible data structure	Data within the passport should have the ability to be partitioned and customised through its life	Mini Study 1	D	
	14	Digital Product Passport concept should keep the data in a raw form only processing for the users understanding		Mini Study 2	D	

	15	The passport should be reusable at End of Life	The passport should be able to be retrieved and data wiped			
Geometry	16	Concept should integrate with existing supply lines	The passport itself should not require any special environmental conditions and any external equipment should be made up from standardised components	Mini Study 2	W	H
	17	Passport should be able to fit into all styles of product within the electronics sub-category	Product should be no bigger than 675cm2	Mini Study 2	W	H
	18	Concept should be a consistent size and shape across all products		Mini Study 2	W	M
	19	Concept should be visible or accessible from all angles		Mini Study 1	W	M
	20	Passport should be easy to make	Use nonspecialised materials and manufacturing techniques	Student	D	
Interaction	21	Passport concept should interact the same way for all products	After testing the process on one product a user should be able to apply the same principles to a second product without assistance	Mini Study 2	D	
	22	Concept should be easy to work with on supply chains	The additional annual downtime in production lines caused by the setup and maintenance of integrating passports into products should be no more than 20 hours	Mini Study 2	W	H
	23	Passport concept should be ergonomic for all potential users	The product should be designed to minimise user interaction and where needed should make it easy for any user to interact	Mini Study 2	D	
	24	Passport concept should not affect the existing uses of the product		Mini Study 2	D	
	25	Essential passport concept functions should be simple enough for people with no experience of technology to use		Concept Presentation	D	
	26	The complexity of interaction with the concept should be adjustable	The data and visual feedback elements should have a form of customisation allowing the user to tailor the passport to their ability	Concept Presentation	W	M

	27	The data on the passport should be accessible both online and offline	There should be a full database either online or offline with essential pieces of data accessible by both	Concept Presentation	W	L
	28	The passport should not affect the aesthetics of the product	Manufacturers should be able to paint, cover or place stickers over the passport or use the same materials as the electronic product	Mini Study 2	W	L
Cost	29	Concept should be accessible for small scale production as well as large scale	Integrating a passport into a product should be able to be completed manually and automatically	Mini Study 2	D	
	30	Passport concept should not require expensive retrofitting to supply chains		Mini Study 2	W	H
	31	Cost of passport should be less than or equal to the savings gained by manufacturer	The cost of the passport itself should be less than £4	Concept Presentation	D	
	32	All prototyping must be below budget	The budget for prototyping is £200	Unit Outline	D	
	33	All parts in final design must be priced	All parts should be listed in a Bill of Materials	Student		
Sustainability	34	Passport Concept should not contribute more to the E-waste problem than it's reducing	Passport should be made from environmentally friendly materials where possible and use minimal electronic components	Concept Presentation	D	
	35	Concept should be resistant to light wear and tear	The passport should be able to withstand 16 years of typical household use for all products within the subcategory chosen	Mini Study 1	W	M
Legislation	36	Passport concept should adhere to Digital Product Passport and EU Circularity legislation		Research	D	
	37	Passport concept should adhere to general supply chain legislation		Mini Study 2	D	
	38	Passport concept should not affect adherence to other legislations for electronic products	UKCA and CE Legislation	Mini Study 2	D	
Safety	39	The DPP should be designed safely	There should be minimal pinch points and sharp edges	Student	D	
	40	There should be no risk of electrocution	The electronics in the passport should be insulated or inaccessible	Student	D	

3.1 Ease of Use – Spec 3

In terms of quantifying the ease of use of a passport, while it would be possible to analyse each aspect, without knowing what form the final concept would take this would be difficult. To simplify this, the time it takes for an interaction will be used. The length of time chosen was 10 seconds as Nielsen states this is limit of absolute focus (Nielsen, 1993). While there may end up being some functions that require more time, this should be the maximum time need for completing standard tasks.

3.2 Data Transfer Speed – Spec 8

The data in a passport should be transferred to or extracted from the device in less than 1 second. This has been chosen as it helps bring the interaction time below 10 seconds. Another reason the transfer speed should be this quick is due to the rate production lines move, approximately 0.1 metres per second (Roser, 2023). The final assembly of electronic devices is typically on continuously moving lines so a quick transfer time is essential.

3.3 Toxic Materials – Spec 11

The World Health Organization states that there are toxic and rare materials used in some components of electronics (World Health Organisation, 2023). Due to this the components containing these materials, which are typically the ones that are harder to recycle, will be prioritized.

3.4 Product Geometry – Spec 17

Due to the variability in the geometry of products, specific dimensions for the passport cannot be defined. A volume for the passport was defined however to ensure that, even if the shape is adjusted, it will fit within a product without much need for a redesign. The volume chosen is 675cm^2 as this is approximately the extra space needed when comparing a regular toaster to a smart toaster. The exact method used can be found in Appendix A.

3.5 Use in Supply Chains – Spec 22

Downtime in manufacturing chains is costly, around $129 million dollars per year among Fortune 500 companies (Lääts, 2023), due to not only the lack of produced goods but also the knock-on effect across a business. Typical annual downtime is approximately 800 hours (Brand, 2020). For the DPP to be enticing for manufacturers to implement, the added downtime for integration and maintenance of a DPP system should be no more than 20 hours or 2.5% of the current 800 hours.

3.6 Passport Cost – Spec 31

The cost of each passport is another factor that manufacturers will be considering when implementing it into their products. A manufacturer is unlikely to want DPPs unless they can recover the costs when the product needs to be recycled. Therefore, with a toaster, as it is the smallest and device within the bounds set earlier, the material cost that can be recovered is $5.14 (£4.08) according to Massachusetts Institute of Technology (Massachusetts Institute of Technology, n.d.). This led to the passports maximum cost of £4.

3.7 Lifetime – Spec 35

The lifetime of a DPP should at least match the lifespan of the product. A paper on the lifetime of household appliances was reviewed that gave the average lifespan of household appliances to be 10.65 years (Alejandre et al., 2022). Assuming that in most cases the repairability and enhancement of life expectancy that a DPP can provide will prolong this by 50%, the passport should be able to withstand 16 years of typical household use.

4 INITIAL CONCEPT IDEAS

Using the guidelines from section 2.4, it was possible to start concepting ideas. The guidelines were used to help aid the ideation process however each concept did not need to abide by all of them.

4.1 CONCEPT 1 - STANDARDISED RFID BLACK BOX

The first concept, Figure 5, is a standardised RFID box. This box would sit within the product and would function similarly to an aeroplane black box, recording data about the critical components. For example, the motor in a washing machine.

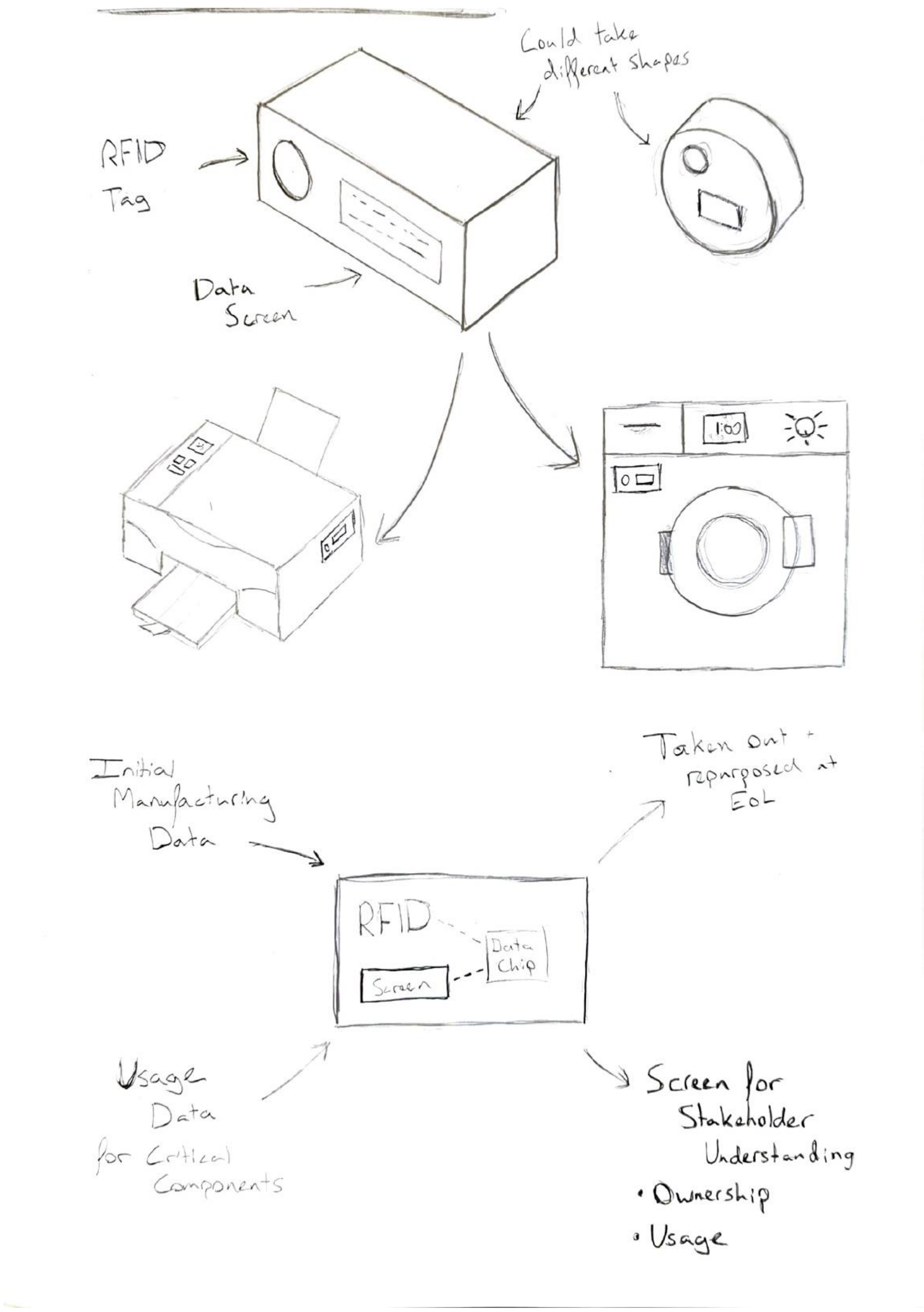


Figure 5: Concept 1 - Standardised RFID Black Box.

It would also contain the ability to receive user inputs of data that the automatic data collection cannot sense such as a replacement part. This black box could then be read by a recycling contractor, so they know what parts to salvage. There is also potential for a screen to be introduced that would allow the passport to display some key data it has recorded for the user to see.

4.2 Concept 2 - QR Code with Human Elements

The second concept, Figure 6, uses a QR code to take the user to a database where data about the product can be entered. There is therefore no automatic collection of data about the product, a situation found to be less than ideal in Mini Study 2.

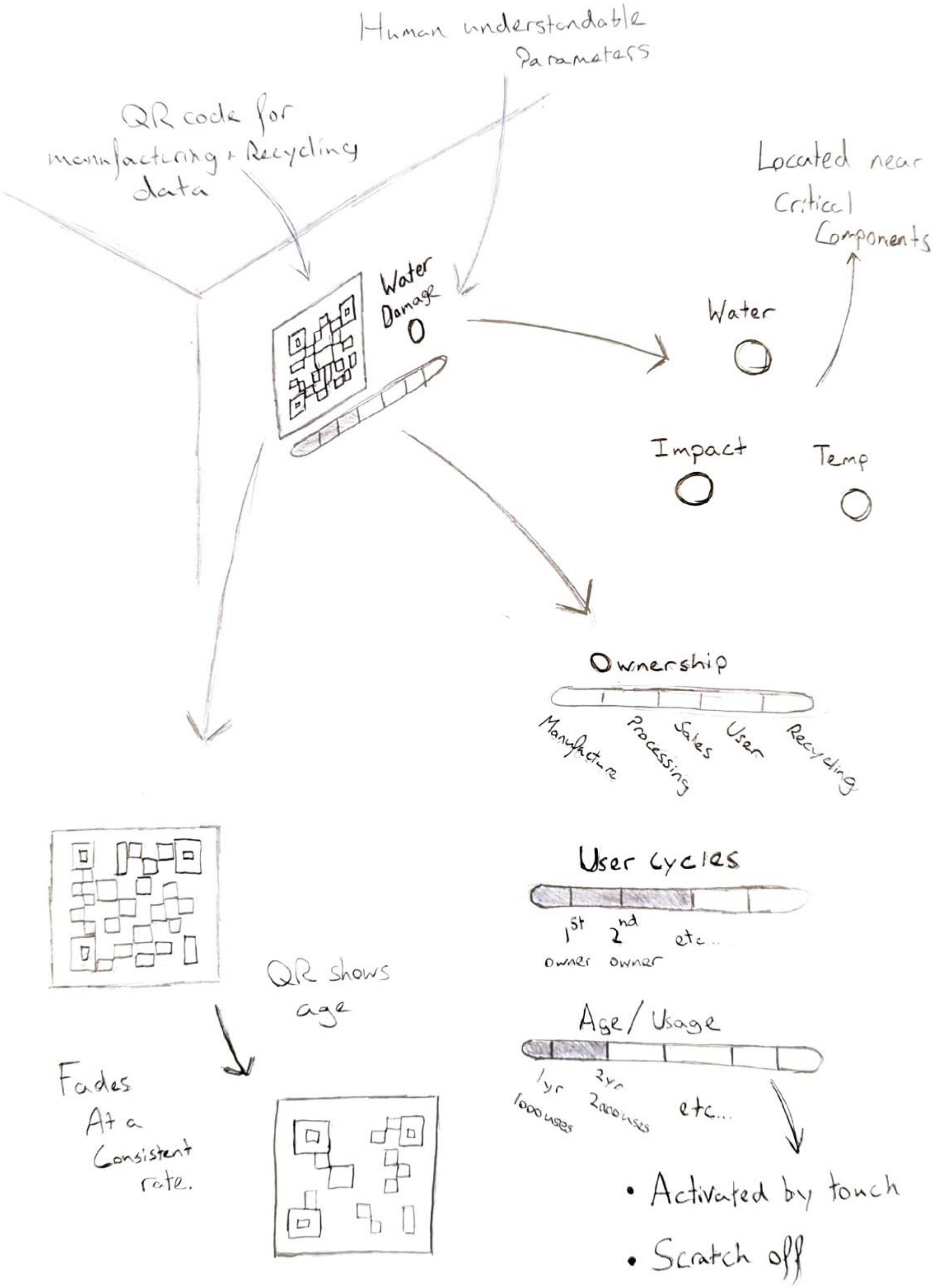


Figure 6: Concept 2 - QR Code with Human Elements.

There are other elements that can be understood by a human without any external equipment that provide valuable data about the condition of the product. There are markers that could indicate changes in environmental conditions, such as water or extreme heat. The slider feature could be used to show stages of the products life such as ownership or number of previous owners. The QR code would also fade consistently with age.

While the technology is in place for some elements of this design, considerable work would need to be done to ensure the proper functioning of all elements, like a QR code that fades at a constant rate and isn't affected by wear and tear.

4.3 Concept 3 - Non-invasive RFID Sticker with Handheld Reader

The final concept, Figure 7, created is a non-invasive RFID sticker, similar to those seen on security tags in supermarkets, that pairs with a stand-alone handheld reader or phone. The stand-alone reader would be owned by the customer and used on all their products that contain a DPP. The data for the product would be kept on both the RFID tag and the handheld reader for security.

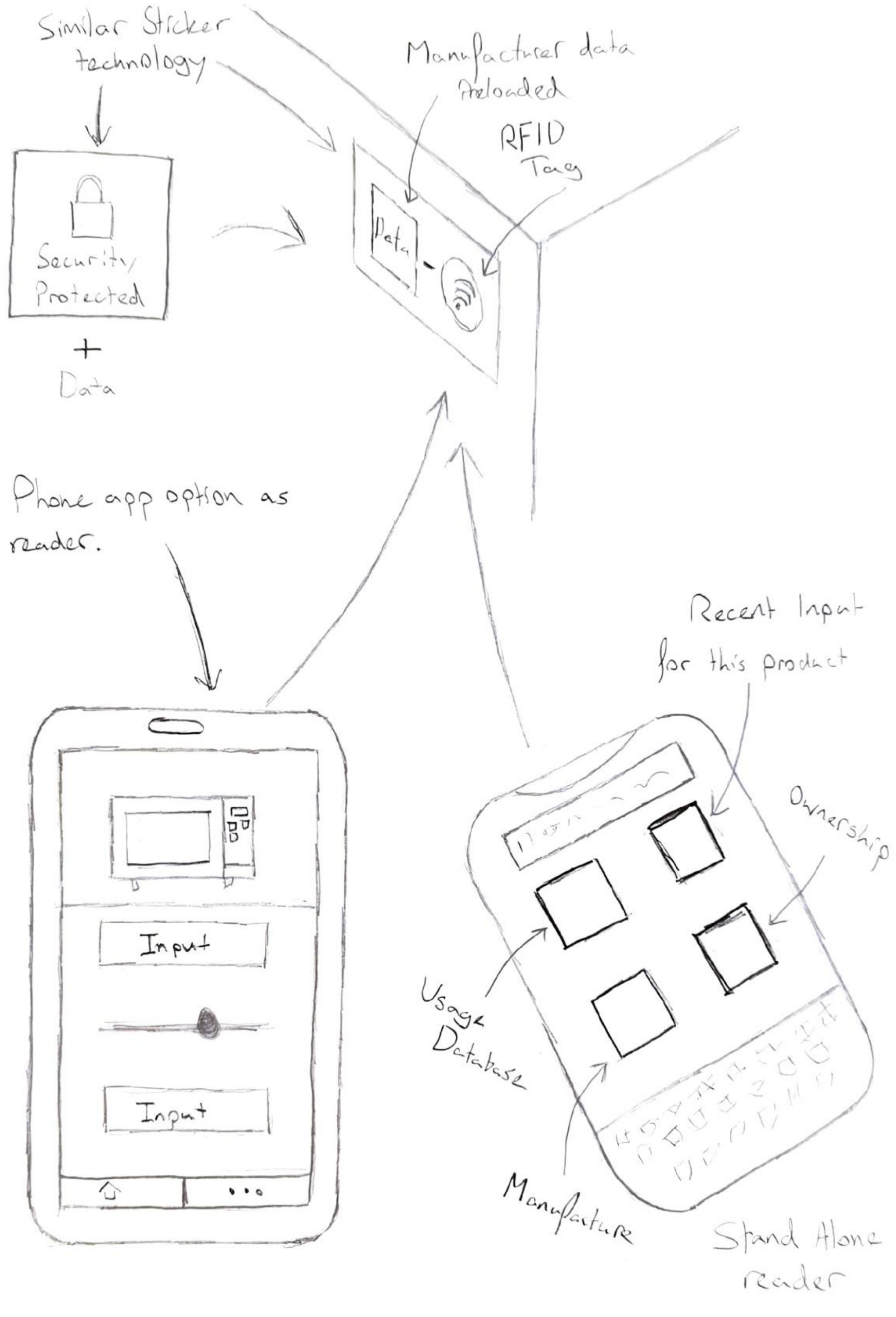


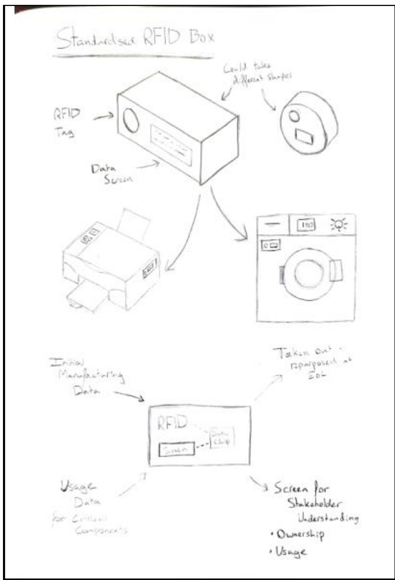
Figure 7: Concept 3 - Non-invasive RFID Sticker with Handheld Reader.

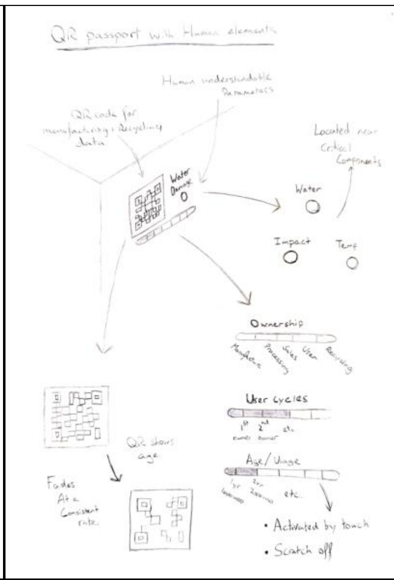
Similarly to concept 2, there is no automatic collection of data. A phone could also be used to input data where the user would be able to customise the complexity of their interaction.

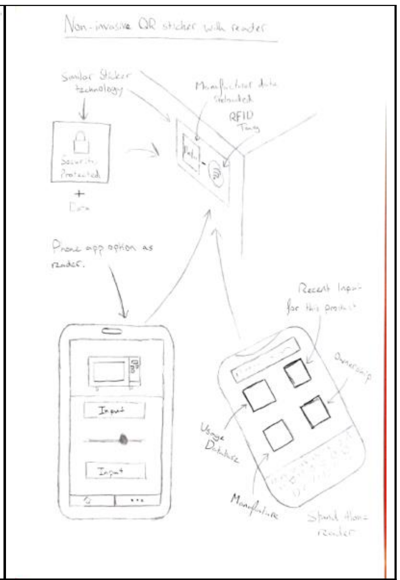
5 FINAL CONCEPT

With a detailed design specification created the initial concepts were compared to these points as well as each other. To do this the Harris Profile method was chosen, shown in Table 2. This was chosen as it does not require a datum for comparison, which would be difficult due to the infancy of DPPs. The criteria used in the Harris profile have been created based on specification points.

Table 2: Harris Profile comparing concepts to specification points.







		Concept 1 - Standardised RFID Box				Concept 2 - QR Passport with Human elements				Concept 3 - Non-invasive RFID sticker with reader			
	Criteria	-2	-1	1	2	-2	-1	1	2	-2	-1	1	2
Data	Adaptability												
	Tranfer Speed												
	Visual Feedback												
	Production Line Equipment												
Cost	Maintenance												
	Material												
	Value												
Geometry	Flexibility												
	Size												
	Need for Redeisgn												
	Accessibility												
	Complexity												
Interaction	Customisability												
	Simplicity												
	External Equipment Requirements												
Other	Future Proofing												
	Durability												
	Total	8				6				0			

As can be seen from the Harris profile concept 1 should be pursued. Concept 2 could be kept as a backup should concept 1 proved not to be feasible. Future proofing and durability were criteria that it excelled in and are very important due to the expected lifespan of a DPP. A more detailed drawing is shown in Figure 8 alongside a system architecture diagram, Figure 9, explaining its function.

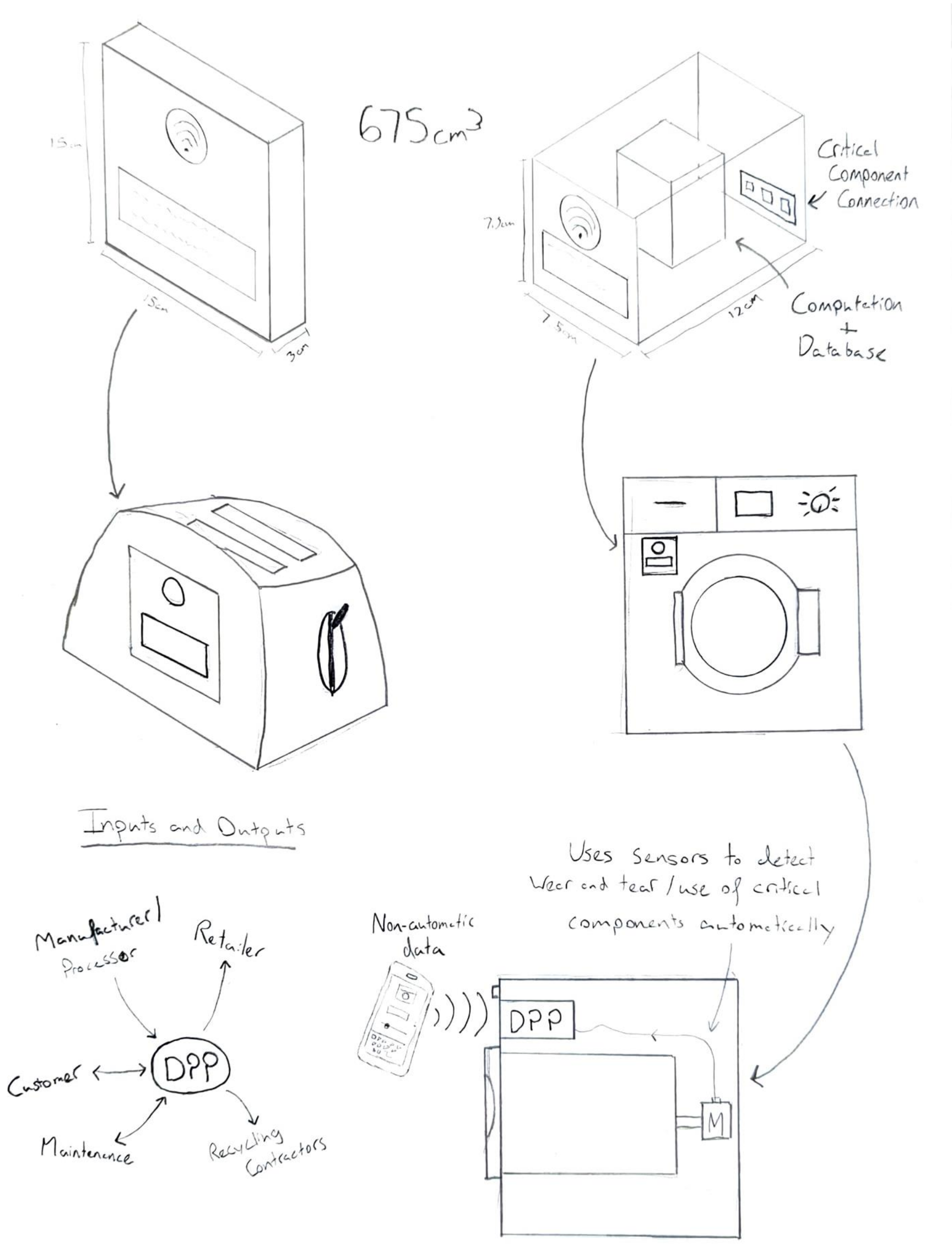


Figure 8: Drawing of the final concept.

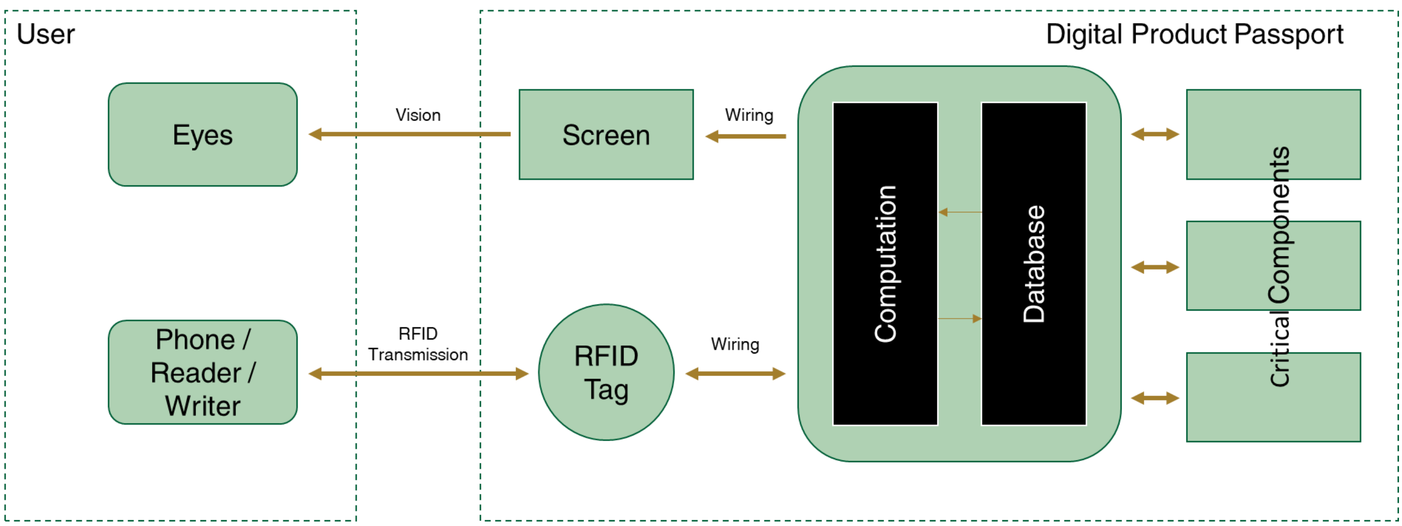


Figure 9: System architecture of RFID Black Box.

6 FUTURE WORK PLAN

With a final idea selected, the concept will need to be iterated upon and certain features need to be tested to ensure functionality. Some features take a higher priority due to their vital role in the functioning of the product and the little effect iteration will have on them, such as the RFID technology. Below in Figure 10, a time plan has been created to ensure that the project stays on track. A lot of time has been left for combining elements in the rough and final prototyping stages as, from previous project experience, this takes longer than expected.

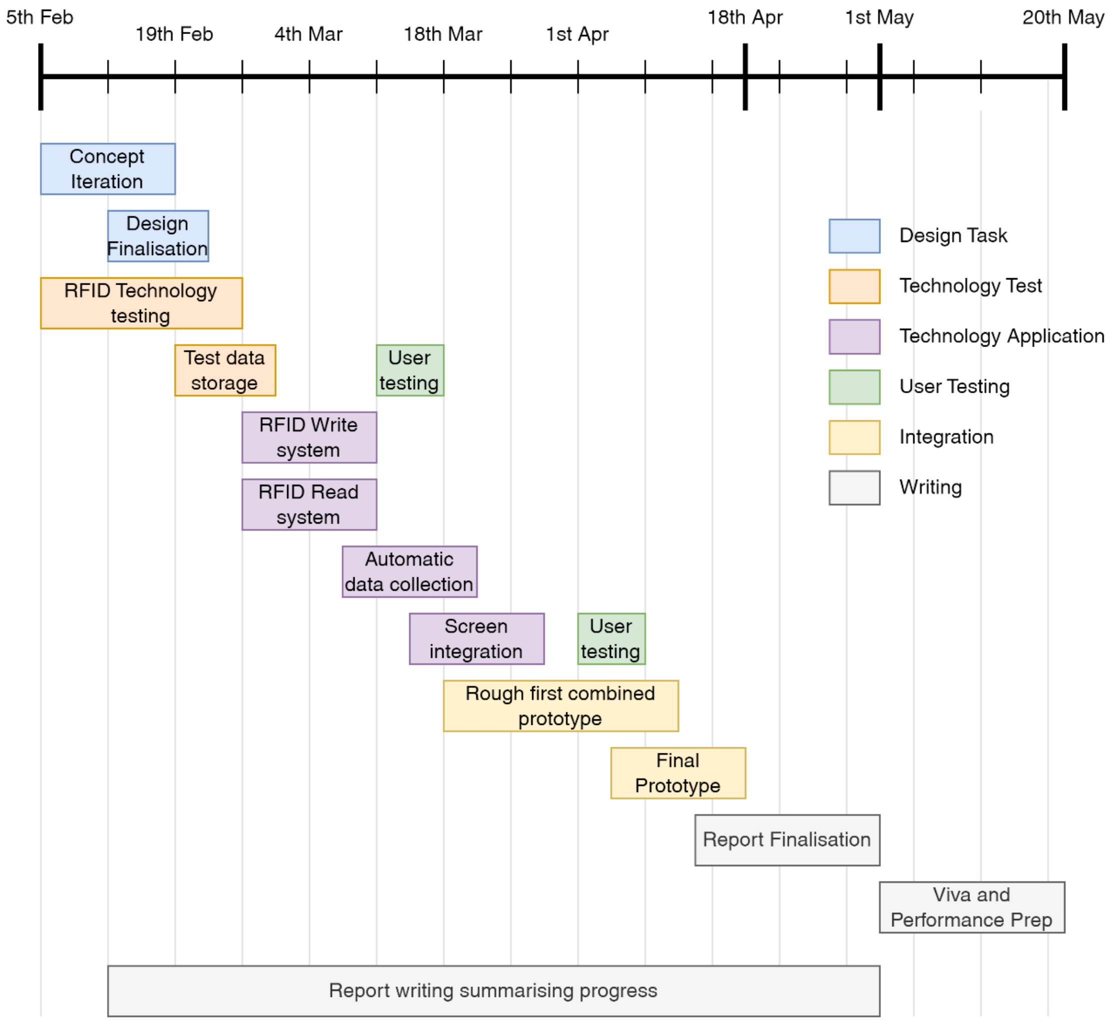


Figure 10: A time plan for Semester 2.

7 CONCLUSION

To conclude the first semester of work on the project, firstly a selection of technologies were tested and analysed to access their ability to function as the conveyor of information for DPPs with RFID showing the most potential, followed by SmartTags. Next stakeholders from across the supply chain were interviews to gain their views on interactions, important factors in the design and data collection. What was found was that users want a passport that is easy to use, as automated as possible and easy to understand while still providing a cost benefit for the manufacturer. Using the insights gained in this study it was possible to identify an opportunity of “creating a simple and easy to use passport for everybody that only targets certain products.” A detailed design specification was created that quantified lots of the aspects of the design while providing requirements that the concepts should adhere to. Three concepts were generated and compared against each other and the specification points using a Harris profile. The chosen concept was a standardised RFID Black Box that automatically collects data about critical components and conveys the data to stakeholders through RFID. Going into semester two there is still some iteration to be completed, however a plan is in place to ensure that the project stays on track.

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9 APPENDICES

APPENDIX A – DPP VOLUME CALCULATION

To calculate the volume constraint for the DPP as smart toaster and regular toaster were compared:

Product dimensions 26.8D x 15.6W x 19H centimetres

As can be seen from the dimensions, both toasters have approximately equal widths and heights of 15cm and 20cm respectively. As the smart features of the smart toaster only take up 3/4 of the height however the cross section size of the smart technology can be assumed as 15 x 15cm.

There is then a 3cm difference between the depths of the toaster. Multiplying the cross section by the difference in depth, a volume of $675cm^2$ is calculated.