Bachelor Thesis

New Product Development of a waste and recycling bin for Coventry University

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Declaration of authorship

„I hereby declare that I have written this thesis by myself without any help from others and without the use of documents and aids other than those indicated. All text excerpts used, quotations and contents of other authors are explicitly denoted as such. "

Horw, 01.06.2014

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Fabian Gartmann

Abstract

This report considers mainly the design of a waste and recycling bin for Coventry University. The aim is to design a waste and recycling bin system that meets the needs of UK Universities (especially Coventry University), the students, and restrictions on sustainability.

Following the introduction with a literature review, the project is discussed (Chapters 2 & 3). The literature review focuses on NPD (New Product Development) models and environmental/sustainable production. It was important for me to get a basic knowledge about well-known NPD models, environmental strategies and standards in NPD and then apply those relationships between the environment and NPD to ensure a structured and sustainable product design in the planned design project. Using information from the literature review, I tried to apply and modify a NPD model which best fits this project (Chapter 4).

The NPD model, described in chapter 4, was used as a guideline which provides step by step details of the project. This starts with market research (Chapter 6) with an interview with the Sustainability Manager of Coventry University, Mrs Selina Fletcher, an E-Mail interview with the Development Manager (Midlands) of Leafield Environmental Limited, Mr Garry Mills, a student questionnaire with over 100 responses, personal talks with dozens of students at the Coventry University Green Week, and a desk/internet based investigation with derived information for the specification of a sustainable waste and recycling bin system (Chapter 7).

In the “concept design” phase and “detailed concept design” phase, covered in chapters 8 and 9, a virtual waste and recycling bin is designed by considering the generated specifications and using information from the market research. In the design process, different creative techniques are used which help to establish a user and customer orientated result.

Because it is not possible to manufacture this planned waste and recycling bin for this Thesis, the NPD stops with the “cost estimation” (Chapter 10) where the costs of the planned waste and recycling bin are calculated. This cost estimation is necessary to ensure that the designed product can be economically successful in the market.

The conclusion (chapter 11) provides the final and detailed design concept of a waste and recycling bin for Coventry University with a discussion about the design with the Coventry University Sustainability Manager.

Acknowledgement

This project involved many different people during the development. At Coventry University I would like to thank everyone who was involved in any way in this project. I would like to thank especially my project supervisors from Coventry University and HSLU Luzern Switzerland: Mr Ray Jarvis, Mr Richard Anderson and Mr Timothy Granata for their great support and monitoring throughout the whole project. Furthermore, I would like to thank the Coventry University Sustainability Manager Mrs Selina Fletcher for the interview and advice, the business development manager at Leafield Environmental Limited Gary Mills for the E-Mail interview and all students who spent time filling in the questionnaire and discussing the subject at the Coventry University Green Week.

Finally, I thank Mrs Alison Taylor and my mother, Marianne Gartmann, for proof reading and their help in language matters. My English skill has much profited!

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1 Introduction

1.1 Introduction

When I first came to Coventry I was shocked how dirty it was at Coventry University. There was litter and waste from the students on every table and left in the working and social places with very little cleaning (Figure 1).

Figure 1: Litter situation at Coventry University

The longer I frequented these places, the more I was suspicious that some students had a strange relationship to the litter and waste they produced. During my research I found that this problem does not seem to be a local one. In articles and reports I found an alarming increase in the numbers for future waste (Figure 2). A World Bank study in 2012 showed an alarming result. If the behaviour with waste does not change, the amount of waste in urban regions will increase from 1.3 billion up to 2.2 billion tons between 2012 and 2025 (Hoornweg & Bhada-Tata, 2012). With the increasing amount of waste the question of “what’s happening with our waste” becomes significantly more important in the next few years. Resources are running out, the space for landfills is less, and the taxes for landfills have increased dramatically (shown in Figure 3). Statistics from the last several years show that England improved the recycling and composting rate for household waste dramatically and reduced the landfilled waste (Figure 2). But Figure 4 shows that in 2010 still approximately 50% of all produced waste in England was deposed of in landfills. The fact of the increasing costs for landfill, the amount of approximately 50% landfilled waste, and the increasing recycling rate makes it really interesting to consider the separation of waste and recycled materials.

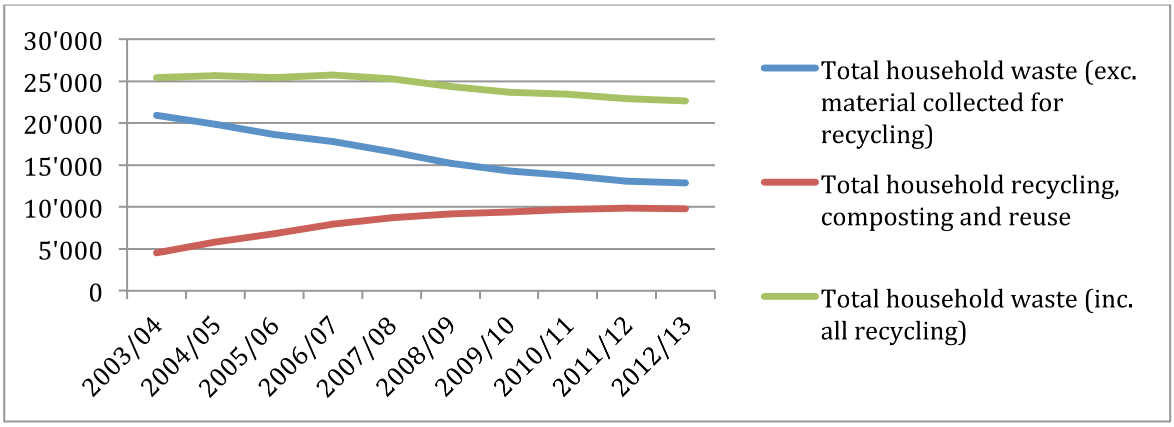
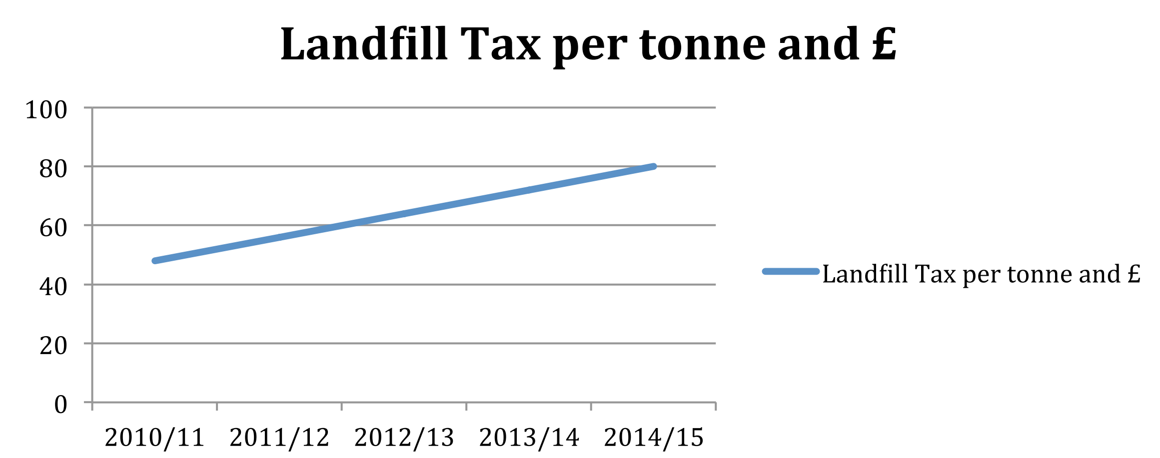


Figure 2: Recycling and Recovery Rates 2003/04 to 2012/13

Source: (www.gov.uk, 2010) and (www.gov.uk, 2013)



Landfill Tax per tonne	2010/11	2011/12	2012/13	2013/14	2014/15
	£ 48	£ 56	£ 64	£ 72	£ 80

Figure 3: Landfill Tax, Source: (letsrecycle, 2013)

The key question on this complex and extensive topic is where to start. Experts think that the waste reduction starts with the individual user (NSCC, 2007). Where better than in schools or Universities can one educate more people with a good waste management model? In 2005, the HEFCE (Higher Education Funding Council for England) came to the same conclusion and launched an EMS (Environmental Management System) and an award scheme for the higher education sector (EcoCampus). This scheme gives universities a step by step tool to identify, evaluate, manage, and improve their environmental performance and practice. For every step, EcoCampus gives an award to honour the effort. The highest is the Platinum award, which includes all the standards for ISO 14001 Standard (EcoCampus, 2013).

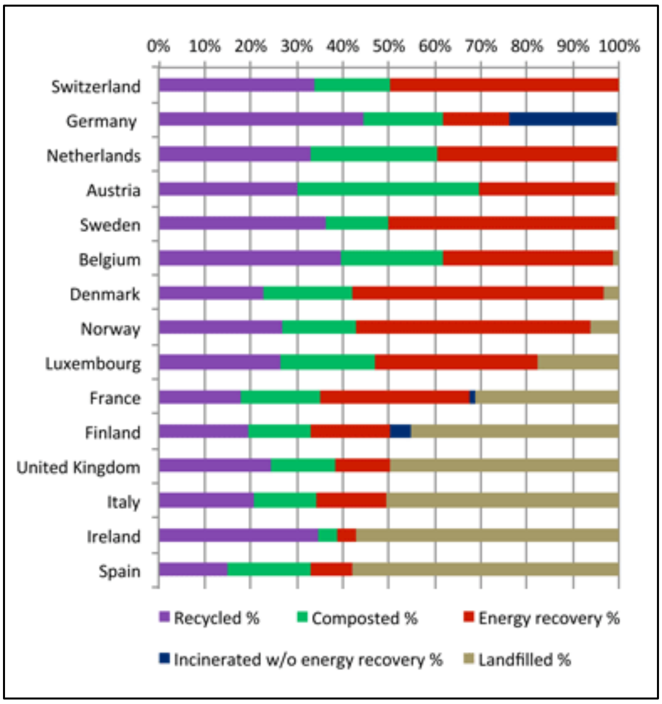


Figure 4: Recycling and recovery rates (WtERT, 2013)
Data source: (Eurostat, 2010)

For all the effort Universities invest in reducing carbon emissions, they need specialised tools and gadgets to achieve future targets. This final year project focuses on design and product development aspects of an environmental and sustainable waste and recycling bin system for Universities in the UK. Specifically, it deals with the design of a waste and recycling bin for Coventry University, which encourages the users to care about their litter, contribute to a clean environment, and be sensitive to recycling and disposal.

1.2 Aim

The aim of this design project is to create a new waste and recycling bin system, designed to meet the needs of universities, and especially optimised for Coventry University. Thus the research will focus on analysing the needs of universities, with a special focus on Coventry University, and designing a new collection system. The new bin and recycling system needs to meet requirements of the University and students, as well as environmental restrictions. This project will start with an evaluation of new product design (NPD) strategies and design of sustainable and environmentally friendly products, and will end with a virtual waste and recycling bin system concept.

1.3 Objectives

1.) Investigate New Product Development (NPD) models and identify the best method for designing a waste bin system in this project.
2.) Conduct market research to define the need for a new waste bin system for universities in the UK
3.) Identify customer and user requirements for a new waste bin system for universities in the UK
4.) Create a practicable waste bin solution by taking in account customer and user requirements
5.) Conduct an approximate cost calculation and a survey with targeted customers to find a realistic production and selling price for the new bin system.
6.) Design a unique and virtual waste and recycling bin system for the Coventry University

1.4 Structure of the project

The Literature review covers the chapters 2 to 4. Chapter 5 concerns the research approach, chapter 6 the research. Chapter 7 defines the specifications. Chapters 8 and 9 focus the conceptual design of a waste and recycling bin for the Coventry University. Chapter 10 consists of a cost estimation for the designed bin and finally chapter 11 discusses the results of the waste and recycling bin concept designed for Coventry University.

2 New Product Development models

NPD is the acronym for New Product Development and is a term used to describe the creation of new products. NPD has a wide definition and is influenced by many factors like the product size and complexity, the background of the designers and the company size, structure and culture. There are many more factors, however what is important is that the NPD process cannot be always the same, and therefore should have different structures to meet different needs (Morris, 2009). In the past, many different NPD and Product design models have been developed. This final year project cannot cover them all. It tries to give an overview of NPD models which focus on products with small to medium complexity and size and will cover a selection of different NPD models which find their practice in today's manufacturing companies. The different NPD modules are structured in three different packages: "Design process models", "Business activity models" and "Organisational Project models".

2.1 Design process models

Design process models focus on design and development activities in the NPD and are often the core models for designers and inventors. A useful model was developed by the British engineer Stuart Pugh in 1990. The model is called the Pugh's model of total NPD (Figure 5). It starts with identifying market needs, goes through a design and manufacturing section and finishes with the product sales. (Roy, 2006:20).

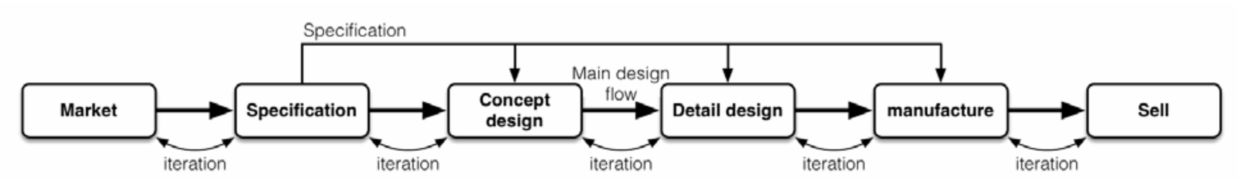


Figure 5: Pugh's total design activity model adopted from (Phug, 1990:6)

The model's core activities have their main focus on the design and manufacturing section, which is directly influenced by the specification section. In the year 2000, a similar model was presented by Ulrich and Eppinger from the Massachusetts Institute of Technology (Figure 6).

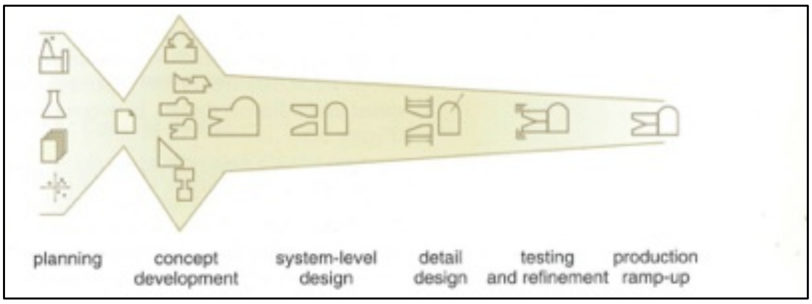


Figure 6: Massachusetts Institute of Technology's model of NPD (Roy, 2006:23)

This model is known as MIT model of NPD and it shows two key differences compared with the Pugh's model. The MIT model of NPD starts with a preliminary strategic planning phase, which leads to a similar research, specification and concept design phases as the Pugh's model. However, the design phase is expanded with a system-level design. In the design phase of this system, the step level of the MIT-model focuses more on manufacturing of products with arrangements of different components (Roy, 2006).

2.1.1 Conclusion

The names of the different phases of the Pugh's model and the MIT model may differ, but the modules describe essentially the same process that has been adopted or modified to many other NPD models. For example the PS 7000 model for NPD from the British standards includes the same structure.

In conclusion, all these models start with interactive processes of identifying a need or opportunity and converting them into a specification. The specification leads to a concept, the concept to a design, and the design is manufactured and sold afterwards. This process is visualised in Figure 7.

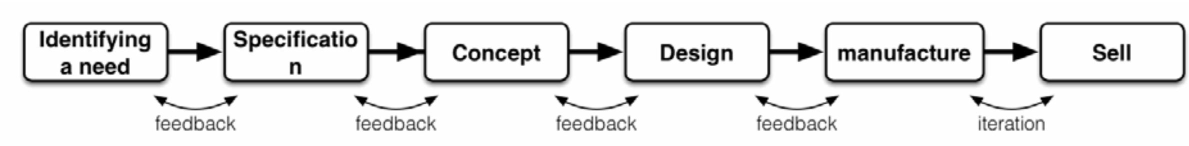


Figure 7: Conclusion of design process models adopted and interpreted from the source: (Roy, 2006:25)

To use these models successfully, many authors recommend that a standard Design process model should be adopted and modified to the company needs. The different stages should have feedback loops between the phases, and special attention should be laid on the product specification generation process. Detailed product specifications should be drawn up before starting with design to ensure that the design meets the customers' requirements. On this point there are criticisms in the literature that these models focus too much on technical aspects and do not sufficiently cover the market and customer needs. It is necessary to integrate a customer and market orientated specification phase to bring economical aspects in these models (Roy, 2006).

2.2 Business activity models

While Design Process models focus on design and development processes (see Chapter 2.1), Business Activity models focus on business and economic aspects. Often the NPD business activity models involve intensive business and market analysis and production planning before the product can be designed and manufactured.
One of the most used Business Activity models in industry is the generic stage-gate model (Roy, 2006). The Stage-Gate model was developed in 2001 by Robert G. Cooper (Figure 8) and elucidated in his book “Winning at New Products” (Cooper, 2001).

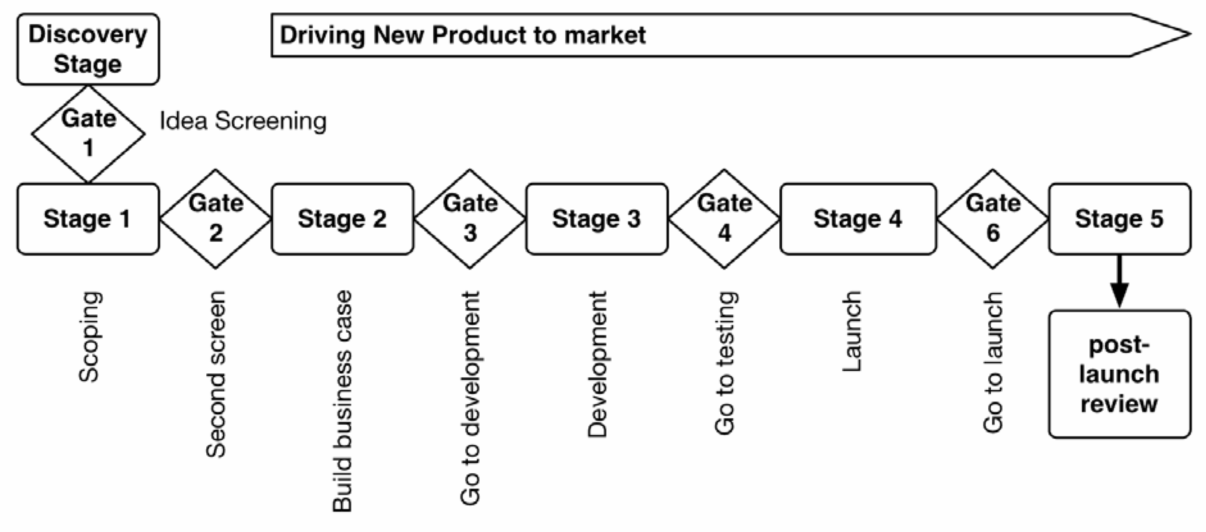


Figure 8: Stage-gate model adopted from: (Cooper, 2001:130)

The Stage-Gate model divides an NPD process into different stages with management gates between them. The management gates function to set a “go" or "no-go” decision point where the project team delivers the results from the previous stages to the senior managers. The senior managers then will decide if the project should or should not go to the next stage. The Stage-Gate model has formal and structural similarities to project management tools like a Gantt chart with tasks and milestones. This makes the Stage-Gate model easily implementable in many traditional company structures. The stages of the Stage-Gate model, which are shown in Figure 8, start with the crucial activity “discovery stage” where new opportunities and ideas for the new product get detected. In Stage 1 the project team analyses the project feasibility, the attractiveness for the company and the integration in the company’s product range. Stage 2 implies intensive economical and technical feasibility studies. After all the market research, the product gets designed and developed in Stage 3 and tested in the marketplace in Stage 4. In Stage 5 the planned, designed, and tested product goes into manufacturing, and marketing and sales begin. The last step, the Post-launch review, implies a review of the performance, the product, and project. (Roy, 2006).

The structure of the Stage-Gate model is part of an idealised model (Roy, 2006) and does not cover all needs. Cooper suggests that different organisations should adapt this model to their own needs (Cooper, 2001).

2.3 Organisational project models.

“Design process models” focus on design and development, the “Business activity models” focus on business and marketing, and the “Organisational project models” focus on organisational and company internal team-based aspects for a NPD. While the structures of conventional design process NPD models and business activity NPD models are linear (Figure 9a), the structure of Organisational Project models show similarities to a Volleyball game (Figure 9b) and Design thinking with its circulating structure to a Rugby game (Toyota NPD model) with its strategic team-based structure (Figure 9c).

Section 2.3.1 will address two models with different strategies and foci. The first is an advancement of the Design process models called “Design thinking” (Figure 9b) and the other one is an advancement of the business activity models called “Toyota’s lean NPD” (Figure 9c).

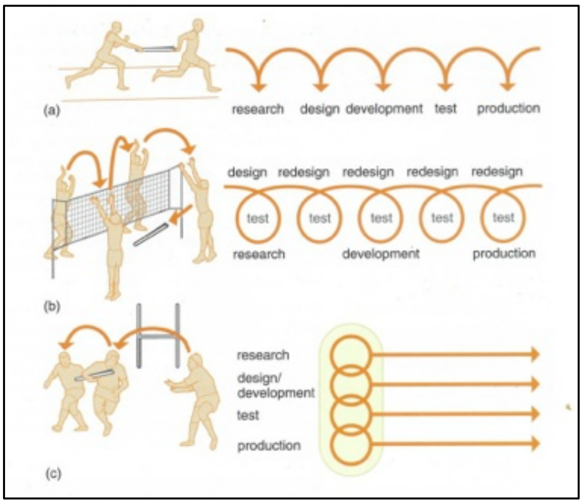


Figure 9: Structure of NPD models (Roy, 2006:49)

2.3.1 Design thinking

Design thinking is a style of thinking that considers a people-centred way of problem solving. The model's approach is to seek innovative solutions to problems and can be used to develop products, services, experiences, and strategies. It follows a cross-functional, team based strategy to achieve solution-based thinking. The model focuses on observing users in their physical environments, on showing them prototypes, and on feeding the observation results back into the design (Curedale, 2013) (Innovation Through Design Thinking, 2006).

The design process of “Design thinking” has seven steps in a repeated cycle. Figure 10 illustrates an idealised and simplified design process of “Design thinking” is shown.

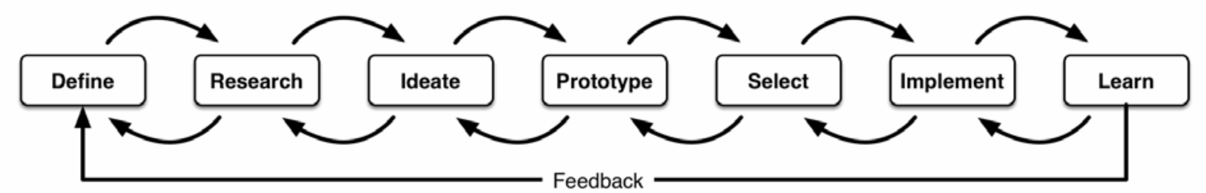


Figure 10: Design thinking adopted from (Ambrose & Harris, 2010) and (Curedale, 2013)

In the Define phase, the NPD team establishes the definition of the problem. In the following Research phase, primary and secondary data are used to collect background information on the problem. The information from the Define and Research phase will be used to create a potential solution in the Ideate phase. From these potential solutions, the best ones get selected and tested with prototypes. In the Selection phase, the best prototype solution gets selected for the Final development. In the Implementation phase, the detailed design gets presented and tested. While the design and business process models have a linear or sequential workflow character (Figure 9a), Design thinking works with interactive loops before moving to the next stage (Figure 9b). The process of Design thinking can be best described as a project volleyball game, where cross-functional teams pass the project back and forth.

2.3.2 Toyota’s lean NPD

In the 1980s the Japanese car manufacturer Toyota integrated the NPD development into its lean production system. Their aim was to use the character of a Business activity model with phases and decision gates, and combine it with a team-based and integrated approach. While the character of Design thinking looks like a Volleyball game, the character of the Toyota’s lean NPD looks like a Rugby game (Figure 9c) where a cross functional team works together, passing the NPD project back and forth as it proceeds. The aim of this model is to reduce waste and increase productivity and quality (Roy, 2006:49). With this method, Toyota can react faster to the market, have a more customer orientated focus, and reduce the internal costs of their NPD in comparison to its competitors (Liker & Morgan, 2006). With these advantages Toyota has a steady flow of high quality new product development and can launch new products faster.

2.4 Summary

The current literature indicates that a general successful NPD model solution does not exist. Every company needs to find its own solution. Roy (Roy, 2006) advises following a standard model and modifying its structure to the users needs, as every situation is different and needs different structures and tools. The four NPD models, introduced in chapter 2, differ in the following points: the Design and business activity models follow a traditional linear or sequential approach, whereas the Design activity models try to generate innovations with a focus on technical and design aspects. The Business activity model(s) focuses on innovations with a more market and business-orientated approach. Models which follow a linear or sequential approach have a simpler structure and their implementation in companies is probably, in most cases, easier than Organisational project models. Usually to properly use the NPD tools and Organisational project models requires a specific company culture with a continual improvement, a motivated cross-functional team, and a strong discipline. Organisational project models follow not only a structure or a technique, they are rather a style of thinking, and every employee needs to follow the structure.

For the last 30 years, questions about environmental problems and eco-friendly production have been more and more important. Still, many NPD models, especially the Design Process models introduced above, do not account for sufficient environmental factors (Roy, 2006). The world is running out of raw materials, waste pollutes the ground, water, and atmosphere, and therefore the importance of focussing on eco-friendliness and sustainability in production and product generation is urgent for every NPD.

The next chapter concerns the relationship between NPD and the environment.

3 NPD and the environment

3.1 Introduction

Historically, industrialisation involved a growing economy based on product and service production, without considering environmental issues and problems. That means they did not consider increasing pollution in production, the waste itself, and resource depletion. Since 1972, when a United Nations conference addressed environmental protection and social economic development, environmental aspects in development and production have become more important (Roy, 2006:77). In 1987, the term “Sustainable development” became established and popular through a report called “Our Common Future” from the “World Commission on Environment and Development”. Today the term “Sustainable development” means a development with a social, economic and environmental concern (DEFRA UK, 2005:12).

Many environmental issues arise from industrialisation and consumer societies. It is recognised that design and technology have a high impact on social, economical and environmental sustainability. In a NPD, many fundamental decisions are taken which significantly influence the environment, either positively or negatively. Because of this high impact, environmental issues have become an essential part of New Product Development, which the industry needs adapt in order to ensure a sustainable and forward thinking orientated production (Roy, 2006).

3.2 Environmental influences on NPD

In today’s NPD, a number of external and internal factors influence the designing process of products and force business managers, designers, and engineers to address environmental issues and manufacturing in NPD. A number of internal and external factors are listed below (Roy, 2006).

3.2.1 Internal factors:

- The wish to increase the market share with environmentally-friendly products
- Saving money by using more efficient and environmentally-friendly techniques in the production
- Commitment from the Management for a CSR (Corporate Social Responsibility, explained in chapter 3.6)

3.2.2 External factors:

- Environmental regulations, standards and voluntary agreements
- Pressure from others in the supply chain
- Introduction of green products by competitors
- Innovations in technology, materials, components, and manufacturing
- Pressure from insurance companies, ethical investors, environmental groups, and consumers

3.3 Green design, Eco-design, and design for sustainability

In the NPD process, the design stage has a direct influence on products and their production. Approximately 70% of the critical decisions on cost, performance, environmental impacts and quality are made in the design phase (Roy, 2006). This fact makes the design phase of NPD an important phase for sustainable and environmental matters. Because this phase is positioned between the marketplace and production, designers have the power and the responsibility to focus on ecological, environmental, ethical, and social matters and include them properly in the NPD.

For ecological, environmental, ethical, and social factors, there are three main environmental design philosophies that have evolved from green design through eco-design to sustainability design. The following provides a short list of the different philosophies.

Differentiation of environmental design philosophies:

- **Green design**: Green design focuses on single issues, for example the inclusion of recycled/recyclable materials or the consideration of energy consumption in the production.
- **Eco-design**: Environmental objectives are considered at each stage of the design and production process. This approach is much more comprehensive than green design. It attempts to balance the reduction in environmental impacts throughout production's life cycle.
- **Design for sustainability**: Sustainability design considers environmental (for example resource use, end of life impact) and social impacts of a product (for example usability and responsibility). This approach is sometimes also called green function innovation.

Adapted from (Bhamra & Lofthouse, 2007) and expanded with (Roy, 2006)

This project focuses mainly on Eco-design and its expansion to Design for Sustainability. In the following section these two designing approaches will be examined in more detail.

3.3.1 Eco-design

While green design is mainly concerned with environmental problems in the production, Eco-design goes a step beyond. Eco-design is concerned with designing long life products with a focus on ecological materials, energy efficacy, low emission, and less waste in the production, as well as during the lifetime and at the end of the life-cycle. It includes all aspects of Green-design and expands on it with the focus on environmental impacts for the entire lifecycle. The aim is to reduce environmentally negative impacts of the production during the product lifecycle and at the end of the product lifecycle. Compared to Green design, the aim of Eco-design does not end when the product is sold to the customer. Therefore, it is concerned with the whole eco-efficiency during the product's lifecycle. It starts with designing, passes through production, goes through distribution and usage by the customer and ends with the products reuse, recycling or recovery. Eco-Design is not only a NPD strategy, it is more a way of thinking. It results in a rethinking of the process and expects new creative, economical, and environmental strategies (Greenpeace, 2012).

3.3.2 Design for Sustainability (sustainable design)

While Eco-design mainly focuses on environmental factors, sustainable design goes a step farther. Sustainable design, like Eco-design, is more a way of thinking, and it combines all the environmental responsibilities of Eco-design with social responsibilities. Meaning, it is not enough to produce products in an eco-friendly manner and take care to reduce environmental impacts during the lifecycle. It is an approach, where the companies take responsibility for their product, the social impact and the consequences of it (Roy, 2006).

In this project, the aim is to design a new waste and recycling bin system for UK universities. Environmental factors to be consider in the production and lifecycle approaches are: 1) to use recycled material and 2) to make the product recycled recyclable. Social/economic factors could be that a customer-optimised waste bin will generate money from increased recycling of material while saving money by reducing the amount of waste and the cost of disposal.

3.4 3R's = Reduce, Reuse, Recycle

The 3 R's are the simplified version from the Waste Hierarchy shown in Figure 12. The Waste Hierarchy is a collection of waste management options. The order of this Hierarchy is arranged with the worst environmental impact at the bottom (base) and the best environmental impact at the top. The 3 R's of Reduce, Reuse and Recycle represent the important environmental impacts of waste management and the three essential components for the environmentally responsible consumer behaviour (Waste Recycling, 2012). They form the basis for many Recycling logos (Figure 11) and environmental strategies for Household waste reduction.

Figure 11: 3'Rs (NSCC, 2007)

Figure 12: Waste Hierarchy (Royal Veterinary Collage, 2013:12)

3.4.1.1 Reduce

Reduce is the most important message of the 3 R's. The reducing aspect starts with the design of a product and involves mainly the reduction of single-use and disposable products and materials. A big impact in waste reduction is due to the packaging.

3.4.1.2 Reuse

If a product or material cannot be satisfactorily reduced, it should be made so it can be reused (e.g. plastic shopping bags, refillable milk bottles from the farmers, reusable Starbucks coffee cups). (theguardian, 2013).

3.4.1.3 Recycle

If a product or a material can neither be reduced nor reused it should be recyclable (e.g. the typical daily household waste: paper, cardboard, Glass, Aluminium, Metal, plastics as dry recyclable materials and food waste as green recyclable/compostable materials).

3.5 C2C (Cradle to Cradle)

Cradle to Cradle is a product life cycle concept, which has a close relationship to Eco-Design (Vezzoli & Ezio, 2008). It is a concept for the Industry that describes a cyclic use of resources. It was created in 2002 by Michael Braungart and William McDonough (McDonough & Braungart, kein Datum). The goal of this concept is to reduce the negative impacts for the eco efficiency of organisations and companies. This concept is special because it combines the technical manufacturing cycle with the biological and ecological cycle to make a No-waste strategy. In 2005, the Cradle to Cradle certification process was launched by McDonough Braungart Design Chemistry (MBDC) (MBDC, 2013). Figure 13 shows, that every material used in production is in a closed cycle and needs to be recycled in the biological or technical nutrient without influencing the eco balance. To achieve this goal this concept uses the "7Rs Golden Rule" (McDonough & Braungart, kein Datum). The 7R's is an expanded version of the 3 R's and means reduction, reusing, recycling, recovering, rethinking, renovation and regulation.

The cradle to cradle concept also presents some difficulties. Cradle to cradle is in conflict with some international ISO Standards like ISO 14040 and 14044, which describe the Life Cycle Assessment and make certificate processes very difficult (fh-duesseldorf, 2013).

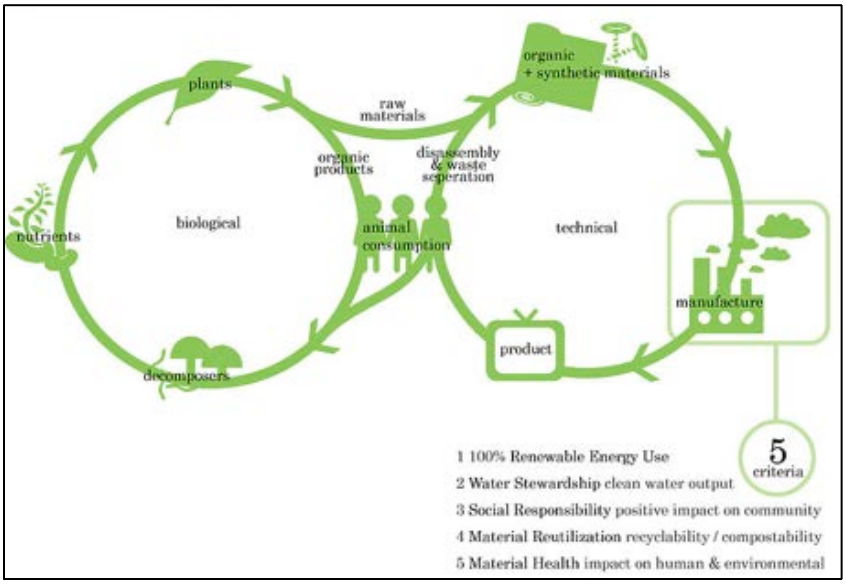


Figure 13: Cradle to cradle concept (www.n2e.org, 2013)

3.6 CSR (Corporate Social Responsibility)

The Corporate Social Responsibility concept has a close relationship to sustainability design. CSR addresses the concern of industry to meet the needs of present generations without compromising the needs of the next generation and it does this in the product's live-cycle and in the production supply chain. That means that Companies need to consider environmental and sustainable aspects from the top of the production/service chain which includes the suppliers and contractors (D'Amato , et al., 2009). The commission of the European Communities defined social and environmental matters as the central points of CSR. Because CSR has so many external and internal aspects, it is very difficult to generate a proper standard for CSR. To find a practical solution, the ISO (International Organisation for Standardisation) in 2010 announced a new standard (which is actually a guide) under the name ISO 26000. As mentioned before, ISO 26000 is actually not a standard but a guide (ISO 26000 - Why is social responsibility important?, 2010). In the scope of ISO 26000, the following sentence explains this: "This International Standard is not a management system standard. It is not intended or appropriate for certification purposes or regulatory or contractual use. Any offer to certify, or claims to be certified, to ISO 26000 would be a misrepresentation of the intent and purpose and a misuse of this International Standard. As this International Standard does not contain requirements, any such certification would not be a demonstration of conformity with this International Standard. "(British Standarts, 2010:1).

3.7 ISO Standards

ISO is the International Organisation for Standards and an independent, non-governmental organisation. ISO was formed in 1947 and today it includes approximately 18000 standards for industry. For example ISO develops standards for products, services, processes, methods, management systems and much more (ISO 14067 progress and issus, 4th PCF world summit, 2012). ISO has a network of national standard (members) bodies in 163 countries. Each body of this network represents the ISO standards in its own country. There are three categories of members, which are described in the following list and visualised in figure 14 (ISO, 2014):

1. Full members = They are the national bodies of the ISO and fully integrated.
2. Correspondent members = They do not have their own standard organisation but get informed about standards.

3. Subscriber members = They have a small economy, pay a reduced membership and can follow the development of standards.

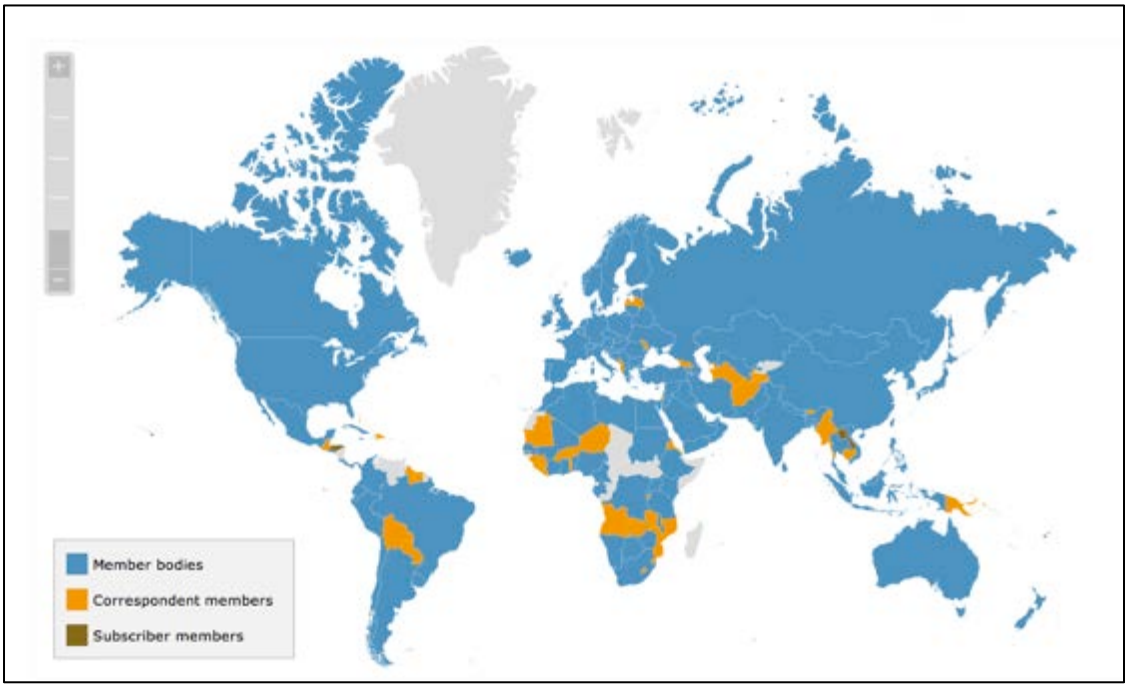


Figure 14: ISO Members (ISO, 2014)

The following sections give a short overview of some important, environmental aspects for ISO standards.

3.7.1 ISO 14001 Family

The ISO 14000 Family concerns various aspects of environmental management. These standards can be implemented in any type of organisation in the public or private sector.

The following list of the ISO 14000 family is not complete and should give a short overview of their special focus (ISO, 2009):

- ISO 14001 = is a framework for environmental management systems (EMS) and explained in more detail in Chapter 3.7.2.
- ISO 14004 = complements ISO 14001 with additional guidance and useful explanations.
- ISO 14031 = provides guidance on how an organisation can evaluate its environmental performance.
- ISO 14020 = is a family of standards which addresses a range of different approaches for environmental labels and declarations.

- ISO 14040 = is a family of standards which provide guidelines for organisations about principles and conduct of LCA (Live cycle approach) studies.
- ISO 14064 = is a greenhouse gas (GHG) accounting and verification standard and supports organisations for emission reduction.
- ISO 14065 = complements ISO 14064 by specifying the requirements
- ISO 14063 = concerns about environmental communication and gives guidelines and examples to help companies.
- ISO 14045 = provides principles and requirements for eco-efficiency assessment.
- ISO 14051 = provides a guideline for general principles and framework of material flow cost accounting (MFCA)
- ISO 14067 = focuses on the carbon footprint from products and provides requirements for the quantification and communication of greenhouse gases (GHGs) associated with products.
- ISO 14005 = is a guideline for the phased implementation of an EMS to facilitate and include the use of environmental performance evaluation.
- ISO 14006 = provides a guideline for eco-design.
- ISO 14033 = provides a guideline and examples for compiling and communicating quantitative environmental information

3.7.2 ISO 14001

ISO 14001 is part of the ISO 14000 Family and one of the most recognised environmental management systems (EMS). This ISO standard has been adopted in more than 80 nations as a national standard (ISO, 2009) and implemented in more than 148 countries. For example British standards adopted ISO 14001 to a national standard for the UK. This standard can be adopted in manufacturing and service companies.

ISO 14001 specifies the requirements for an EMS system but does not dictate how they should be achieved. That makes ISO 14001 very flexible and simpler to implement them in different types of organisations, countries and cultures. ISO 14001 is a tool for systematic and continuous improvement. It starts by identifying the environmental impacts of activities from a company, followed by setting environmental objectives and targets to improve the situation. To achieve these objectives some activities need to take place. In the last step a review phase assesses how well these objectives have been improved. Then it starts again with identifying new issues.

This EMS improvement cycle is illustrated in Figure 15. It is illustrated in a simplified way and not complete.

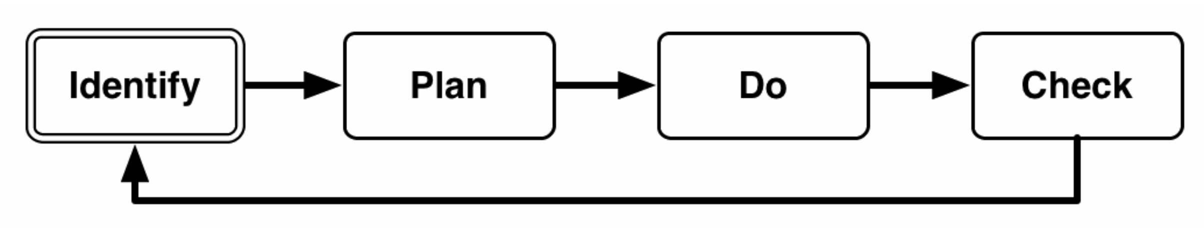


Figure 15: ISO 14001 Source: adopted and modified from (Whitelaw, 2004:20) and (ISO 14001 - the world's EMS standard, 2007)

Implementation of ISO 14001 can lead to benefits like less pollution, reduced cost for waste management, savings of consumption of energy, lower distribution cost and an improved image.

4 Evaluation of the NPD strategy used in the Project

4.1 Introduction

This chapter concerns finding an optimal NPD strategy for the designing process of an innovative, sustainable, and user-orientated waste and recycling bin system for Universities in the UK. As mentioned before experts agree that there is no ideal NPD strategy. All strategies have their own specialisations and can, well implemented, lead to a successful result. The implementation of a method in a company leads to many fundamental structural decisions in management, strategy, manufacturing, and team internal social factors. This fact makes it more difficult to change and optimise a NPD strategy without involving the complete company structure. This chapter cannot address specific company structures and will mainly focus on the requirements for my final year project.

4.2 Evaluation part 1

The NPD models from chapter 2 can be divided into two fundamentally different groups (shown in figure 16 as the Structural group). While the Process and Activity models follow a similar structure with a different focus, the Organisational Project models follow a significantly different approach.

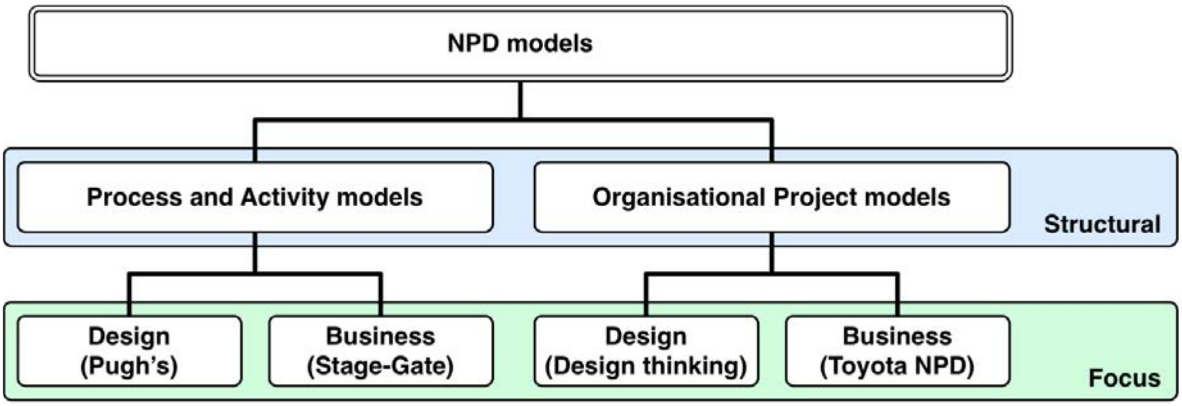


Figure 16: NPD model groups and subgroups. Interpreted from (Roy, 2006)

The selection process of one of these groups is definitely influenced by the company structure. While the Design Process and the Business Activity models follow a classical step-by-step approach, the Organisational Project models focus on company internal cross functional team structures, which leads to a more flexible approach. The following list shows some advantages and disadvantages of the two model groups.

Process and Activity models	Organisational Project models
– Have a simple step by step structure.	– Have usually a more complex project structure and need a cross-functional team.
– Have many visual and formal similarities with classical project management strategies.	– Depending on the model they follow also a more or less classical project management approach.
– Are usually more easily implemented in a company structure.	– Before an Organisational Project model can be implemented in a company, the company needs a specific company culture with open communication.
– Lead, with the right implementation and use, to successful result.	– Lead usually, with the right implementation and use, to a better, faster, more to market and customer orientated results than Process and Activity models.

– Good teamwork influences these models less than the Organisational Project models, but it is also fundamentally important for successful use.	– Without a good teamwork these models do not deliver a successful result.

Table 1: advantages and disadvantages of Activity, Process and Organisational Project models

Source: Interpreted information from chapter 2.

4.3 Conclusion part 1

In his book "Products: New product development and sustainable design" (Roy, 2006) Robin Roy has shown that the structural decision for the NPD Models is mainly influenced by the company structure, culture and focus. If a company has a cross functional project team at their disposal, the implementation of an Organisational Project model opens the optimal way to success and benefit. But if the project team does not fulfil these qualifications, a classical step-by-step approach Process or Activity model would be a better choice. These two groups of models are more established in industry and fit better to small projects like this one-man-final year project.

4.4 Evaluation part 2

In the second part of the evaluation, the focus is on Design Process models and Business Activity models. These two NPD models have a different focus but a similar structure, which makes the decision more difficult. In the following table some differences are listed.

Design process models	Business Activity models
– Historically older than the Business Activity models.	– Historically newer than the Design process models.
– Focus more on Design and Function processes.	– Focus more on Business and Marketing activities.
– Have a classical step-by-step structure. Can, with the right company implementation, lead to good results.	– Are optimised for classical company organisation structures, with working phases and management decision gates. Follow also a step-by-step structure.

– Critics show that finance is not represented enough in standard design process models.	– Implement a financial part.
– The focus on Sustainability and Eco-factors is not covered enough in the standard Design process model structures (Pugh's model).	– The focus of Sustainability and Eco-factors is not covered enough in the standard Business activity models (Stage-Gate).

Table 2: advantages and disadvantages of design process and business activity models

Source: Interpreted information from Chapter 2

4.5 Conclusion part 2

Both models have their attractiveness. Roy (Roy, 2006) presented some examples from the industry. He illustrated that business activity models follow a strategy where innovations are focused on maximising financial profit. While this standpoint is represented from business-orientated people, design-orientated people believe that this strong financial focus blocks the creativity and therefore many opportunities are not recognized. Roy has shown that with a good implementation both models can generate a good result (Roy, 2006). In my opinion the main difference is the focus on business/marketing (Stage-Gate) or design/function (Pugh's). As my project focuses on design and functionality, I have chosen a Design activity model. In the next section the Pugh's model will be modified to the specific needs of this final year project.

4.6 Modification of the chosen model (Pugh's model)

Roy found that the standard design process modules are constructed for an idealised systematic approach and need to be adapted, expanded and optimised for individual use. Furthermore, literature states that this model has two main parts missing, which should be taken in account: a. the model does not sufficiently consider sustainability; and b. the financial element gets too little consideration. To reduce these issues it would be good to implement a sustainable section in the research, a more detailed concept design which considers sustainable aspects and a cost estimation for the concept design.

4.7 Result

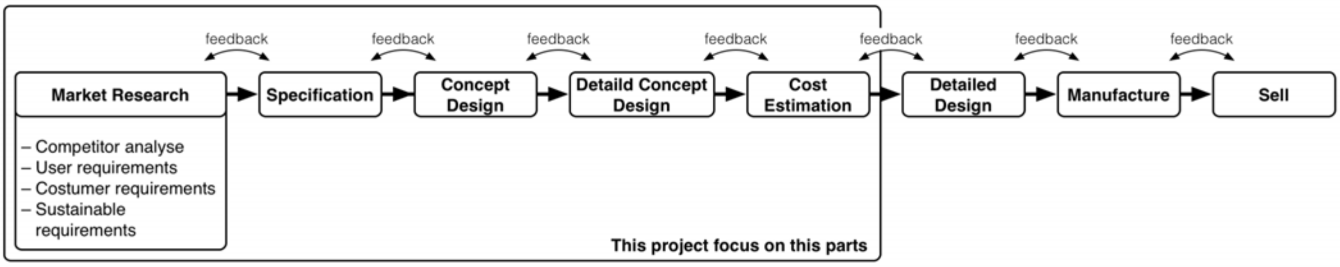


Figure 17: Used NPD model for my Project adopted and expanded with elements of a Pugh’s model

The NPD model presented in figure 17 starts with a “Market research” phase where the results lead to a “Specification” phase. With the results of the specification phase a concept is worked out in the “Concept design” phase and in more detail in the “Detailed Concept Design” phase. With the Detailed Concept Design a first cost estimation takes place to ensure that the final product meets the market needs before it enters the detailed design. After the cost estimation, the detailed concept design gets optimised for the specific production in the “detailed design” phase and afterwards manufactured and sold. The following report of the final year project will focus on the first 5 steps for the NPD structure which is shown in figure 17. After the research approach, the project report will follow with the “Market research” phase.

5 Research Approach

5.1 Introduction

For this project, to design a waste and recycling bin, it is important to properly define the requirements of the different stakeholders and of the environmental influence. To define these requirements intensive research with different research methods has to be done. This chapter focus on the methods, process and methodology used in this project.

5.2 Research Process

This designing project will use a deductive research approach. It is a “top-down” approach which starts with a broad spectrum of information and focuses to a specific conclusion in form of a new design for a waste bin for the Universities in the UK, especially Coventry University.

5.3 Research Methodology

Whereas the literature review was desk-based research, which builds the guideline for this project, the following report covers a research section with quantitative and qualitative data, a concept design section where the results of the research ideas are formulated, a detailed concept design section, where the different ideas are filtered and worked-out to a final concept, and a cost estimation section where the production price is calculated and evaluated for the bin design.

The research starts with finding market, customer and user opportunities, then defining the requirements for a recycling and waste bin for Coventry University. Design projects often use a qualitative research approach because it gives a better understanding and interpretation of the requirements for a new product.

The research part began with desk-based marked research focusing on competitors and their products with public information gleaned from the Internet. It was also important to get an overview of the market, which includes a competitor analysis, competitor price analysis and a design research.

To define the customer and user requirements, a questionnaire with approximately 100 students was initiated to gather quantitative and qualitative data. The quantitative data from the questionnaire is limited but it delivers measurable data from the standpoint of a student. Students have a different knowledge about the questions and different critical opinions about their behaviour, which leads to reality being different from the results in the questionnaire. To overcome these limitations, I used the opportunity to talk personally with

students at the Green Week event (Chapter 6.2.2). I also made two interviews, one with the Coventry University Sustainability manager Mrs Selina Fletcher (Chapter 6.2.3) and the Business Development Manager of the waste bin company Leafield Environmental Limited (Chapter 6.2.4) posing qualitative questions.
The following technology and the sustainability research section (which follows in chapter 6.3-4) is again a desk and Internet based research. The technology research uses qualitative data from innovations, which could influence a recycling and waste bin concept. The sustainability research part uses qualitative and quantitative data from government sources and official publications from non-profit organisations and recycling companies.
In the conceptual and in the detailed conceptual design phases, survey information and requirements of the research get filtered and formed to a specific design idea by using different creative techniques.
The last part deals with a production cost estimate of the designed waste bin. This cost estimate is based on qualitative data from a desk and internet based research.

5.4 Data Collection method

The following Table 3 shows which data collection methods were used in this design project:

Section	Research approach
Literature review	**Desk-based and Internet-based** – mainly based on NPD strategy books.
Competitor analysis	**Internet-based** – based on public information from waste and recycling bin companies
Student questionnaire	**Quantitative and qualitative research** – based on a questionnaire with approximately 100 students
Green-Week	**Qualitative research** – based on personal talks at the event Green-Week which is organised with the student ambassador group Green@CU

Interview	**Qualitative research** – based on an interview with Selina Fletcher, the Sustainability manager at Coventry University
E-Mail interview	**Qualitative research** – based on an interview with Gary Mills, the Development Manager at Leafield Environmental Limited
Technology research	**Desk- and internet-based research** – based on reports, articles and company publications.
Sustainability research	**Desk- and internet-based research** – based on articles, reports from governmental / non profit organisations and publications from Recycling companies
Production technology and Material selection	**Desk-based research** – based on information from the program CES Material selector, production books and material books
Cost estimate	**Desk-based** – based on articles, books and reports.

Table 3: Data collection methods.

6 Market research for a UK University waste bin system

For the specification of a waste and recycling bin system a detailed market research forms the basis. This market research includes competitor, user, customer, technology and sustainability research.

6.1 Competitor analysis

The following is a list of competitors domiciled in the UK that produce waste and recycling bins for half-public areas. The list is not complete but sufficient to give a consistent overview of the market and the selling prices.

Competitor	Description
Taylor	Taylor is a big British manufacturer of waste bins. The company mainly specialises in big containers, urban outdoor and collecting bank bin solutions. They also produce waste bins for offices and companies but this is not their core business. According to the company's own information they are the world-leading manufacturer of metal waste and recycling containers. **Selling price:** The prices for office solutions are from £70 and £150 per bin (recycling and waste bin are separate).
Wybone	Wybone is a UK waste bin manufacturer, producing indoor and outdoor waste and recycling bin solutions. The material of the waste bins is plastic or metal. According to the company's own information, they produce 97% of all products in-house in England. **Selling price:** Plastic office waste and recycling bins cost from £50 to £100, combined waste and recycling Metal bins cost from £100 to £300 (small and standard) and £300 to £500 (bigger and more advanced).
Glasdon Recycling	International waste and recycling bin manufacturer which produces mainly outdoor and indoor waste and recycling bins for public and semi-public areas. The company is based in Blackpool in the UK. **Selling price:** Small to medium plastic waste or recycling bins cost from £50 to £100 pounds per bin (recycling and waste bin are separate), combined small to medium plastic waste and recycling bins cost £70 to £150, a combined medium to big waste and recycling bin system costs £150 to £200.
The Bin Company	More conventional bins for the home usage. It also has a collection with office waste bins. But these office bins do not usually have separate bins for recycling and general waste. The design for Office waste bins look very conventional and use metal material in the production. **Selling price:** for small to medium metal waste bins is from £80 to £150 for a medium to large metal waste bin from £200 and £350.

Leafiel environmental	Is an English premium waste bin manufacturer who produces indoor and outdoor waste and recycling bin solutions for public and semi-public areas. This company specialises mainly in innovative and high quality products. Leafiel environmental focuses on products which are sustainable in the production and in the use. **Selling price:** £60-130 for a medium plastic waste or recycling bin (bins are separate and the price is per bin), £150-250 for big plastic waste or recycling bin (bins are separate and the price is per bin), £160-230 for dual or triple waste/recycling plastic bins (combined waste and recycling bin).
CleanRiver	CleanRiver is an English indoor and outdoor waste and recycling bin manufacturer. They produce more customised waste and recycling bin solutions. Some of the waste bins look more like a piece of furniture for offices, restaurants or shopping malls than a traditional waste bin. The waste and recycling bins are manufactured with plastic, metal and wood. There is no general price list available.

6.1.1 Competitor selling prices

According to the competitor analysis, the prices of standard waste and recycling bins vary from £100 to £300. The price variation depends on size, function and quality. The following list shows the competitor selling prices in more detail.

£50 – £150	For a small to medium (30l – 90l) sized plastic waste bin which collects general waste, general recycling, glass, cans, plastic (bottles) or paper.
£150 – £300	For a medium to big (90l <) sized plastic waste bin which collects general waste, general recycling, glass, cans, plastic (bottles) or paper.
£100 – £300	For a small to medium (30l – 90l) sized metal waste bin which collects general waste, general recycling, glass, cans, plastic (bottles) or paper.
£300 – £500	For a medium to big (90l <) sized metal waste bin which collects general waste, general recycling, glass, cans, plastic (bottles) or paper.
£100 – £250	For a small to medium (30l – 90l) sized combined plastic waste and recycling bin which collects general waste and general recycling.
£250 – £500	For a medium to big (90l <) sized combined plastic waste and recycling bin which collects general waste and general recycling.

6.2 User and customer requirements:

To evaluate the user and customer requirements, the project includes a students' survey with primary data, personal talks with students at the Coventry University Green Week and an interview with the sustainability manager.

6.2.1 Student / Staff Questionnaire

This questionnaire was given to approximately 113 students (probands). To get different and randomly selected individuals for this survey, the questionnaire was distributed manually. The evaluation of the manual questionnaire takes more time in comparison to an online questionnaire, but it delivers more relevant answers from randomly selected persons in a short period of time. Due to the limitation of this questionnaire the result represents the personal and subjective view of the students. It does not necessarily show the real behaviour because it always relates back to the knowledge and interest in the topic. For example people with a high level of knowledge say honestly that they do not care much about recycling while someone else with less knowledge says that he recycles a lot. But if you ask people who affirm they recycle a lot what they recycles, then they may answer that they just recycles paper because they do not know what else can be recycled.
In creating the questionnaire it was important to elicit a representative answer. The structure of the questionnaire started with general questions about environmental problems and focused at the end on design criteria of a waste and recycling bin for universities. The questionnaire is based on quantitative and qualitative orientated questions. The questionnaire and the results can be found in the appendix.

6.2.2 Coventry University Green Week with the student ambassador group Green@CU

To overcome the limitations of the questionnaire it was necessary to talk individually with different student groups. For that I worked with the group Green@CU (a Coventry University student ambassador group which addresses environmental problems at the University) together. We organised a green week in the hub (Centre for student living) between the 3rd and the 5th of March, 2014, where we informed students about environmental issues. I used this event to talk individually with many students about recycling, recycling systems and in general the need to care about our own litter.

Figure 18: Green Week at Coventry University

6.2.3 Interview with the Coventry University Sustainability Manager Mrs Selina Fletcher

To evaluate the customer requirements, general regulations, behaviour of students and the overall waste and recycling situation at Coventry University, an Interview with Mrs Selina Fletcher, the sustainability officer from the Coventry University, was done. The questions and the interview notes can be found in the appendix. The questions focus specifically on the situation in Coventry University. The interview responded to the need to get an internal view of the waste and recycling situation at Coventry University.

6.2.4 Interview with Mr Gary Mills from the waste and recycling bin manufacturing company Leafild

Because trends usually come from outside the Project includes also an (E-Mail-) interview with Gary Mills from the waste bin manufacturing company Leafild. The questions focus on one the hand was on the product which Coventry University is testing at the moment and on the other hand on trends which occur in the waste and recycling bin market.

6.2.5 Results from the research

6.2.5.1 The awareness of environmental issues and recycling of students:

The student questionnaire showed that environmental awareness is quite high. Approximately 75% of students said they cared > 50% about environmental problems. The most important problems were waste (31% of the students) and air pollution (29%). Approximately 70% of the students showed a general awareness of over 50% for recycling, and just 30% cared < 50% about recycling. These numbers show good will, but if we compare them with the awareness of recycling at Coventry University it looks completely different. Just 57% of the students at Coventry University cared >50% about recycling. That means, that the awareness of recycling at Coventry University is significantly lower than students perceive in private. The students explain this divergence with the fact that there are not enough waste and recycling bins on the campus and that the bins do not properly show what litter goes into which bin. In total, 54 of 115 Students said that more bins are needed at different locations around Coventry University. And 31 of 115 students said that it would encourage them to recycle more if the signs and color-coding on waste and recycling bins were more prominent.

In the interview with the sustainability manager it became obvious that the signing and the colour coding do have a big influence on the amount students recycle. She said that the signings need to be easy to understand with multi-cultural use and obvious graphics to show what goes in which bin. At the moment, approximately 45% of the waste at Coventry University is recycled. The target for 2015 is to increase this number up to 80%. To achieve this target the students needs to be divided into two different interest groups to address them successfully. The first group includes people who would like to recycle but do not recycle because it is too difficult, not obvious enough or not possible. I define this first group with the 70% of students who do have an awareness of > 50% in recycling in private situations. The target should be to increase the recycling awareness of this group from 54% up to this 70%. The second group are people who do not care about waste, who do not focus on recycling and also would not care more if it was easier or more obvious. I define this group with the 30% of students who showed an awareness of < 50% for recycling in private situations.

6.2.5.2 How does the design of a waste and recycling bin influence the behaviour of recycling?

According to the Interview with the sustainability manager, design plays a significantly important role to alter behaviour towards more recycling. At the moment Coventry University is testing a waste and recycling bin from the company Leafiel (presented in Chapter 6.3.3 and shown in Figure 21). The company's internal test shows that the recycling rate went up approximately 15%. This increase of 15% is the result of a practical, user-friendly and innovative design concept. In the design of a waste bin it is important that the recycling and the general waste bins are always together and are not separated by a large distance in the room. The bins need good labelling and clear instructions about what material goes in which bin. In personal talks at the Green Week and in the questionnaire, students agreed that good understandable labelling with a practical design would encourage them to recycle more. They often do not recycle, because they are not sure what litter goes in which bin, or there is only one bin available. And if just one bin is available, it makes no difference whether it is a waste or a recycling bin.

6.2.5.3 What colour does a practical waste and recycling bin need.

The colours for the signs, which the company Leafild use, are consistent with Wrap. Wrap is a not-for-profit organisation founded from the Defra (Department for the Environment, Food and Rural Affairs) in the UK. The Colours which Wrap uses are: Light green for general recycling, white for general waste, red for plastic, darker green for food waste, blue-green for glass, blue for paper and blue-grey for tins. The student questionnaire and personal talks at the Green Week showed that many students associate a dark black colour with general waste and a green fresh colour with recycling, a green, blue or brown colour with paper and a blue colour with plastic.

6.2.5.4 Amount of waste bins:

One important fact emerging from the student questionnaire and the discussion with students at the Green Week is that there are not enough recycling and waste bins at the University. According to the student questionnaire, approximately 65% of students agreed that they would recycle more, if the university had more bins dispersed on campus and if it was easier to recycle.

It is not directly related to the design of a bin, but it represents the high need for a dense distribution of waste bins at universities.

6.2.5.5 Trends for the future

According to the interview with the sustainability manager, modularity is an important feature for the design. Because regulations can change, waste and recycling bins need to be adaptable to new trends all the time. At the moment it is obvious that many universities which had implemented a single-stream recycling collection have gone back to a mixed recycling method. The reasons for a mixed recycling collection is that the collecting process is much easier and that the awareness of students for mixed recycling is higher than with a detailed single-stream collection. According to the Leafild-expert, Scotland has recently introduced a new legislation which focuses on the need to divide food waste from landfill waste. This campaign resulted in an increased need for food waste bins. The industry anticipates that it is only a matter of time until this requirement also appears in the rest of the UK.

6.3 Technology research

This section mainly focuses on innovative ideas which could be implemented or adopted in a waste and recycling bin system. It presents the most interesting technologies which I found during the research.

6.3.1 Bin Cam

"Bin Cam" is a research project between the Culture Lab at Newcastle University, LiSC at University of Lincoln and the University of Duisburg Essen. Bin Cam is designed to increase the awareness of recycling and composting behaviour of students who live in students' accommodations. It is a standard kitchen bin with an attached photo mobile phone on the bottom side of the bin lid (shown on the left side in Figure 19). This photo mobile shoots a photo every time the bin gets closed and uploads it directly to facebook, where a community can judge the photos on the criteria whether the litter has been disposed of the right bin.

Figure 19: Bin Cam system

6.3.2 Weight system (Bossard SmartBin Logistiksystem)

SmartBin is a logistic system from the screw distributor company Bossard. SmartBin is a logistic system for customers of the company Bossard. SmartBin evaluates automatically the amount of screws in a box and orders new stock if needed. The system works with a weight measuring system in the boxes where the screws are kept. Data on weight is sent over wireless or cable to a central computer server from Bossard and gets analysed. This system enables the logistic company Bossard to refill the screw stock immediately when the customer needs a new delivery and it enables the customers to reduce production stand time and to observe and calculate the amount of used screws (C parts) more efficiently (Bossard, 2006). In Figure 20 on the left side the whole logistic process cycle is illustrated and on the right side an illustrated 3D model of a screw storage station with screw boxes, weight measuring systems under the boxes and a wireless station is shown.

Figure 20: Bossard SmartBin Logistiksystem (Bossard, 2006) and (Smartes C-Teile Management mit Bossard SmartBin, 2013)

The usage of a weight measuring system in comparison to an online data analysing system from the SmartBin could also be integrated in a waste control and measuring system. It could help to optimise the waste management.

6.3.3 Innovative waste bin concept

The company Leafield environments is an innovative premium waste and recycling bin manufacturer. They have designed a special waste and recycling bin for Universities (shown in Figure 21) in the UK. This bin has a big recycling section and a small general waste section with a separate lid. The lid has the function of creating a barrier that makes users reflect on their actions before they open the lid to throw in their litter. The green big recycling section promotes an increase of recycling disposal. Coventry University is testing this bin at the moment. The tests brought out, that as a result of these bins the rate of recycling has increased 10 to 15% with a total contamination of 5%. According to the Interview, the contamination of 5% is still acceptable for the recycling companies. In Mrs Fletcher’s opinion this bin shows a great result but there is still room for improvement because in the general waste section a high amount of recyclable material, approximately 50%, is still found.

Figure 21: Waste and recycling bin for Universities of the company Leafield environments.

6.4 Sustainability research

The sustainability research section focuses on different recyclable materials and how they can be collected and used. For this section the focus is on household waste and recycling.

6.4.1 What household waste can be recycled?

Before we talk about designing a waste bin we need to define waste. What is waste? Waste is typically defined as something dirty and useless. But we should move away from this idea to see waste as a useful resource. When we talk about useful resources we need to know what these useful resources are and how we can collect them. This section focuses mainly on the 3rd R from the 3R's (recycling). But what materials can be recycled and how can the materials be identified? In 1988, SPI invented their "resin identification coding system for plastic". This coding system was expanded in 2008 in cooperation with ASTM international (SPI, 2013) to include other materials beside plastics. The following section does not cover all recyclable materials. It mainly focuses on materials found in household waste.

6.4.1.1 Paper / cupboard / carton

20 = corrugated cardboard
21 = other paper
22 = Paper

Figure 22: Recycling signs for paper and cardboard (tabelle.info, 2012)

In household waste paper and carton constitutes the biggest amount of all recyclable materials. Between 2009 and 2010 around 1'300'000t were recycled in England. In the paper recycling process, paper gets sorted and shredded to small papercuts. The papercuts get washed in water and cleaned of plastic and stapler clamps. The paper is processed into a mush and gets pressed in a machine to make new paper. After the drying process the paper gets rolled to form larger paper rolls (Following the Paper Trail, 2010). One tonne of recycled paper uses 64% less energy, 50% less water and 74% less air pollution for the production compared to virigin paper. One tonne recycled paper saves 17 trees (Granata, 2013).

6.4.1.2 Metal

40 = Steel
41 = Aluminium

Figure 23: Recycling signs for Metal (tabelle.info, 2012)

Mainly steel and aluminium can be found in household waste. Steel and aluminium are perfect for food packaging and often not reusable. Approximately 85'060t of cans got recycled in England between 2009 and 2010 (www.gov.uk, 2010).

6.4.1.2.1 Steel

Steel found in household waste was used for food packaging. Steel is a material that is 100% recyclable. In comparison to new steel, recycled steel saves 74% energy. One tonne of recycled steel saves 1.2t of steel ore, 0.7t of coal and 1.5t of limestone. (UMassAmherst, 2006)

6.4.1.2.2 Aluminium

Aluminium in household waste is used as packaging and to produce drink packaging. Aluminium is 100 % recyclable and in comparison to new aluminium, saves in the production, 95% energy and 95% air pollution (UMassAmherst, 2006)

6.4.1.3 Plastic

1 = PET / PETE
2 = HDPE / PEHD
3 = PVC
4 = PE-LD
5 = PP
6 = PS
7 = all other plastics

Figure 24: Recycling signs for plastics (tabelle.info, 2012)

A big challenge in plastic recycling is the sorting process of different plastics. While the metal sorting process is easy because of the different properties like colour, density and magnetic attributes, in plastic sorting such attribute do not exist. Plastic can have any colour and overlay in density and properties to other properties (Mike Biddle: Wir können Kunststoff recyceln, 2011). To make this sorting process simpler, SPI invented 1988 a “resin identification coding system” for the most popular plastics in the household waste. In the period between 2009/10 approximately 80’360t of plastic from the household waste got recycled in the UK (www.gov.uk, 2010). But an article of EROP (European Association Of Plastic Recycling) in 2012 shows that 2012 the UK still landfilled approximately 63% of all plastic waste (EPRO, 2012). Modern plastic recycling centres can sort all plastics to 95% (the 5% rest needs to be sorted by persons). In Austria there is a modern plastic sorting recycling centre where approximately 50% of the plastic materials gets recycled, 48-9 % goes to a cement factory and 1-2 % gets burned in incineration plants (Schweizer sind keine Recycling-Weltmeister mehr, 2012).

6.4.1.4 Glass

70 = Glass without colour
71 = Clear glass
72 = Green glass
73 = Dark Sort Glass

Figure 25: Signs for glass recycling (tabelle.info, 2012)

Glass is 100% recyclable and doesn’t lose any quality during the recycling process (Glas Recycling, 2011). The household glass collection only collects glass bottles and jams. It does not collect mirrors, windows and high temperature glass. The problem with other glass like windows, mirrors and others is, that the quality can not be controlled. Some of them are coated with special layers or have special temperature properties (Abfallwirtschaft Glas, 2012). The Grocery Retail in the UK sold 2012 1’873’045 tons of glass packaging. 2012 the glass flow in packaging was 2’753’500t and the recycled 1’626’587 tonnes glass back. That is a recycling rate of 59% (Wrap, 2013).

6.4.1.5 Batteries

Commercial batteries are made out of many highly toxic heavy metals, which are a serious problem for the health of biosphere. Typical household devices like radios, toys and portable devices are powered with batteries. Statistics shows that in 2012 still approximately 72.3% of all portable batteries went to a landfill (Environment Agency UK, 2013).

6.4.1.6 Textile

60 = Cotton
61 = jute

Figure 26: Signs for textile recycling (tabelle.info, 2012)

The main aim of textile collection from households is to reuse them. Clothes get collected, sorted and shipped to developing countries. In the developing countries the clothes get sold again. The clothes which can not be reused because of its poor quality get a second life as cleaning towels in industry (How Textile Recycling Works..., 2011).

6.4.2 Household waste collecting system

England has many different waste and recycling systems for household waste. Usually the city council is responsible for organising and defining the waste-collection system. Some councils collect many different recyclable materials (single-stream), others only collect general waste and mixed recycling and another group does a combination of both. XXX has shown that in general there is no optimal recycling system for the whole of the UK. Every area has different requirements and opportunities. But the article pointed out that a mixed recycling usually increases the amount of collected recyclable materials, but also decreases the quality of the collected materials (WARP, 2009).

7 Specification

For this research, the following bullet points provide specifications for a waste and recycling bin system for Coventry University:

- The product price for a standard waste and recycling bin can be fixed between £100 and £250 depending on the used material, complexity and the size of the waste and recycling bin.
- The product development of a high quality waste and recycling bin needs to follow sustainable principles in the design. If possible recycled and recyclable materials should be used in the production.
- To simplify the cleaning and maintenance of the bin, the material used should be robust, resistant and easily cleanable. If possible edges should be designed round, which greatly simplifies the cleaning.
- The waste and recycling bin needs a minimum of a mixed recycling and a general waste section.
- The waste and recycling bin needs to be modular and expandable to meet future requirements. Trends show that it would also be good to make a food section.
- The colour for general waste should be black and for mixed recycling green
- The waste and recycling sections needs to be close together.
- A weight measuring system for the bin could give Universities a good tool to improve the waste stream management.
- To implement of a bin Cam could be used to monitor the frequency bins are used by students, which would be a second waste management tool.
- To increase the attractiveness for recycling for he 70% of the students who are interested in recycling, prominent signs with clear and understandable labelling should be established.
- To attract the 30% of the students who care less about recycling, the mixed recycling needs to be promoted and the general waste needs a barrier.

8 Conceptual design

The conceptual design phase follows 4 steps. In the first step the collected Information gets ordered in a design idea wall. In the second step the first design ideas get worked out with the help of a morphological box. In the third step a Pugh's matrix helps to compare the alternative designs and evaluate the best solution for the future development. And in the last step the final concept gets worked out. This report can not show all generated ideas but will focus on 3 different solutions which best illustrate the designing process.

8.1 Step 1: Sorting information

8.1.1 Design idea wall.

In research, information and ideas came together. Therefore, the first step was to sort the gathered information and ideas and combine them on a Design wall with a mind map character. The design wall expanded during the whole designing process. This helped to structure research information during the whole designing process. In Figure 27 the final Design idea wall is shown which grew over the whole design process.

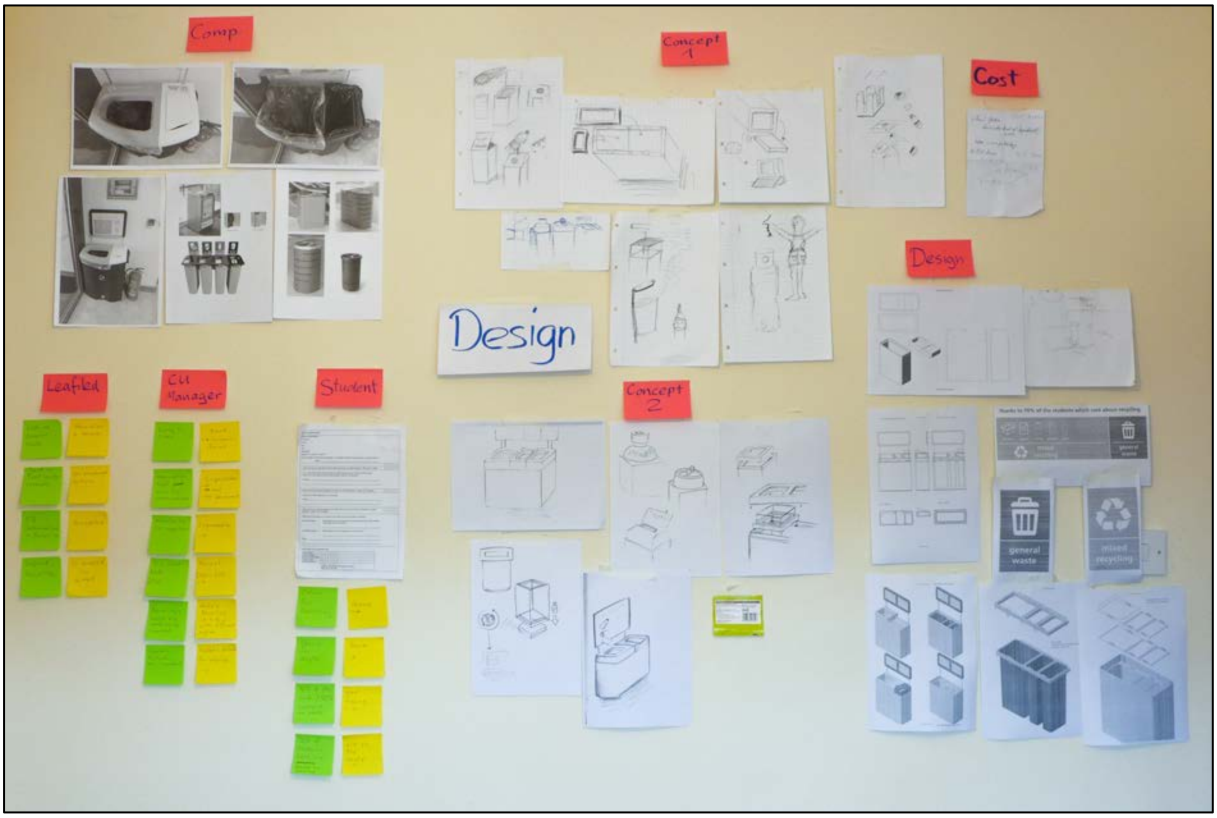


Figure 27: Design wall.

8.1.2 morphological box

With the structured ideas and information from the design wall, a morphological box (shown in Figure 28) helped to find innovative and customer orientated solutions, which are shown in the following section.

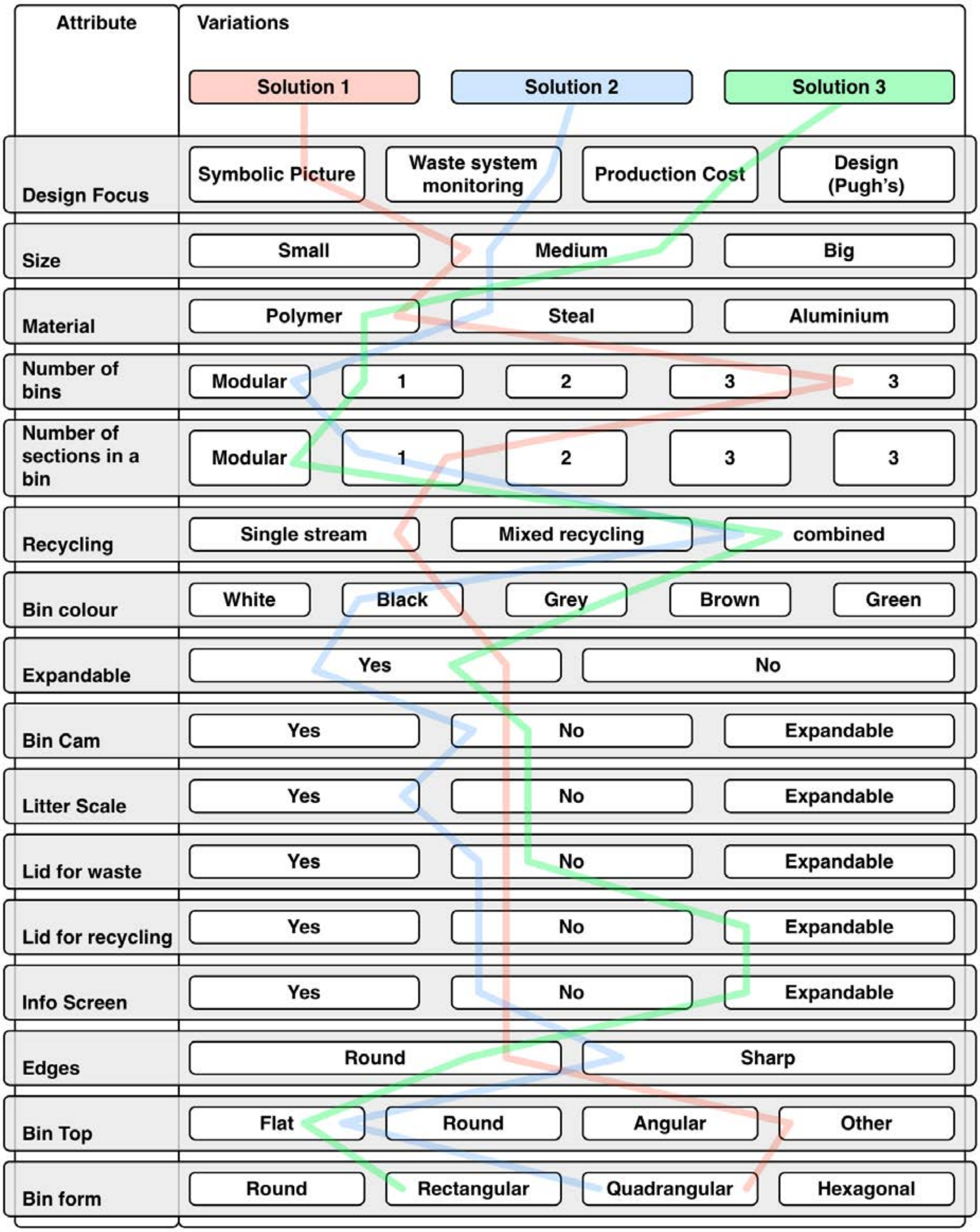


Figure 28: Morphological box.

8.2 Step 2: different solutions

In the following section the evaluated solutions from the morphological box are presented and explained in more detail.

8.2.1 Solution 1:

The first solution mainly focuses on the idea of creating a symbolic picture, understandable by a multi-national community. The idea is to design a waste and recycling bin associated with the design of bins, people already use and so are familiar to them (illustrated in Figure 29). The bin should motivate those students who are not usually concerned about recycling to recycle more. In the discussion with the sustainability officer it was evident that most recyclable waste at Coventry University consists of paper/carton, plastic bottles/packages and cans. Thus this bin system includes four separate single stream recycling collection bins, which can be arranged to ones own needs. They could be placed in a row on a wall or arranged in a square in the middle of the room.

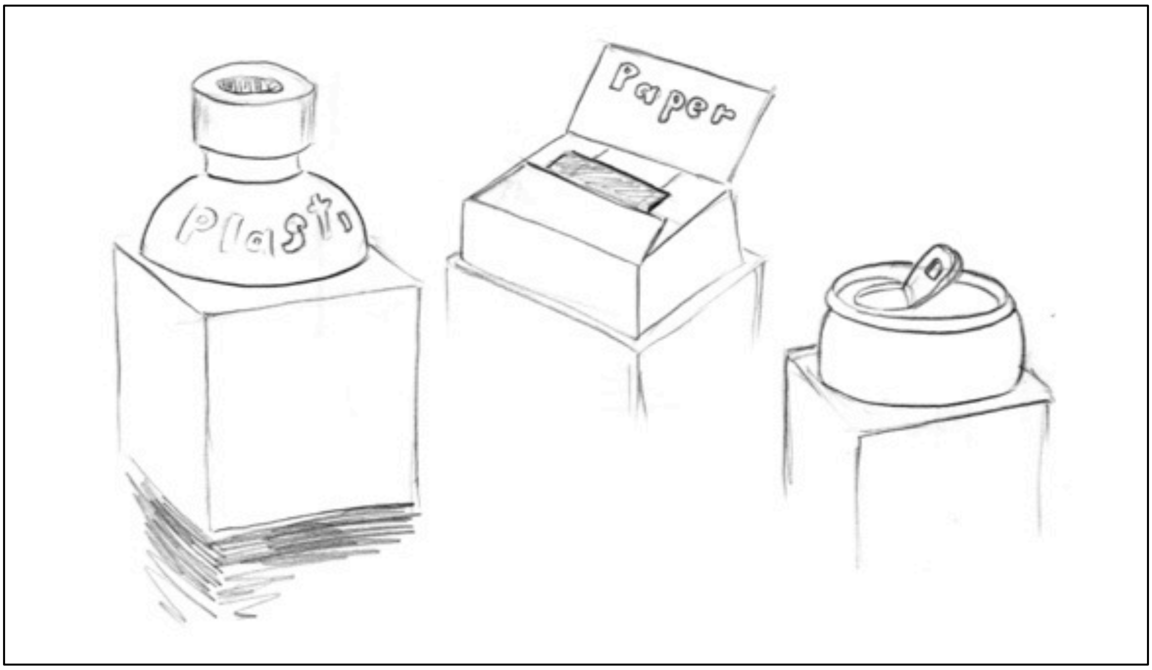


Figure 29: Concept design Solution 1.

8.2.2 Solution 2:

The second solution mainly focuses on waste stream monitoring. The bins should give universities a specialised tool to continually monitor and improve the waste stream. To accomplish this, the idea from the screw distribution company was adapted for a waste bin. Every bin would have a separate scale on the bottom which would transmit data to a server via wireless connection (illustrated in Figure 30). More bins could be combined to the individual needs. In the example of Coventry University, a general waste bin could be placed next to a mixed recycling bin. Every bin would have a scale under the bin and would transmit the weight individually to a server.

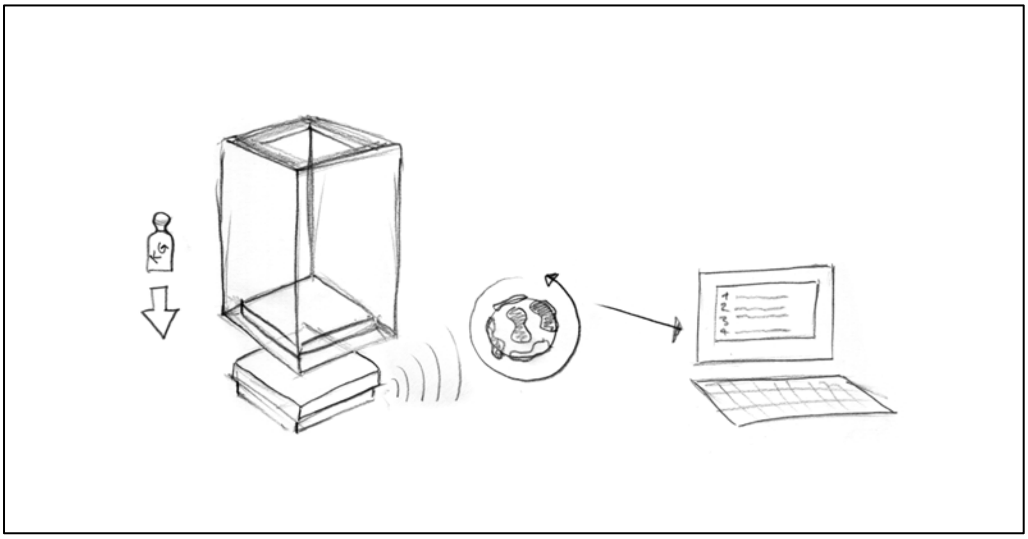


Figure 30: Concept design solution 2

8.2.3 Solution 3

The third solution mainly focuses on the cost factor for an optimised and sustainable waste bin. For universities, it is important to have a tool which is expandable, modular, easy to clean (round edges), and low cost. To achieve these needs this bin uses the idea from landfill by having only one large bin with a set of changeable tops and lids. On one hand this makes the bin modular and on the other hand they are much cheaper to produce (Sketched in figure 31).

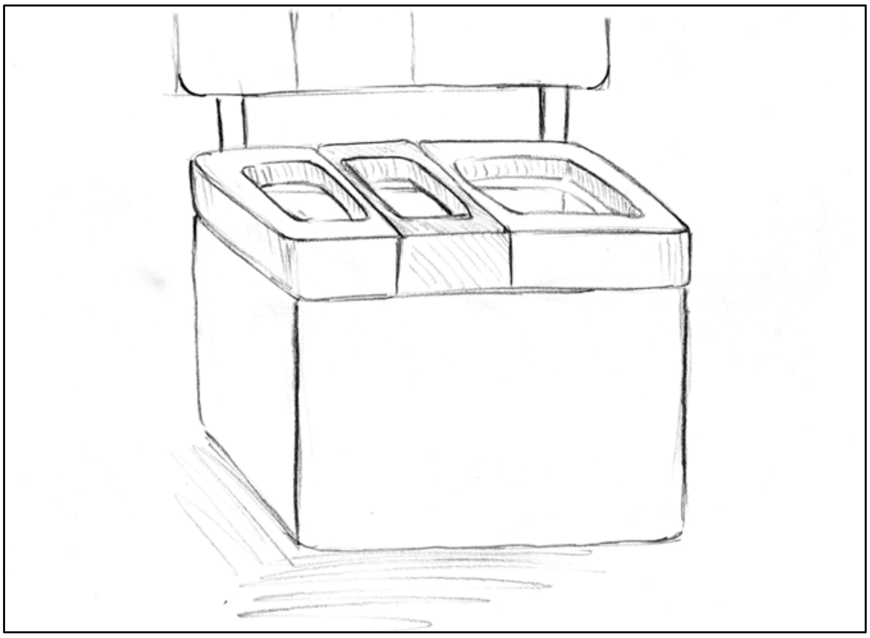


Figure 31: Concept design solution 3 - multiple tops and lids.

8.2.4 Solution 4

The fourth solution integrates the main benefits from solutions 2 and 3 (illustrated in figure 32). This solution: 1) specifically informs users what goes in which bin; 2) includes an expandable weight-measuring system for long-term and short-term waste stream observations; and 3) costs less to produce than versions with separate bins for each waste stream. The strategy is to develop a basic version of a bin which can be modified with tops, lids and a weight measuring system.

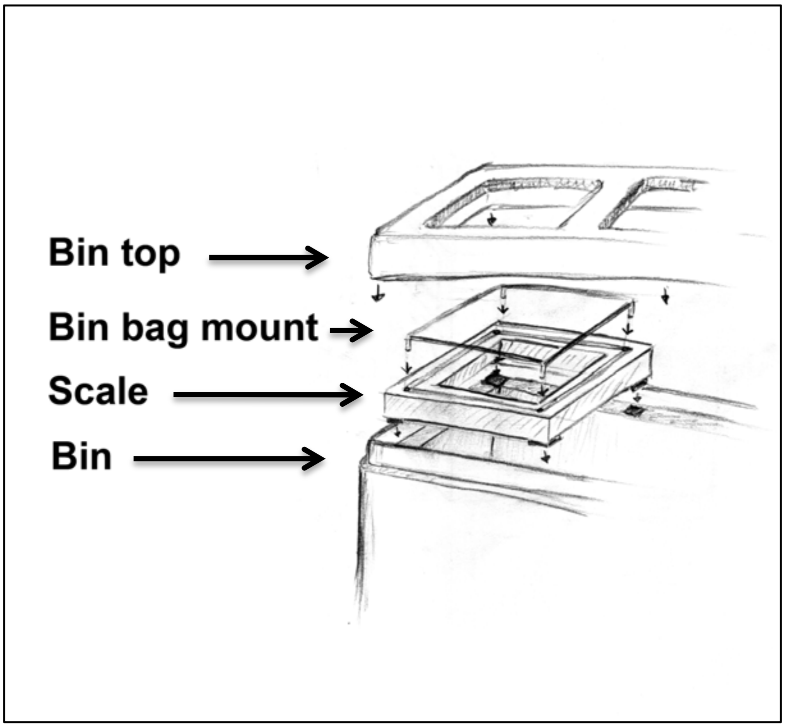


Figure 32: Concept design solution 4.

8.3 Step 3: compare alternative designs

To compare the different solutions with each other a Pugh matrix helped to make subjective observations more objective (Curedale, 2013). The Pugh matrix is a criteria based decision matrix that can be used as design tool and was developed in 1977 by the person who developed Pugh's model of total NPD. Pugh's matrix ranks the different solutions with a positive, negative, or a neutral (S) number for different criteria and gives a positive, neutral, or negative total number at the end. This total number establishes a first impression about the quality of an idea. This technique of ranking has its limitation in that the criteria do not have the same weight of importance relative to each other. For example, for a university, the initial cost factor could be more important than the maintenance.

Criteria	Solution 1	Solution 2	Solution 3	Solution 4
Functionality	S	1	1	1
Cost	-1	-1	1	1 / -1
Aesthetics	S	1	S	S
Manufacturability	-1	1	1	1
Maintenance	-1	S	1	1
Expandable	1	1	1	1
Complexity in the production	-1	S	1	1 / -1
Modularity	2	2	1	1
Stability	S	S	1	1
Total	-1	5	8	8 / 6

Table 4: The Pugh's matrix.

Solutions 3 and 4 show the best results in the rating of the Pugh's matrix. While the basic version of solution 4 delivers the same result as solution 3, solution 4 also delivers the option to include more advanced tools which can be implemented in the bin either temporarily or permanently.

For the next design step, shows the best opportunities for solution 4. It combines a clever expandable waste bin system from solution 3 with innovative features from solution 2.

8.4 Step 4 Workout Final Concept

For the final concept, other aspects also went were also considered.

In the standard configuration, the final concept uses an oblong form for the bin (shown in solution 3 and 4) with a large mixed recycling container on the right and a small general waste container on the left (illustrated in Figure 33 on the left side).

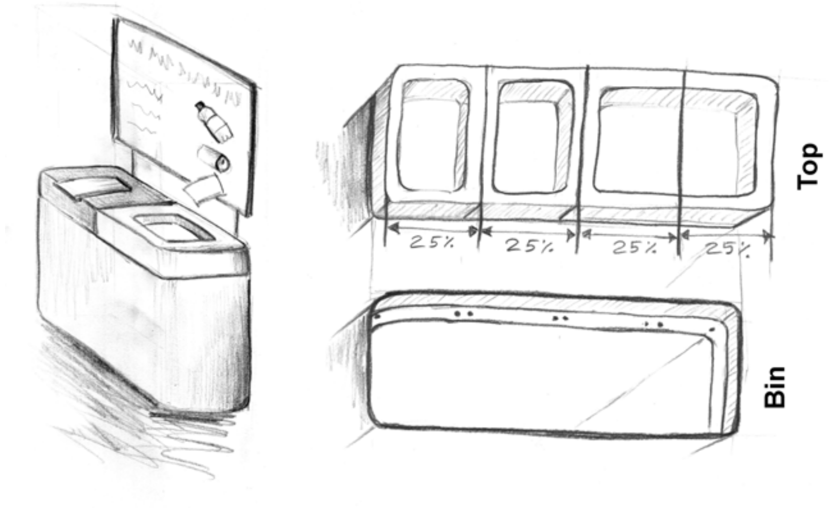


Figure 33: Waste and recycling bin concept design.

Bin Collection: The result of the research showed that a sustainable waste bin needed to be modular and expandable. The trend in universities is moving away from a single-stream recycling to a mixed-stream recycling collection. According to the information from the Coventry University sustainability manager Mrs Selina Fletcher, a massive mixed recycling section and a lid on the general waste section shows a good result and motivates students to recycle more. At the moment a separate food waste section is not required by law but probably will be demanded in the future. According to the interview with Garry Mills, Scotland has introduced a new legislation in 2014 that all food waste needs to be divided from landfill. The implementation of a separate food waste collection at Universities generates higher costs and a more complex collecting system. According to Mrs Selina Fletcher due to these higher costs and the fact that other environmental issues currently need more attention, it makes no sense to start to collect food waste at the moment.

But it is necessary to offer new products which are flexible enough to meet future needs. The idea is to divide the bin in 25% sections which can also be used as 50% sections (illustration on the previous page from the top view of figure 32). For the standard version of the bin, a 50% mixed recycling section and a 25% general waste section are planned. The remaining 25% section in the basic version will be unused but this empty space provides the opportunity to easily upgrade the bin with a food or other single stream litter section without reducing the effect of a bigger mixed recycling section.

Colour: The body of the bucket will have a single colour and only the lids and tops will show the different colours to specify the different waste types. Two colours, black and grey, were closer considered for the body of the bucket. The colour grey was chosen because many students associate black with general waste, so it is not ideal to use black for the bin. According to the student questionnaire, the bin used at the moment has a green top for the mixed recycling section and a black lid for the general waste.

Signs, labelling and manipulation: An important fact, which came out in the students' survey, the discussion with the students during the Green Week, and the interview the Sustainability manager at Coventry University was that waste and recycling bins need to have easy, clear signing. Signs need to be easily understandable and give a clear and a quick answer to the question "what litter goes in which bin?". On a board above the bin, a sign will clearly explain in written words and pictograms what goes into each bin. On this sign there will also be written "Thanks to the 70% of students who care about recycling". This sentence follows the method of social manipulation/motivation. It should motivate students to recycle more. The idea for this "slogan" comes from the book Yess (Goldstein, et al., 2007).

Good impact for recycling: The fact that the recycling bin section is much larger than the general waste section, already communicates to students and users to recycle more. The idea of the company Leafield to mount lids on the general waste container, but not on the recycling container, intensifies this effect. The design of the waste bin in this project will also include a lid on the general waste section. This lid may result in a slightly more contamination in the recycle section, but it force the 30% of the students who care less about waste separation to throw most of the litter in the right recycling bin. For the other 70% of the students who care about recycling, but may not separate their litter because they do not know what litter goes in which bin, a good sign with an obvious and quickly recognisable eye-catching symbol is important.

8.4.1 Expandable features which will not be included in the basic version

In the discussion with the Coventry University Sustainability Manager, it was evident that at the moment the University needs a fast, economical, and expandable solution for a waste bin. In her opinion, extra features like the weight measuring scale system for a permanent observation make no sense. But she would see an opportunity to install such a system for a period of time in order to optimise the waste management. Also the bin Cam could be a useful system to show students what is dumped in the general waste over a day, thereby convincing them that their answers in the questionnaire on what and how often they recycle are not accurate. A screen could be placed on the board above the bin. Both of these systems are specialised tools which would not be produced in large quantities and which would need a separate, more focused development. The scale and the bin Cam system would influence the design by offering the ability to install them later or temporarily in the bin.

8.4.1.1 Weight measuring scale

Inside the bin, a mount for a scale system needs to be considered. The scale system must be able to measure the weight from the recycling and the general waste section separately. To do this, the idea is to mount a ring between top and bin, around the bin bag, where the scale measuring system will be placed (shown in figure 31). The idea is to put a scale ring inside the bin for every collected waste section and measure individual weight from every waste and recycling section separately.

Bin cam

The bin Cam could be useful for waste prevention and helps to increase the habit of recycling at high visibility and high use spots. The idea is to take photos from the inside of the general waste bin after every use and display them on a screen behind the waste and recycling bin. How this installation can be used in the most effective way should be considered in another project. The bin Cam would require an extension of the design with completely individual development, and so will not be covered in this work.

9 Detailed conceptual Design phase

Before the conceptual product idea can be transferred to a detailed design the materials and the manufacturing processes need to be defined and a detailed concept design with a cost estimate needs to be done. The material and the manufacturing process selection define the detailed concept design and especially the detailed final design. For example a metal waste bin needs a completely different design than an injection molded plastic waste bin.

9.1 Material selection process

The material selection is divided in two parts, a general selection and a detailed selection. For the material and manufacturing process selection, information from the Sustainability research and the interview with the Coventry University sustainability manager are important. For the sustainability manager, the acquisition price, the durability, and the maintenance (easy to use and easy to clean) of a waste bin are important factors. The sustainability perspective demands a long durability and eco-friendly materials.

9.1.1 Material selection step 1

In the first step of the material selection, the most used group of materials are defined. The material requirements for the waste and recycling bin are:

1. The material needs to be able to be formed into round edges for easy cleaning
2. Low costs for raw materials and product manufacturing
3. It needs good resistance against water, salt water, oil and in general chemical liquids, common in university waste streams.
4. High stability and durability
5. The material needs to be recyclable
6. If possible, the production be manufactured with recycled materials. At this point in the material selection a compromise between a long life cycle and ecological materials needs to be done.

Selection:

The selection is done with the help of the program CES Material selector (Granta Design, 2013) and some literature. CES is a program from Granta design (a spin-out company from Cambridge University). The program can generate graphs (examples are shown in Figure 33 and 34) which helps, to select the right material for the production. The shape, corrosion resistance, and cost requirements lead to the decision to use a thermoplastic in the production.

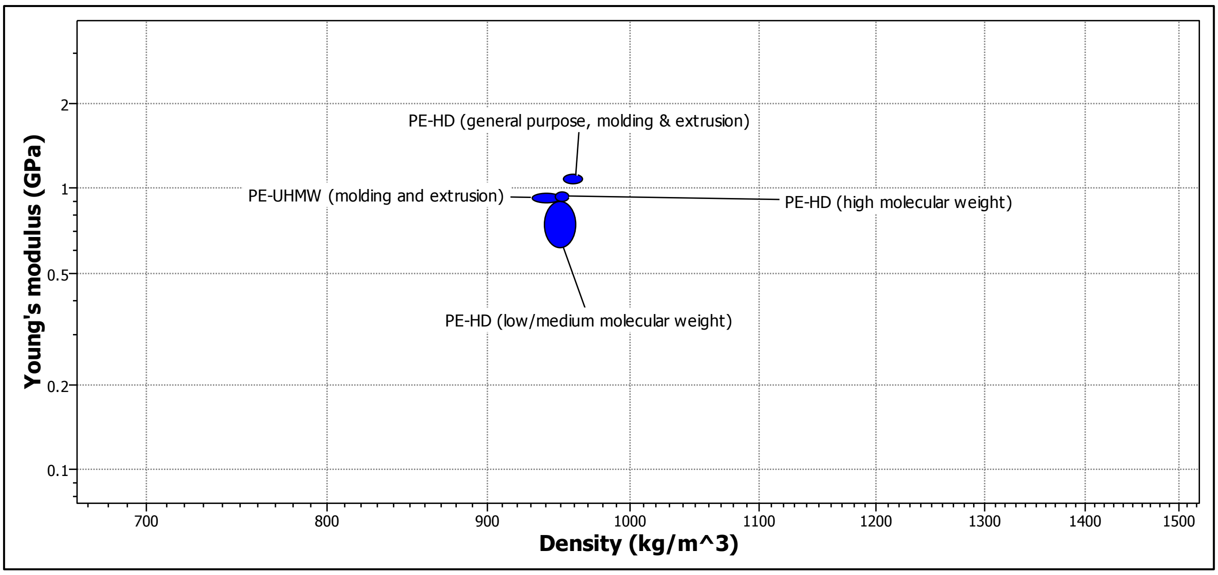


Figure 34: Material selection CES Material selector graph: Young's modulus / Density (Granta Design, 2013).

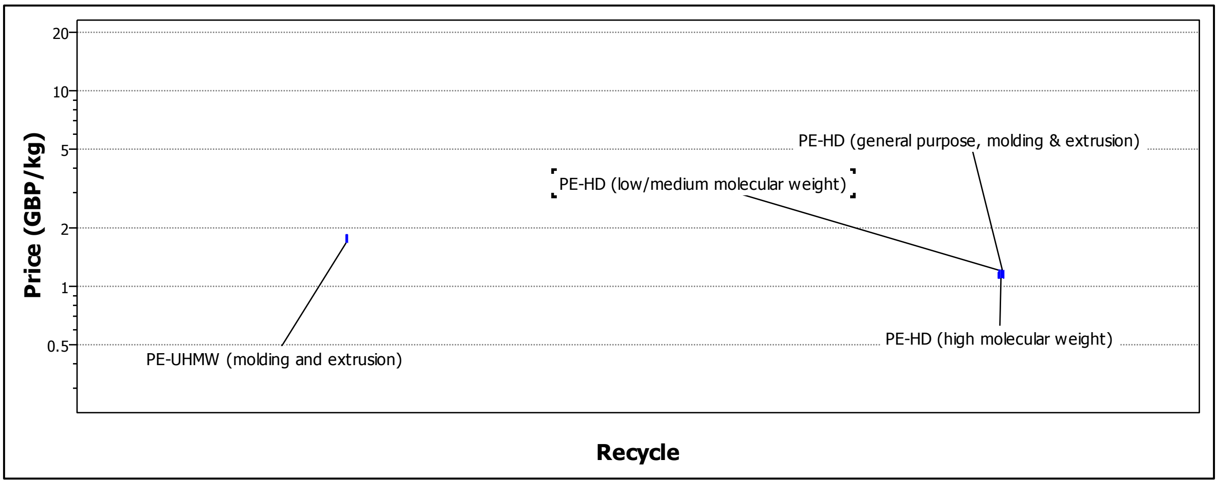


Figure 35: Material selection CES Material selector graph: Price / Recycle (Granta Design, 2013).

The graphs from the program CES (Granta Design, 2013) shown in Figures 34 and 35 helped to find the perfect material. The final decision was for Polyethylene (PE), since it is the most common polymer for rotational molding, is inexpensive, provides good chemical resistance, and is easy to shape (Paul DeGarmo, et al., 2003:150). Furthermore the material has good recyclable properties, which promote sustainable recycling after the end of the product lifecycle.

9.1.2 Detailed material selection

PE is not a specific material but a whole family of materials. The most common members of this family are LLDPE (Linear Low-Density Polyethylene), LDPE (Low-Density Polyethylene), MDPE (Medium-Density Polyethylene), HDPE (High-Density Polyethylene), XLPE (Cross-linked Polyethylene) (Beall, 1998:25).
All these different PE's have different properties which influence the manufacturing processes, either positively or negatively.
The final decision as to use HDPE (High-Density Polyethylene). HDPE provides a good strength to density ratio, is very corrosion resistant, provides good properties in the production, and in general is a durable (Granta Design, 2013).

9.2 Manufacturing process

The final manufacturing process selection is directly related to the material selection. These two sections were developed with the help of Prof. Phil Swanson, based on the manufacturing technologies lecturer at Coventry University.
Injection molding and rotational molding were both considered.

9.2.1 Injection Molding

Injection Molding is a process to manufacture solid plastic components with a hot and liquid polymer, which is forced to flow under pressure into a mold where it solidifies. Injection Molding produces discrete components which are almost always net shape. The production cycle time is typically between 10 to 30 seconds for small parts and one minute or longer for larger parts. With Injection Molding it is possible to produce complex and intricately shaped plastic parts. But the big challenge is to fabricate a mold whose cavity is the same geometry as the part and allows an easy removal of the parts after the solidification. The produced sizes of parts can range from 50 g up to 25 kg. Injection molding is economical only for larger production quantities because it needs a complex and expensive mold (Grover, 2013).

9.2.1.1 Process

The four following figures illustrate the manufacturing process. The process starts in Figure 36 in step (1) with closing the mold with high pressure. Then in step (2) the liquid plastic gets pressed into the form. In step (3) the injected part gets solid and in step (4) the mold unloads the injected part. The sprue and runner will be removed later (Grover, 2013).

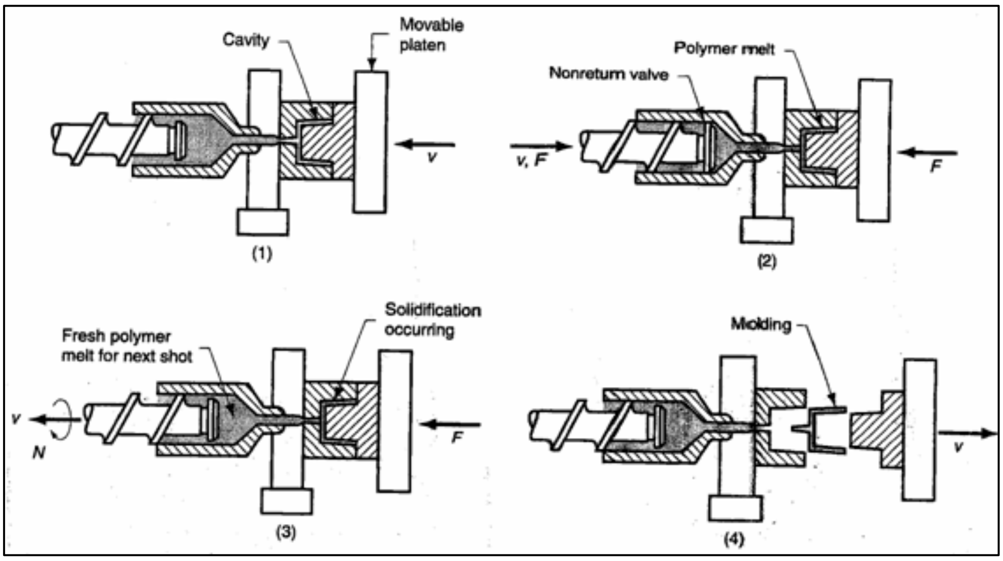


Figure 36: Principles of injection molding (Sinotech, 2014).

9.2.2 Rotational molding

Rotational molding uses the earth gravity in a rotating mold to produce a hollow form. It is an attractive alternative to blow molding and injection molding. Rotational molding is appropriate for simpler geometries, larger parts, and lower production quantities. In comparison to injection molding, the molds are much simpler and inexpensive, but the production cycle of the parts takes much longer. The production cycle for bigger parts in Rotational molding can take 10 minutes or more. To balance these advantages and disadvantages in production, rotational molding usually uses a rotation system with 3 or more arms. In figure 37 a three-arm rotational molding machine is illustrated where in (1) the molds get unloaded and loaded, in (2) the molds get heated and in (3) the molds get cooled (Grover, 2013).

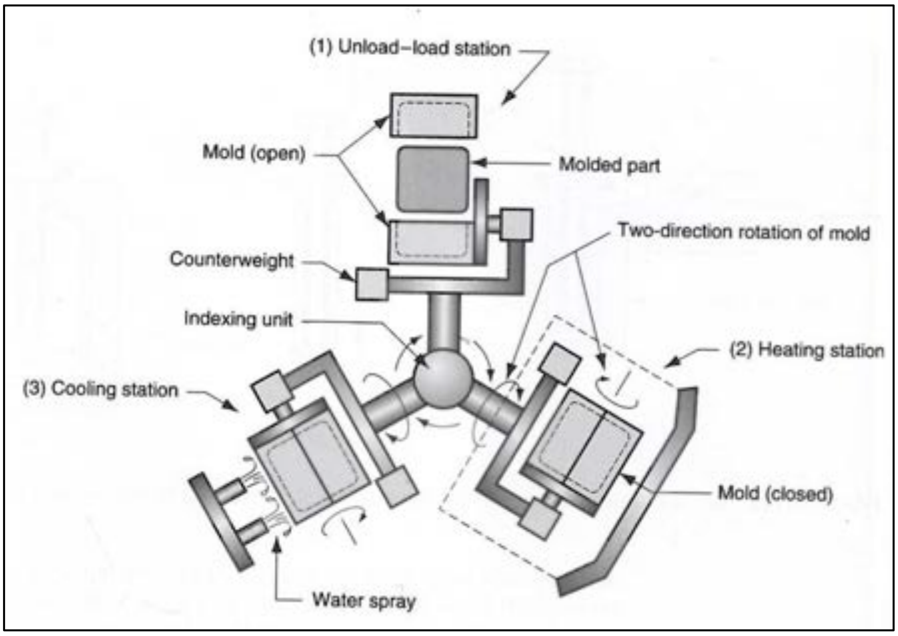


Figure 37: Three-station Rotational modling machine (Grover, 2013).

9.2.2.1 Process

Rotational molding involves 4 steps (illustrated in figure 38). First (a) a predetermined amount of polymer powder is loaded into prepared mold. Second (b) the mold gets heated in a chamber which is approximately 375°C and simultaneously rotated on two perpendicular axes. During this process the polymer power melts in the mold and gradually forms a fused polymer layer of uniform thickness. Third (c) the mold cools down and still rotates on the two perpendicular axes. Fourth (d) the mould gets opened and unloaded (Grover, 2013).

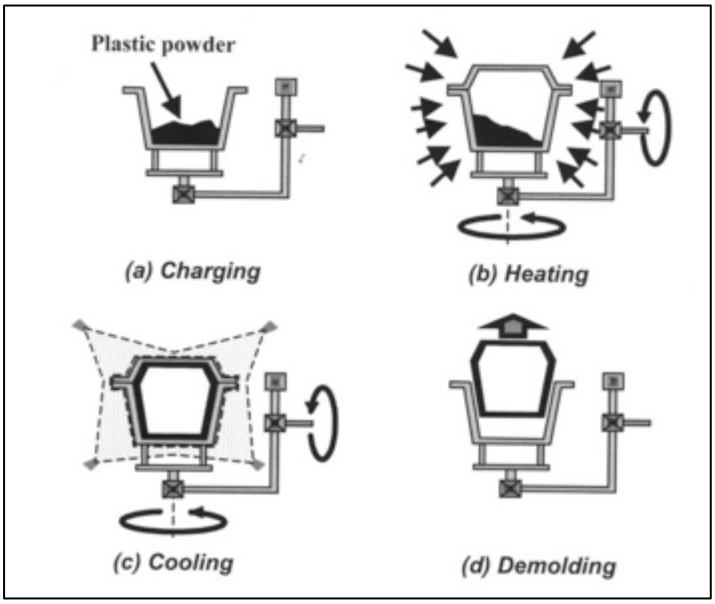


Figure 38: Principles of Rotational molding (Grover, 2013).

9.2.3 Final Manufacturing process decision

The decision for the final manufacturing process was to use Rotational molding. Rotational molding delivers a higher quality, is more flexible in the design, and costs less in a small to medium value production then injection molding. To use Injection molding could make sense if the waste bin was produced in a high value product. But even then the advantages of a less stressed material is not to be underestimated. Rotational molding stresses the material less than injection molding, which results in better quality.

9.3 Detailed design

Designing plastic components is much more complex than designing metal components. In most designs of metal parts, there is no need to consider the effects of time, temperature or environment. But for plastic, it is different. To ensure a high quality in the design, this project follows the design guideline of the British Plastics Federation (Maier, 2004). The final design is presented in the conclusion in chapter 11 and illustrated in Figure 41. Additional figures are shown in the appendix.

10 Cost estimation

The cost estimation process is an important phase in NPD, which minimises the risk that a new product is not competitive in the existing market. A cost estimation in this early phase can deliver a first idea of how much a product can cost but does not guarantee its accuracy. In manufacturing, the cost estimation process is usually built on a company's internal experience over a long time, and is well guarded by the company (i.e a Trade Secret).

The detailed conception design focuses as much as possible on the requirements of rotational moulding. But this optimisation does not mean that it can be produced as it is designed. In rotational molding, the mold design, which in turn influences the design of the product, is often done by a trial and error method. A rough estimation of labour time, working time, and tooling time just focuses on the dimensions and not on exact geometries and details. For this study, all cost estimates are in Pounds (£). The details of these estimates are given below.

10.1.1 Mold parts Cost calculation

In this section the costs for the Rotational molded parts are estimated. The estimation process involves a material cost, a mold cost and a production cost estimation for the molded parts. Cost was calculated based on the following: 1) product costing guidelines (Lovejoy, et al., 2008:2) information from the CES material selector software-2013 (Granta Design, 2013), reference texts on rotational molding technology (Crawford & Throne, 2002) and product design for manufacture and assembly (Boothroyd, et al., 2011).

10.1.1.1 Material:

The material calculation for the molded parts is done by CES (Granta Design, 2013) and guidelines from the “Rotational Molding Technology” (Crawford & Throne, 2002).

In rotational molding of HDPE (High-density Polyethylene), the material gets delivered in pellets and is then milled to a powder. Table 5 shows the part volume, the amount of material, the material cost, and the grinding cost which makes a powder of the material for the production. The overall material cost for the rotational molded parts in Table 5 is £14.22 per bin.

Rotational molding material Costs per bin and in £:						
Part:	**Material**	**Volume [cm^2]**	**Amount [kg] [1]**	**Material (Row) [2]**	**Grinding [3]**	**Cost £/part**
Sign	HDPE	1138.60	1.09875	1.3405	0.1428	1.48
Top recycling	HDPE	690.60	0.66643	0.8130	0.0866	0.90
Top empty	HDPE	477.20	0.46050	0.5618	0.0599	0.62
Top waste	HDPE	491.60	0.47439	0.5788	0.0617	0.64
Lid waste	HDPE	77.980	0.07525	0.0918	0.0098	0.10
Bin	HDPE	80410	7.75957	9.4667	1.0087	10.48
Total						**14.22**

Table 5: Rotational molded parts material cost estimation.

[1] Based on a HDPE density of ρ = 952–965 g/cm^3.

[2] 1.11–1.22 £/kg (Granta Design, 2013).

[3] 0.13 £/kg (Roy, 2006) HDPE is delivered in pellets but molded from a powder

10.1.1.2 Dimension Information:

For the estimation of mold and production costs, some basic dimensions and geometric information from the parts are needed to make accurate calculations. Basic information on bin dimensions are height, length and width (Figure 38). In Table 6, basic dimensions are listed as well as the volume of the material specified in Table 5. Projected area is marked orange in Figure 39.

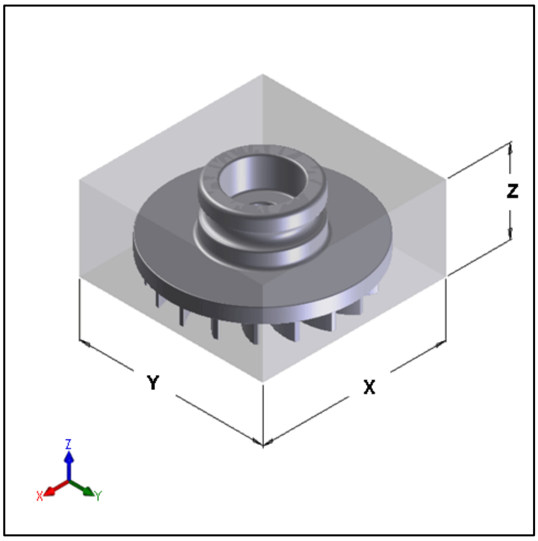


Figure 39: Box dimensions **Es ist eine ungültige Quelle angegeben.**.

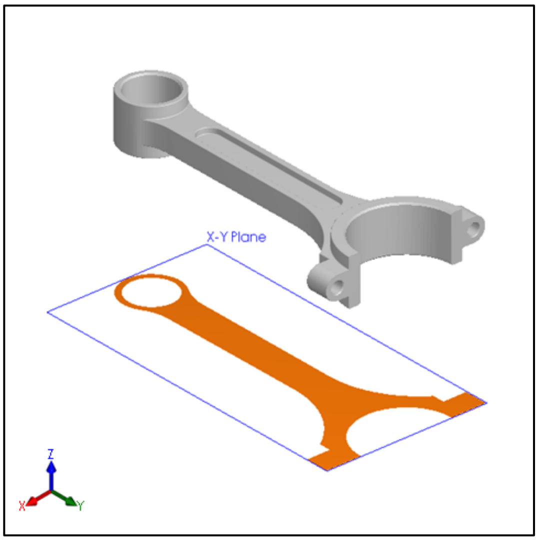


Figure 40: Projected area **Es ist eine ungültige Quelle angegeben.**.

Dimension Information:					
Parts	**Box dimensions [mm]**			**Projected area [cm^2]**	**Volume [cm^3]**
	X:	Y:	Z:	Ap:	V:
Sign	700	300	40	2089.3	418
Top recycling	400	300	115	427.1	85
Top empty	270	300	115	549.3	110
Top waste	220	300	115	275.8	55
Lid waste	140	268	10	374	75
Bin	700	300	700	2092.7	8041

Table 6: Rotational molded part dimensions.

10.1.1.3 Mold production Cost

In the guideline (Lovejoy, et al., 2008), cost estimates for rotational molds is based on the cost estimation method for molds used in injection molding. In reality rotational molding and injection molding use different production technologies for the molds. But because this early cost estimation uses simple geometries in the calculation, the results are accurate enough for a first order estimate the production price. From Table 7, the mold cost is given, based on the mold base cost, the mold machining costs, a mold complexity cost and a mold size cost.

Mold costs per mold and in £:					
Parts:	**Mold base cost**	**Mold machining cost**	**Mold complexity cost**	**Mold size cost**	**Total Mold Cost**
Sign	4387.42	2285.44	351.83	211.52	81433.08
Top recycling	4211.48	1033.32	412.44	247.96	16883.53
Top empty	3272.81	1171.86	293.36	176.37	19857.97
Top waste	2911.78	830.36	475.02	285.58	10933.03
Lid waste	1201.39	966.95	322.31	193.77	12090.19
Bin	12497.74	2287.30	475.02	285.58	89813.43
Total					231011.23

Table 7: Mold production cost estimation.

The formulas used to estimate mold costs were:

Mold base cost in £ based on (Boothroyd, et al., 2011:349)**.**

$$C_b = 1000 + 0.45 \cdot A_c \cdot hp^{0.4} \cdot 0.6012" \quad (1)$$

Mold machining cost £:

$$M_c = 2.5 \cdot Ap^{0.5} \quad (2)$$

Mold complexity cost £:

$$M_x = 2700 \cdot (0.08 + 0.02\ S_P)^{1.27} \cdot 0.6012 \quad (3)$$

Mold size cost £:

$$M_{po} = 300 + 120 \cdot (Ap/6.452)^{1.2} \cdot 0.6012 \quad (4)$$

where A_c is the area of mold base cavity plate [cm^2], A_p is the projected area [cm^2], h_p is the combination of thickness of cavity and core plates in mold base [cm], and S_p is the number of surface patches.

10.1.1.4 Production Cost:

Before the production cost of rotational molded parts can be estimated, the production time needs to be calculated.

Production Time estimate in seconds:					
Part	**Loading**	**Unloading**	**Wall thickness, h= [mm]**	**Heating**	**Cooling**
Sign	10	10	2	21.92	19.68
Top recycling	10	10	2	21.92	19.68
Top empty	10	10	2	21.92	19.68
Top waste	10	10	2	21.92	19.68
Lid waste	10	10	2	21.92	19.68
Bin	10	10	5	24.8	122.98

Table 8: Rotational mold production time estimate.

Table 8 is based on the formulas of (Lovejoy, et al., 2008:30).

H, Heating in seconds:

$$H = 20 + 0.96 \cdot h \quad (5)$$

C, Cooling in seconds:

$$C = 60 \cdot 1.7 \cdot (h \cdot 0.039370079)^2/\pi\ \cdot \alpha \cdot 0.093 \quad (6)$$

where the thermal diffusivity coefficient for HDPE is $\alpha = 0.11[mm^2/s]$, (Lovejoy, et al., 2008:18) and h is the maximal wall thickness [mm].

With the estimated production times and the material and mold costs, the total costs for the rotational molded parts can be estimated. This estimate used a 5 arm, rotational molding machine (needs 5 molds) and an overall production of 10000 waste and recycling bins. In the following table, the work, mold, and material costs for 10000 pieces are calculated and broken down to the cost per Item. The rotational molded parts for one basic waste and recycling bin costs in Table 9 are £132 per bin.

Rotational molded parts cost in £.						
Part	**Work cost / piece**	**Work cost for 10000 piece**	**Mold Cost for 5 Arm**	**Material cost for 10000 piece**	**Cost for 10000:**	**Cost per item**
Sign	0.23	2252.89	407165.39	14833.11	424251.39	
Top recycling	0.23	2252.89	84417.66	8996.79	95667.34	
Top empty	0.23	2252.89	99289.83	6216.72	107759.44	
Top waste	0.23	2252.89	54665.17	6404.32	63322.38	
Lid waste	0.23	2252.89	60450.96	1015.88	63719.73	
Bin	1.26	12639.98	449067.14	104754.13	566461.25	
Total					**1321182**	**132**

Table 9: Cost estimation of rotational molded parts.

The formula to estimate the work cost, WC, was adopted from (Lovejoy, et al., 2008)

$$WC = 12 + 5 \cdot n / h \quad (7)$$

where $n = 5$ and describes the number of production arms and h is the maximal wall thickness [mm].

10.1.2 Cost estimation of the other parts

In this section, all other parts that are not rotational molded are estimated. Table 10 shows raw or pre-assembled part costs based on the result of an internet research. A waste bin needs two 15 ⌀ pipes for the sign, some steel bars and C-Parts for the bin bag mount, stickers for the signing and a Floor liner for under the bin.

10.1.2.1 Material Cost

Additional parts Material Costs in £				
Part:	Material	Cost (raw)	Needed per Item	Cost per produced Item
Carbon Steal Pipe 15 ⌀ X 1.2 X 6000 mm	Carbon steal	17.00	2 X 400 mm	2.27
Stainless Steal Round Bar 3mm X 3000 mm	Stainless steel	6.00	8 X 20mm 1 X 1140mm + 2 X 580mm + 1 X 800mm +2 X 410	8.16
Sticker Recycling	Sticker	1.50	1	1.50
Sticker Waste	Sticker	1.50	1	1.50

Sign Printing	Paper	5.00	1	5.00
Floor liner m^2		8.00	1 X 550 mm X 680 mm 1 X 210 mm X 680 mm	4.13
C-Parts			all-inclusive	2.44
Total per Bin				25.00

Table 10: Additional parts material costs estimation.

10.1.2.2 Production Cost

With the estimated material costs from table 10, the production cost of the different parts, which are listed in Table 11, can be calculated. Since these parts only need assembly and simple work, the cost is very small in comparison to the whole product cost. For simplicity, the work costs/hour are the same for all required work and include machine and labour costs.

Additional parts production costs in £				
Production Cost:	**Work time (sec)**	**Work cost**	**Material cost**	**Production Cost per item**
		40£/h		
Part:				
Bin-bag mount big	60	0.67	5.76	6.43
Bin-bag mount small	60	0.67	4.4	5.07
Sticker Recycling mount	20	0.22	1.5	1.72
Sticker Waste mount	20	0.22	1.5	1.72
Sign Printing and mount	20	0.22	5	5.22
Floor Liner	60	0.67	4.13	4.80
Sign	20	0.22	2.67	2.89
Total:		**3**	**25**	**28**

Table 11: Additional parts production costs estimation.

10.1.2.3 Final Cost estimation for the designed waste and recycling bin

In this final cost estimation, the results of the Tables 9 and 11 are combined with an estimation of every cost needed to produce the basic version of the designed waste and recycling bin. The minimal, final selling price will be at £190, which includes all cost (material, production, administration and a minimum revenue of 5%)

Final Product cost estimate table in £	
Cost Parts:	Cost per item
Rotational molded material cost:	14
Rotational molded production cost:	118
Total Rotational molding part cost:	**132**
Additional parts material cost:	25
Additional parts production cost:	3
Total additional part cost:	**28**
Final assembly and packaging flat-rate cost:	5
Total Production cost:	**165**
Administration flat-rate 10%:	17
Revenue 5%:	8
Total Cost	**190**

Table 12: Final production cost estimation.

10.2 End of Lifecycle

As previously mentioned, recycling of plastic is difficult. The many different colours and additives make it nearly impossible to recycle a proper high quality recycled PE for use in all parts. The decision is to use in all parts where it is possible recycled PE and in the remaining parts recyclable PE from virgin material. Depending on the colours of the components, the amount of recycled PE can be vitiate. The focus on the material is to produce a high quality bin with as much recycled material as possible by not influencing the high material quality. To ensure a proper recycling at the end of the lifecycle, the idea is to include a RFID chip on the bottom of the bin with includes detailed material information about every part. This material information offers the opportunity to return the bin, after the end of life, back to the company. The company can use these materials properly and feed the old bin materials directly back into the production without losing quality.

11 Conclusion

11.1 Basic Version of the final detailed waste and recycling bin concept

In figure 41, the basic version of the detailed concept design is shown. It includes a big, green recycling section on the right side and a small, black general waste section with a lid on the left side. It has a large sign with clear and symbolic instructions on a board above the bin, which are illustrated in Figure 42, a basic bin bag mount, shown in Figure 41-2 between bin and top and a floor liner under the bin which encourages people to recycle more (i.e. a greener Footprint). The bin is divided in four, 25% (top view) bin sections which can be used for a 25% and a 50% bin section by simply changing the top and the bin bag mount as Illustrated in the middle of Figure 41-3. The clear signing is done for the 70% of the students who care about recycling but might not recycle assuming that they did not understand the recycling system. The recycling section and the waste section are combined in one container, so that the recycling section and the waste section can never be divided and placed separately in a room. For the 30% of students who do not care enough about recycling, the green recycling section is significantly bigger and placed on the right side to promote recycling. The right side symbolises in social behaviour rules good and the left bad (Goldstein, et al., 2007). Furthermore, the general waste section has a lid which works as a barrier to improper disposal, helping the user to correctly deposit most of the litter in the recycling section. This may result in slightly more contamination in recycling section, which is, according to the Coventry University sustainability manager, still acceptable. For sustainability and a long product life, this bin is produced in a stress free rotational molding. It will be easy to clean and maintain since all edges of the bin are round. All sides of the bin are straight so that the bin can be expanded or combined with a second bin on all sides as illustrated in figure 41-4). Additional details and technical drawings of the bin can be found in the Appendix.

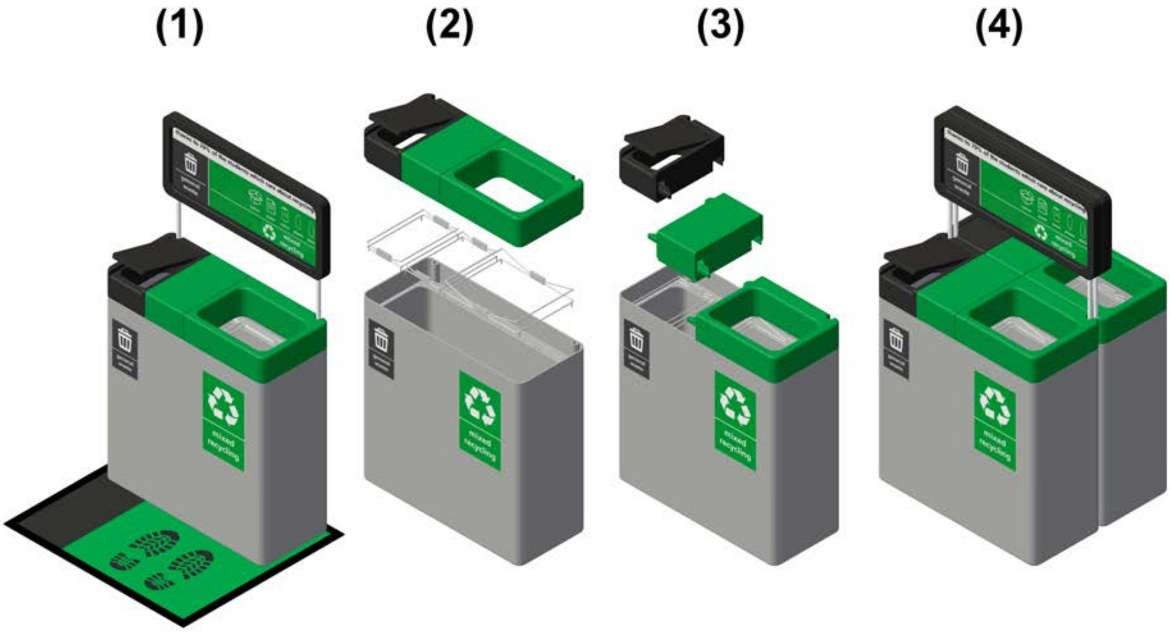


Figure 41: Final detailed concept design of the basic version of the waste and recycling bin.

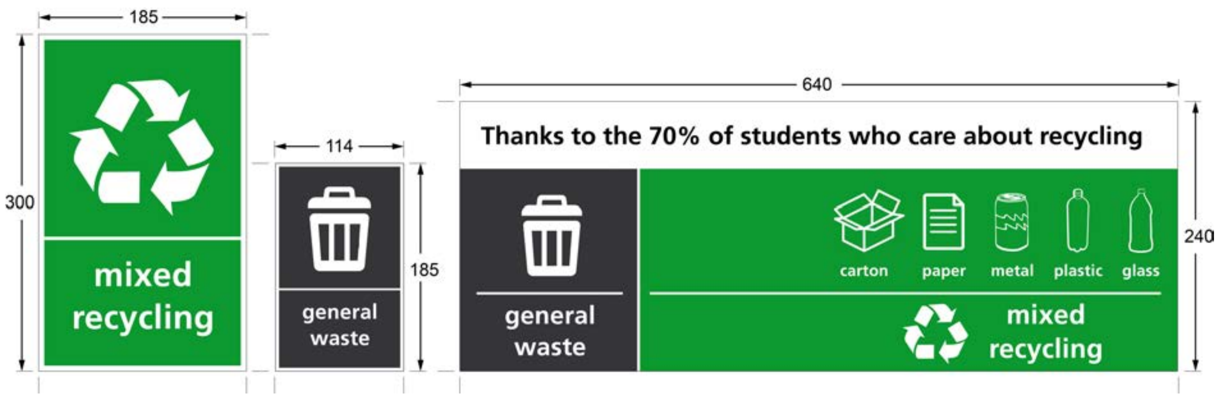


Figure 42: Stickers and signings for the waste and recycling bin [mm].

11.2 Optional expansions of the waste and recycling bin

The designed waste and recycling bin also considers different expansion ideas discussed in chapter 8.4.1. The first is to implement a permanent or temporary weight measuring system, which is shown in figure 43. The weight measuring system includes a scale in form of a ring (shown in Figure 43-4). Some separate waste and recycling bins can be placed into the original waste and recycling bin with the scale rings and illustrated in Figure 43-3.

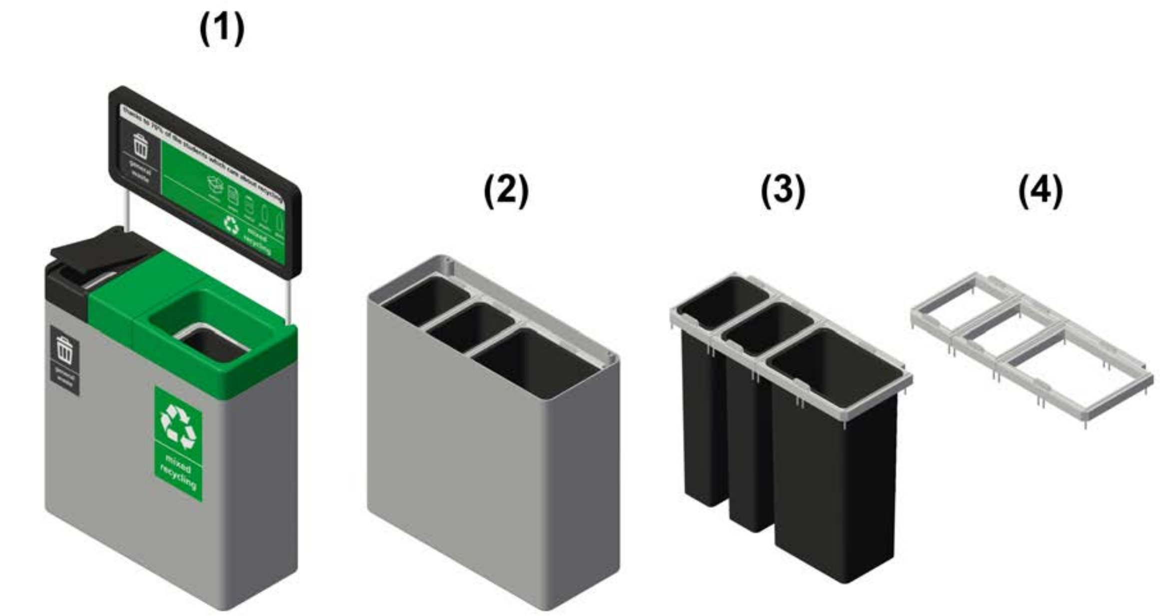


Figure 43: Waste and recycling bin with a concept of a weight measuring system.

While the scale influences the waste and recycling bin in the way of planning some extra space for a scale, the bin cam idea needs no extra design consideration. To implement the bin cam idea, just a specially designed top for the general waste needs to be designed. This specially designed top replaces the original lid of the general waste section.

11.3 Presentation of the final detailed concept design to the sustainability manager

At the conclusion of this Thesis, the final concept design was presented to the Coventry University sustainability manager, Mrs. Selina Fletcherm. She liked the modularity of the bin design. In her opinion it is very important to have a tool which can be modified and expanded to new needs and regulations. Over the time the waste management at Universities constantly change their needs and requirements for waste bins. With the straight walls and the 25% sections the bin can meet nearly all needs by just changing the tops or if needed by placing a second bin on one side or on the back. In the opinion of the Sustainability manager, the signing is good and easily understandable. She liked the idea of the floor liner and the green footprint under the bin, which encourages to recycling. She agrees this floor liner points out the recycling section and secures the surrounding around the bin against dirt, which may come from litter. For maintenance, she can see on one hand an advantage with the floor liner because the surroundings are protected against dirt. On the other hand, it could give the cleaning staff additional work to clean the liner, because the staff may need different equipment to clean the liner than they usually need for the other spaces in the room.

For the sustainability manager, the concept with the scale could be an interesting tool for the future to improve waste stream management. She can see a temporary usage of a scale to observe, analyse, and improve recycling in difficult areas.

In the future, she recommended adapting the concept design ideas from this project to a smaller bin version for student accommodations. In student accommodations, the space is usually more limited hence they could use such a modular and thought-out waste and recycling bin system.

Based on the flexibility of the design in this Thesis, this is not a problem……… The idea of a functional waste system is born, the system can be adapted to any possible individual user need.

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14 Appendix

14.1 Project Management:

During the progress of my project a lot of changes had to be made. The most significant change was necessary after the interim report. In my research I came to the conclusion that my planned final year project idea was too wide and covered too many aspects.
After presenting the Interim-report I decided to focus on the design of a waste, litter and recycling bin system for schools. This decision led to a fundamentally different structure of the work, which resulted in complete different aims, objectives and project plan. The following logbook shows the step-by-step decisions in more detail, in two sections: the first one concerns the changes of the planned and the actual Gantt chart and the second covers the conventional Logbook on a weekly basis.

14.1.1 Planned and actual Gantt chart structure

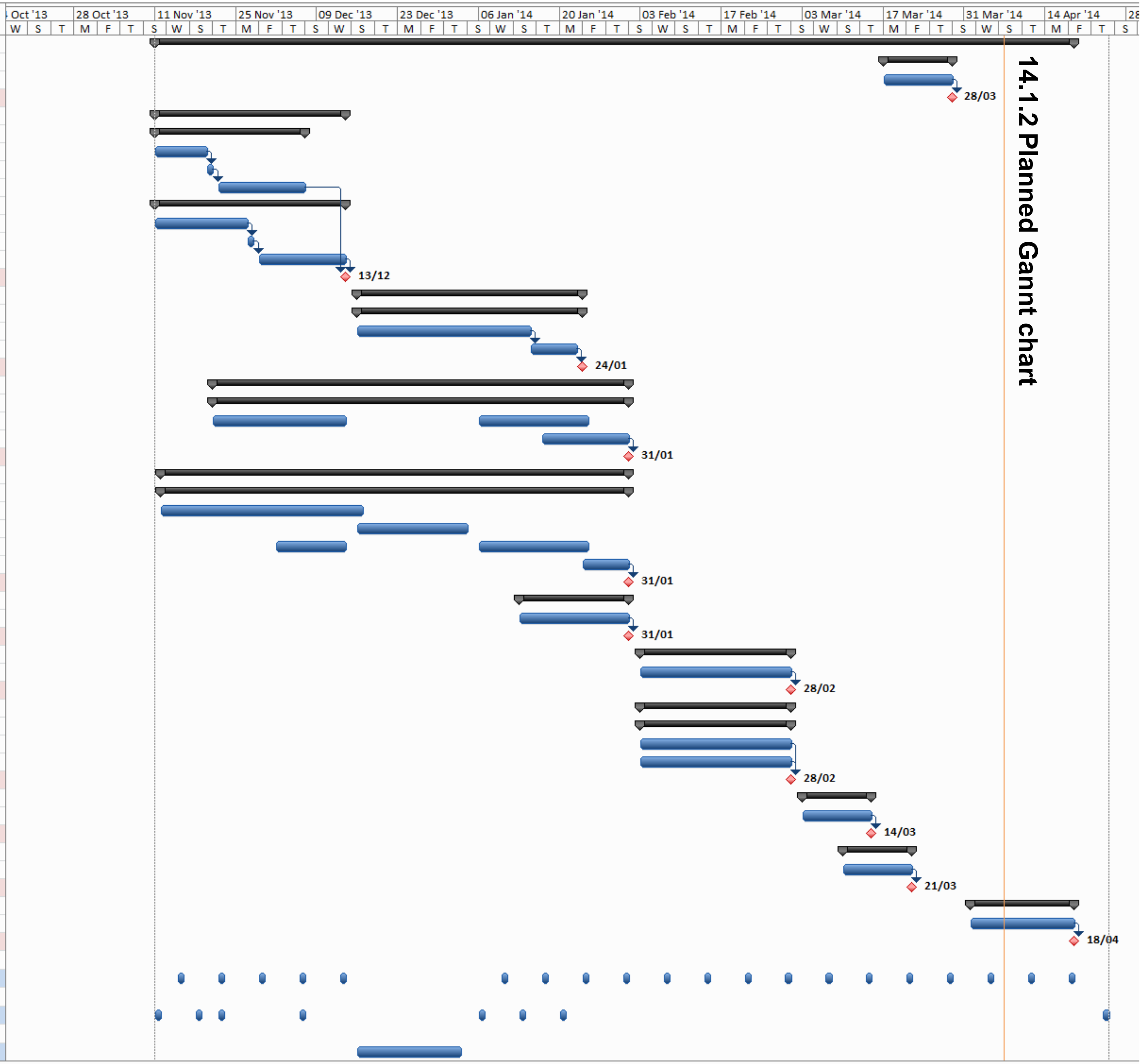
During the period of developing my final year project several changes had to be made on my planed Gantt chart. The following list shows what I have changed and the reason for doing so.

Date	Why the Gantt chart is different	Solved problems
18.11.13	- I was not able to do the activity sample. It was not a normal day. The whole hub was unexpectedly full of graduates.	- Delay the activity sample to 27.11.2013
25.11.13	- Because of many course works which I had to deliver, the analysis of the activity sample data had to be delayed.	- Delay the data analyse to 4.12.2013
02.12.13	- I started to rethink the planned final year project. I had to reduce my focus to one aspect.	- I started the literature review.
20.01.14	- After the Interim report I had to change most of the chapters to focus on design and product development of a waste and recycling bin.	- I worked out a new plan (Gannt chart) with the new and more specific deliveries
27.01.14	- The new project plan (Gannt Chart) didn’t cover the	- Marketing got more time

	marketing aspect enough.	in the project plan (Gannt chart)
29.02.14	- To arrange the Interview with the sustainability manager of Coventry University and with a responsible person of the incineration plant of several institutions was much more difficult than planned	- I needed more time for the interviews in the project plan and changed the interview partner from a responsible person of an incineration plant to a specialist of a waste and recycling bin manufacturing company.
03.03.14	- The evaluation of the gathered primary data caused much more work than planned. This delay was critical because I had to start with the concept design phase and needed the evaluations from the research part.	- I summed the evaluation up with keywords and bullet points and spent some time on the written text at the end of this project.
17.03.14	- I found out that I needed to rewrite the research approach	- I planned time for the research approach at the end of the project in the buffer time.

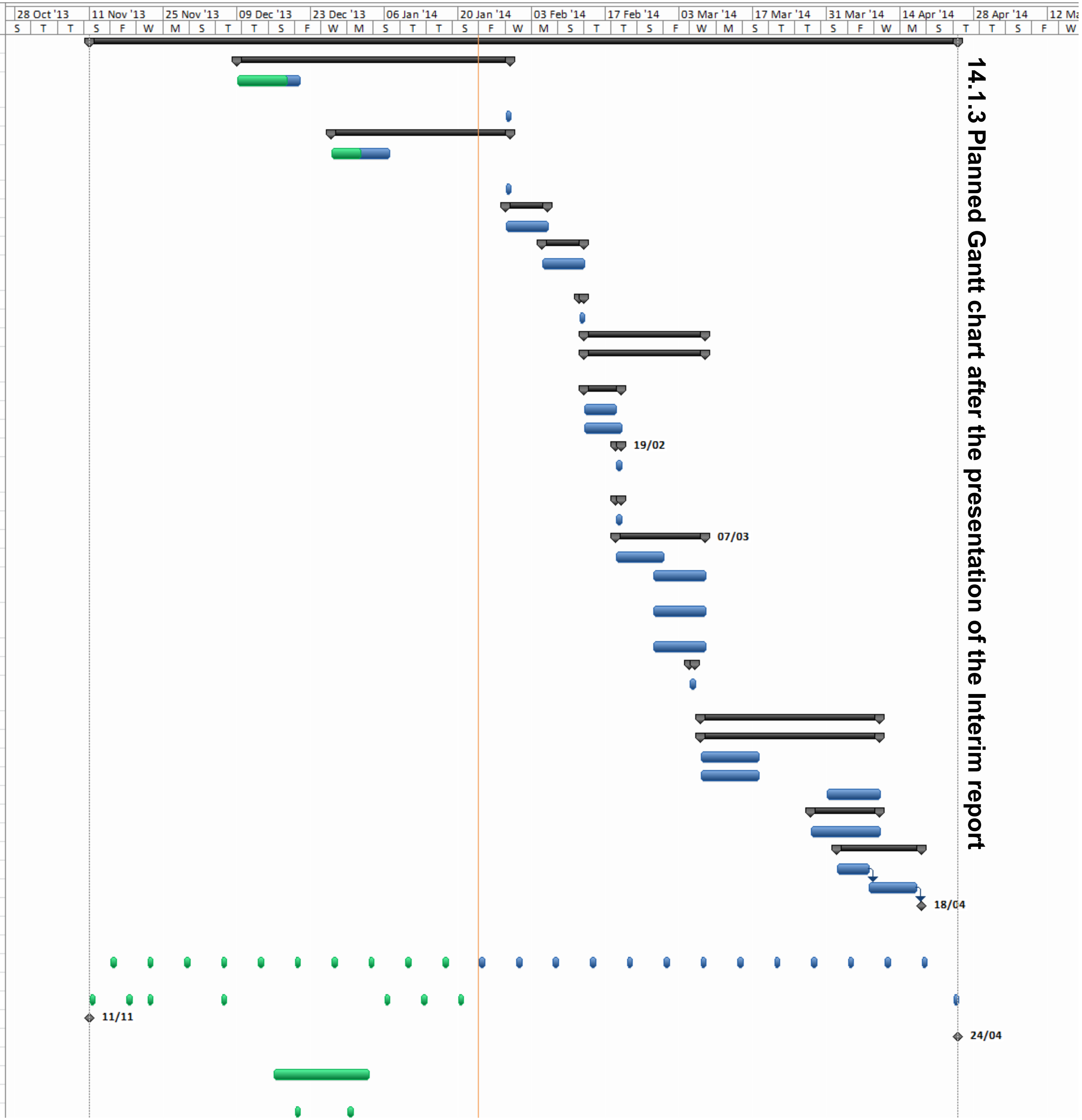
14.1.2 Planned Gannt chart

ID	Task Name	Duration	Start	Finish
1	**Project**	**116 days?**	**Mon 11/11/13**	**Fri 18/04/14**
2	**Chapter 1**	**10 days**	**Mon 17/03/14**	**Fri 28/03/14**
3	Induction, background, aims, objectives	10 days	Mon 17/03/14	Fri 28/03/14
4	Finish chapter 1	0 days	Fri 28/03/14	Fri 28/03/14
5	**Chapter 2**	**26 days?**	**Mon 11/11/13**	**Fri 13/12/13**
6	**Activity sample 2. floor Hub**	**21 days?**	**Mon 11/11/13**	**Fri 06/12/13**
7	Prepare activity sample	7 days?	Mon 11/11/13	Tue 19/11/13
8	Collect data	1 day?	Wed 20/11/13	Wed 20/11/13
9	Analyse data	12 days?	Fri 22/11/13	Fri 06/12/13
10	**Student and staff interviews**	**26 days?**	**Mon 11/11/13**	**Fri 13/12/13**
11	Prepare question	12 days?	Mon 11/11/13	Tue 26/11/13
12	Collect data	1 day?	Wed 27/11/13	Wed 27/11/13
13	Analyse data	12 days?	Fri 29/11/13	Fri 13/12/13
14	Deliver chapter 2 (Observation and interview report)	0 days	Fri 13/12/13	Fri 13/12/13
15	**Chapter 3**	**29 days?**	**Mon 16/12/13**	**Fri 24/01/14**
16	**Literature review recycling methodologies**	**29 days?**	**Mon 16/12/13**	**Fri 24/01/14**
17	reading	22 days?	Mon 16/12/13	Tue 14/01/14
18	writing report	6 days?	Wed 15/01/14	Wed 22/01/14
19	Deliver chapter 3 (literature review: waste reducti	0 days	Fri 24/01/14	Fri 24/01/14
20	**Chapter 4**	**53 days?**	**Thu 21/11/13**	**Fri 31/01/14**
21	**Case study English waste system**	**53 days?**	**Thu 21/11/13**	**Fri 31/01/14**
22	**reading and research**	**48 days**	**Thu 21/11/13**	**Fri 24/01/14**
25	writing report	11 days?	Fri 17/01/14	Fri 31/01/14
26	Deliver chapter 4 (case study: English waste sys	0 days	Fri 31/01/14	Fri 31/01/14
27	**Chapter 5**	**60 days?**	**Tue 12/11/13**	**Fri 31/01/14**
28	**Interviews with the Industry**	**60 days?**	**Tue 12/11/13**	**Fri 31/01/14**
29	Prepare and organise	26 days?	Tue 12/11/13	Mon 16/12/13
30	Reserved swiss-interview time	15 days?	Mon 16/12/13	Fri 03/01/14
31	**Reserved UK-interview time**	**40 days**	**Mon 02/12/13**	**Fri 24/01/14**
34	write report	6 days?	Fri 24/01/14	Fri 31/01/14
35	Finish chapter 5	0 days	Fri 31/01/14	Fri 31/01/14
36	**Chapter 6**	**15 days?**	**Mon 13/01/14**	**Fri 31/01/14**
37	Literature review: Manipulation and motivation techr	15 days?	Mon 13/01/14	Fri 31/01/14
38	Finish chapter 6	0 days	Fri 31/01/14	Fri 31/01/14
39	**Chapter 7**	**20 days?**	**Mon 03/02/14**	**Fri 28/02/14**
40	System aspect (Bin, cleaning, structurally enginee	20 days?	Mon 03/02/14	Fri 28/02/14
41	Deliver chapter 7 (Create new waste concept)	0 days	Fri 28/02/14	Fri 28/02/14
42	**Chapter 8**	**20 days?**	**Mon 03/02/14**	**Fri 28/02/14**
43	**Social aspect**	**20 days?**	**Mon 03/02/14**	**Fri 28/02/14**
44	Staff and Professors (Inform, educate, advice)	20 days?	Mon 03/02/14	Fri 28/02/14
45	Students (Inform, educate, animate)	20 days?	Mon 03/02/14	Fri 28/02/14
46	Deliver chapter 8 (Create new waste concept)	0 days	Fri 28/02/14	Fri 28/02/14
47	**Chapter 9**	**10 days?**	**Mon 03/03/14**	**Fri 14/03/14**
48	Implementation in CU	10 days?	Mon 03/03/14	Fri 14/03/14
49	Deliver chapter 9	0 days	Fri 14/03/14	Fri 14/03/14
50	**Chapter 10**	**10 days?**	**Mon 10/03/14**	**Fri 21/03/14**
51	Conclusions, reverences, Tasks	10 days?	Mon 10/03/14	Fri 21/03/14
52	Deliver chapter 11	0 days	Fri 21/03/14	Fri 21/03/14
53	**Revise, Submit final Report**	**14 days?**	**Tue 01/04/14**	**Fri 18/04/14**
54	Revise	14 days?	Tue 01/04/14	Fri 18/04/14
55	Submit final report	0 days	Fri 18/04/14	Fri 18/04/14
56				
57	**Supervisor meeting**	**112 days**	**Fri 15/11/13**	**Fri 18/04/14**
78				
79	**Known exams and coursework**	**120 days**	**Mon 11/11/13**	**Thu 24/04/14**
95				
96	stay in switzerland	14 days?	Mon 16/12/13	Thu 02/01/14



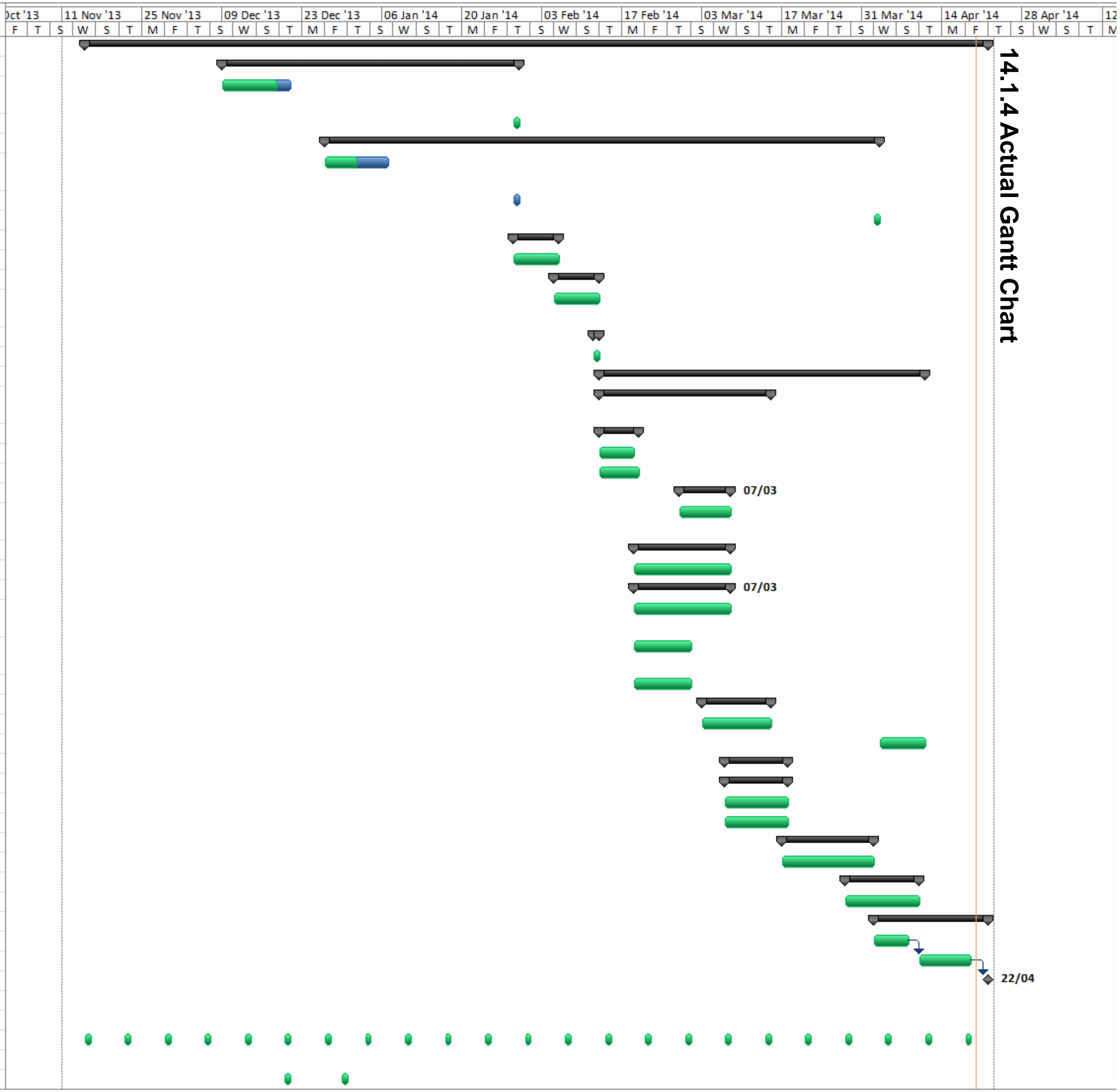
14.1.3 Planned Gantt chart after the presentation of the Interim report

ID	Task Name	Duration	Start	Finish
1	**Project**	**119 days?**	**Mon 11/11/13**	**Thu 24/04/14**
2	**Chapter 1**	**38 days?**	**Mon 09/12/13**	**Wed 29/01/14**
3	Induction, background, aims, objectives first draft	10 days	Mon 09/12/13	Fri 20/12/13
4	Overwork and adopt	1 day?	Wed 29/01/14	Wed 29/01/14
5	**Chapter 2**	**24 days?**	**Fri 27/12/13**	**Wed 29/01/14**
6	Research Overview, process, mytholoty and data collection	7 days	Fri 27/12/13	Mon 06/01/14
7	Overwork and adopt	1 day?	Wed 29/01/14	Wed 29/01/14
8	**Chapter 3**	**6 days**	**Wed 29/01/14**	**Wed 05/02/14**
9	Literature review: NPD	6 days	Wed 29/01/14	Wed 05/02/14
10	**Chapter 4**	**6 days**	**Wed 05/02/14**	**Wed 12/02/14**
11	Literature review: NPD and the Environment	6 days	Wed 05/02/14	Wed 12/02/14
12	**Chapter 5**	**1 day**	**Wed 12/02/14**	**Wed 12/02/14**
13	Design strategie for this project	1 day	Wed 12/02/14	Wed 12/02/14
14	**Chapter 7**	**17 days?**	**Thu 13/02/14**	**Fri 07/03/14**
15	**Evaluate the needs to design a optimal waste bin system**	**17 days?**	**Thu 13/02/14**	**Fri 07/03/14**
16	**Marketing research**	**5 days**	**Thu 13/02/14**	**Wed 19/02/14**
17	Product	4 days	Thu 13/02/14	Tue 18/02/14
18	Price	5 days	Thu 13/02/14	Wed 19/02/14
19	**Costumer**	**1 day?**	**Wed 19/02/14**	**Wed 19/02/14**
20	Interview with Environmental Sustainability Officer at CU	1 day?	Wed 19/02/14	Wed 19/02/14
21	**Userbility**	**1 day**	**Wed 19/02/14**	**Wed 19/02/14**
22	Student Questionaire	1 day	Wed 19/02/14	Wed 19/02/14
23	**Sustainability**	**13 days?**	**Wed 19/02/14**	**Fri 07/03/14**
24	Interview with...	7 days	Wed 19/02/14	Thu 27/02/14
25	Recycling statistics household waste	8 days	Wed 26/02/14	Fri 07/03/14
26	Household waste collecting system in the UK	8 days?	Wed 26/02/14	Fri 07/03/14
27	Standarts: ISO	8 days?	Wed 26/02/14	Fri 07/03/14
28	**Economic Factor**	**1 day**	**Wed 05/03/14**	**Wed 05/03/14**
29	Interview with a responcible person from an incinoration	1 day	Wed 05/03/14	Wed 05/03/14
30	**Chapter 8**	**24 days**	**Fri 07/03/14**	**Wed 09/04/14**
31	**Design Process**	**24 days**	**Fri 07/03/14**	**Wed 09/04/14**
32	Idea finding	7 days	Fri 07/03/14	Mon 17/03/14
33	Idea evaluation	7 days	Fri 07/03/14	Mon 17/03/14
34	Design	8 days	Mon 31/03/14	Wed 09/04/14
35	**Chapter 9**	**9 days**	**Fri 28/03/14**	**Wed 09/04/14**
36	Conclusion and recommendations	9 days	Fri 28/03/14	Wed 09/04/14
37	**Revise, Submit final Report**	**12 days**	**Wed 02/04/14**	**Fri 18/04/14**
38	Overwork Literature review	4 days	Wed 02/04/14	Mon 07/04/14
39	Revise	7 days	Tue 08/04/14	Wed 16/04/14
40	Submit final report	0 days	Fri 18/04/14	Fri 18/04/14
41				
42				
43	**Supervisor meeting Coventry**	**111 days**	**Fri 15/11/13**	**Fri 18/04/14**
67				
68	**Known exams and coursework**	**119 days?**	**Mon 11/11/13**	**Thu 24/04/14**
84	Known exams and coursework	0 days?	Mon 11/11/13	Mon 11/11/13
85	Known exams and coursework	0 days?	Thu 24/04/14	Thu 24/04/14
86				
87	stay in switzerland	14 days?	Mon 16/12/13	Thu 02/01/14
88				
89	**Supervisor meeting switzerland**	**7 days**	**Fri 20/12/13**	**Mon 30/12/13**



14.1.4 Actual Gantt Chart

ID	Task Name	Duration	Start	Finish
1	**Project**	**112 days?**	**Fri 15/11/13**	**Tue 22/04/14**
2	**Chapter 1**	**38 days?**	**Mon 09/12/13**	**Wed 29/01/14**
3	Induction, background, aims, objectives first draft	10 days	Mon 09/12/13	Fri 20/12/13
4	Overwork and adopt	1 day?	Wed 29/01/14	Wed 29/01/14
5	**Chapter 2**	**69 days?**	**Fri 27/12/13**	**Wed 02/04/14**
6	Research Overview, process, mytholoty and data collection	7 days	Fri 27/12/13	Mon 06/01/14
7	Overwork and adopt	1 day?	Wed 29/01/14	Wed 29/01/14
8	Second Overwork	1 day?	Wed 02/04/14	Wed 02/04/14
9	**Chapter 3**	**6 days**	**Wed 29/01/14**	**Wed 05/02/14**
10	Literature review: NPD	6 days	Wed 29/01/14	Wed 05/02/14
11	**Chapter 4**	**6 days**	**Wed 05/02/14**	**Wed 12/02/14**
12	Literature review: NPD and the Environment	6 days	Wed 05/02/14	Wed 12/02/14
13	**Chapter 5**	**1 day**	**Wed 12/02/14**	**Wed 12/02/14**
14	Design strategie for this project	1 day	Wed 12/02/14	Wed 12/02/14
15	**Chapter 7**	**41 days?**	**Thu 13/02/14**	**Thu 10/04/14**
16	**Evaluate the needs to design a optimal waste bin system**	**22 days?**	**Thu 13/02/14**	**Fri 14/03/14**
17	**Marketing research**	**5 days**	**Thu 13/02/14**	**Wed 19/02/14**
18	Product	4 days	Thu 13/02/14	Tue 18/02/14
19	Price	5 days	Thu 13/02/14	Wed 19/02/14
20	**Costumer**	**7 days**	**Thu 27/02/14**	**Fri 07/03/14**
21	Interview with Environmental Sustainability Officer at CU	7 days	Thu 27/02/14	Fri 07/03/14
22	**Userbility**	**13 days**	**Wed 19/02/14**	**Fri 07/03/14**
23	Student Questionaire	13 days	Wed 19/02/14	Fri 07/03/14
24	**Sustainability**	**13 days?**	**Wed 19/02/14**	**Fri 07/03/14**
25	Recycling statistics household waste	13 days	Wed 19/02/14	Fri 07/03/14
26	Household waste collecting system in the UK	8 days?	Wed 19/02/14	Fri 28/02/14
27	Standarts: ISO	8 days	Wed 19/02/14	Fri 28/02/14
28	**Economic Factor**	**10 days**	**Mon 03/03/14**	**Fri 14/03/14**
29	Interview with Leafield	10 days	Mon 03/03/14	Fri 14/03/14
30	Extra Time for completion	6 days	Thu 03/04/14	Thu 10/04/14
31	**Chapter 8**	**7 days**	**Fri 07/03/14**	**Mon 17/03/14**
32	**Design Process**	**7 days**	**Fri 07/03/14**	**Mon 17/03/14**
33	Idea finding	7 days	Fri 07/03/14	Mon 17/03/14
34	Idea evaluation	7 days	Fri 07/03/14	Mon 17/03/14
35	**Chapter 9**	**12 days**	**Mon 17/03/14**	**Tue 01/04/14**
36	Design	12 days	Mon 17/03/14	Tue 01/04/14
37	**Chapter 10**	**9 days**	**Fri 28/03/14**	**Wed 09/04/14**
38	Conclusion and recommendations	9 days	Fri 28/03/14	Wed 09/04/14
39	**Revise, Submit final Report**	**14 days**	**Wed 02/04/14**	**Tue 22/04/14**
40	Overwork Literature review	4 days	Wed 02/04/14	Mon 07/04/14
41	Revise	7 days	Thu 10/04/14	Fri 18/04/14
42	Submit final report	0 days	Tue 22/04/14	Tue 22/04/14
43				
44				
45	**Supervisor meeting Coventry**	**111 days**	**Fri 15/11/13**	**Fri 18/04/14**
69				
70	**Supervisor meeting switzerland**	**7 days**	**Fri 20/12/13**	**Mon 30/12/13**



14.1.5 Log Book

The Log Book is based on a weekly observation and shows the planned tasks, the problems and the actions to solve the problems

Date	Work achieved	Encountered problems	Solved problems
11.11.13	- I worked out criteria for the activity sample - I worked out criteria for the student questionnaire	- I had no experience in preparing an "activity sample"	- I asked the maths support for help to generate questions and the criteria for the activity sample
18.11.13		- The planned activity sample (2nd floor Hub on 20.11.2013) could not be held. It was graduation week and therefore not a normal workweek.	- Delay the activity sample to 27.11.2013
25.11.13	- I hold the activity sample for 1 day every half hour from 8 am to 10 pm	- The data of the Activity sample were not specific enough and not useful for an academic project. Questions came up: How can I prove that a chosen activity samples' day is a usual day? Is the frequency and structure of the University visitors/users the same every day? And how is the content of the litter bins composed (amount of the right litter in the right bin, etc.).	- I started to rethink the planned final year project and changed the structure of the Gantt chart. I moved the literature review parts to the front and got deeper into the topic of recycling, in order to acquire a better knowledge of recycling.

02.12.13		- This week it was not possible to work for the final year project. I had to write 3 different Course work papers.	- I delayed the work for a week and profited from the few free moments to rethink the structure of the diploma work.
09.12.13	- I started with the literature review, part “Waste management strategies” and part “Technical information about recycling” - I analysed the generated data of the activity sample.	- It is difficult to find useful information in books. My approach in this part is to acquire knowledge about the different recycling methods	- I used public information from the internet and from non profit organisations in addition to the printed specialised literature
16.12.13	- I finished the literature review parts “Waste management” and “Technical information about recycling”. - I had a meeting with the supervisor from HSLU Luzern (Switzerland)	- The supervisor expressed a critical view on my project and showed me some difficulties in my plans for the final year project.	
23.12.13	- I started with the literature review part “Motivation techniques for recycling”		
30.12.13	- Presentation of the final project topic to my supervisor and to the	- The evaluation showed that my final year project topic was still too wide. It	- I realised that two of the areas I focussed on (1. Sociological and

	external expert at HSLU Luzern (Switzerland) - I wrote the interim report	considered too many different aspects. I needed to focus.	educational aspects, 2. Economical aspects) couldn't be treated in my work. The centre of my investigations will be the designing and product development of a waste, litter and recycling bin system for schools.
06.01.14	- I handed in my Interim report to Coventry University - Presentation of the Interim report in Coventry	- I lost most digital data I had written down in Switzerland; they were not restorable.	
13.01.14	- Adapt the Gannt Chart to the new focus of the final year project - First meeting with my new Coventry University Supervisor	- Because of the fundamental changes of the project focus the planned Gannt Chart did not fit any more into the project	- I rewrote the Gannt Chart related to the new focus of the project.
20.01.14	- Meeting with sustainability manager	- Too little time planned for the Economical factors in the Gannt Chart	- I improved the Gannt Chart to give the market research more time
27.01.14	- I improved the Objectives for the new direction of the project - Start reading literature of NPD		

03.02.14	- Start with the literature review of NPD	- Many different NPD models are on the market	- I focussed on 3 different NPD groups
10.02.14	- I worked on the literature review - I started with the planning of the interviews - I worked out questions for the student questionnaire	- It was more difficult to find the right Interview partners than thought	
17.02.14	- I finished the literature review	- Another coursework needed more time to be completed	- I had to delay the project for 2 working days
24.02.14	- I hold the student questionnaire with 113 probands - I searched interview partners of the professional area	- To get the interviews with professionals is more difficult than planned	- I changed the interview partner of the professional institutions
03.03.14	- Collaboration at the Green Week with the group Green@CU - Interview with the sustainability manager of Coventry University - Start with evaluating the questionnaire and the interview	- To evaluate all the gathered data took much longer than planned	The evaluation was done by keywords. For the complete version some spare buffer time at the end of the project will be used to formulate the gathered data into the report

10.03.14	- Email-interview with Mr Garry Mills - I finished the sustainability and technology research - I defined the specifications for the waste and recycling bin with the information from the research		
17.03.14	- I started with the concept design	- The difficulty was to gather the specifications of the market research	- I used creative tools to ensure a structured and marked orientated concept design
24.03.14	- I started with the detailed concept design - I start drawing the detailed concept design in a CAD	- I made a fundamental error in the planning of the drawing. I had rework two days of drawing	- I had to redraw the 3D CAD painting
31.03.14	- Finished the concept design - I drew a 3D draft of the bin in a CAD program - I presented the bin to the Sustainability manager		
07.04.14	- I reworked the whole project report and		

	finished the research.
14.04.14	- I reworked the project report
21.04.14	- I handed the final project report in at Coventry University

14.1.6 Risk management

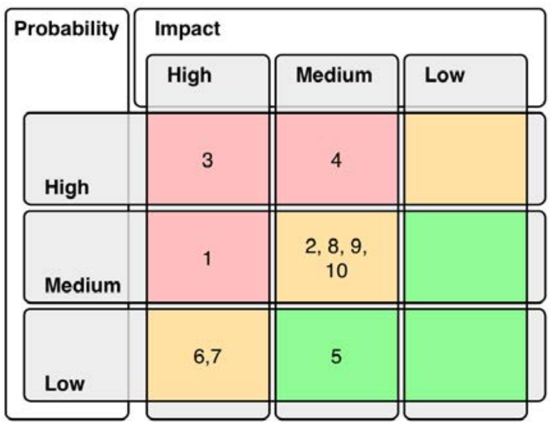
External and internal impacts, which can influence a project negatively during the development, are called project risks. To overcome/minimise the impact of the risks a Risk matrix is used for the risk management. In a risk matrix different risks get rated on an estimate probability and on an impact category (shown in the next Figure). Actions to overcome the risks have to be defined (shown in the next Table)

Red marked risks have a big impact for the project and can often appear. These risks are called high risks. These risks need the highest attention.

Yellow marked risks have a medium impact on the project and can appear during the whole project. These risks are called medium risks and need normal attention.

Green marked risks are called low risks. They have a low impact on the project and appear seldom. To overcome these risks does not necessarily need any special actions.

14.1.7 Risk Matrix:



14.1.8 Risk Analyse

Nr:	Risk:	Prob-ability:	Impact:	Actions:
1	- lose data on the computer	M	H	- Save data on different places and use online storage. - Never work on USB sticks.
2	- Not meeting the defined objectives	M	M	- Good communication with the supervisor
3	- Tasks need more time than estimated	H	H	- The plan needs to be re-planned and if needed, selected tasks get reduced.
4	- To get the interviews is more difficult then planned	M	H	- Clear communication with the probands. If a planned interview is not possible, change the interview partner
5	- Not enough participants for the questionnaire are available	L	M	- Ask the statistic support at Coventry University for their help and advice
6	- Interviews do not deliver satisfyingly relevant information	L	H	- Good communication with the supervisor - Ask the statistics support at Coventry University for their help and advice
7	- Unclear aim and objective	L	H	- Good communication with the supervisor
8	- The concept design does not meet the specifications	M	M	- Use creative tools in the concept design to ensure a customer and user orientated design

9	- Not skilled enough in 3D modelling	M	L	- Use a familiar 3D modelling programme
10	- Problems with the ethic formula	M	M	- Good communication with the Coventry University supervisor

Table 13: Risk analysis, L= low, M = medium, and H = high.

14.1.9 Project reflection

When I started with the final year project topic finding process last September, I had many difficulties to find a convincing topic which fitted into the requirements of Coventry University and the HSLU Switzerland, and also meets my own professional plans. In November, I finally started my final year project with a topic concerning the students' behaviour with litter and waste at Coventry University.

In the literature review process between November and January I realised that this topic chosen for the project still involved too many aspects and that I should focus on a clearly enclosed process/product. In my interpretation I analysed three different main aspects:

- Sociological and educational aspect: Observation of the behaviour of students concerning their litter.
- Economic aspects of cleaning and waste disposal in Coventry University
- Designing and product development aspects of a waste, litter and recycling bin

After the interim presentation and with the agreement of my two supervisors, I decided to focus on the design and product development aspects of a waste and recycling bin for Coventry University. This decision resulted from the fact, that the most of the already completed literature review was, though highly informative, but not directly usable for the project report. This decision was fundamentally necessary. On one hand it caused more work but on the other hand it provided me security and the opportunity to focus on a targeted, practical, and creative orientated final year project. As I had spent so much time to find my orientation, in January the project became time-critical. My aim to deliver a good project demanded a tight time schedule to make up for the delay of the two months.

Twice I felt a little behind my planed schedule, due to the tight time schedule and some unexpected external factors. But with a good flow and some little adjustment I was able to reach the planned tasks and finish my project on time.

In this project I have learned much about new product development, sustainable/environmental aspects, production methods, cost estimation, design aspects, project management and the technics to build up a final year project. I'm certain that I will benefit of all this new knowledge and experience in my future work life.

14.2 Student questionnaire

14.2.1 Student questionnaire questions

Student questionnaire

General information:

University: Coventry University ☐ , Other ☐ : ____________________

Student ☐ , Teacher ☐ , Staff ☐

Faculty: ____________________

Sex: Male ☐ , Female ☐ , Other ☐ : ____________________

Age: ____________________

Nationality: ____________________

Accommodation: Private Accommodation ☐, University Student Accommodation ☐, Family home ☐,
Other ☐: ____________________

	1	2	3	4
– How much do you care about environmental problems on a scale between 1 (0%) and 4 (100%)	☐	☐	☐	☐

- If you care about environmental problems, which aspects are you most concerned about?
- If you do not care about environmental problems, why you do not care?

Answer: ____________________

	1	2	3	4
– How much do you recycle (separate your litter) on a scale between 1 (never) and 4 (always)	☐	☐	☐	☐

- What kind of litter (materials) do you recycle?

Answer: ____________________

	1	2	3	4
– How much do you recycle (separate your litter) when you are at Coventry University on a scale between 1 (never) and 4 (always).	☐	☐	☐	☐

- What would encourage you to recycle more when you are at Coventry University?

Container Design ☐ What features on current designs of recycling containers inhibit / restrict / discourage you for recycling?

____

Container Location ☐ What location would encourage you to recycle more?

____

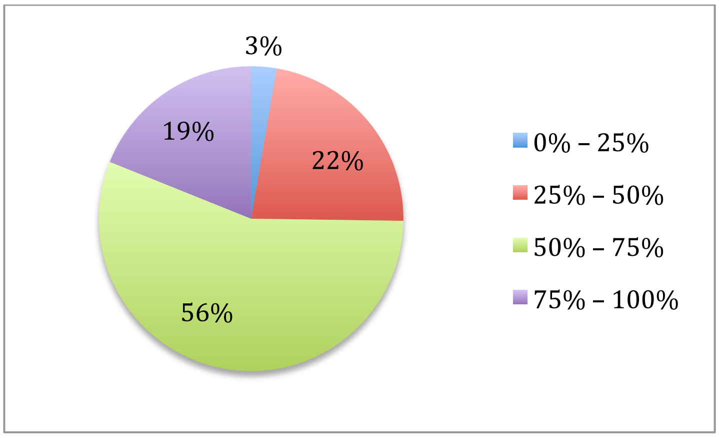
Other: ____________________

- What colour do you associate with:

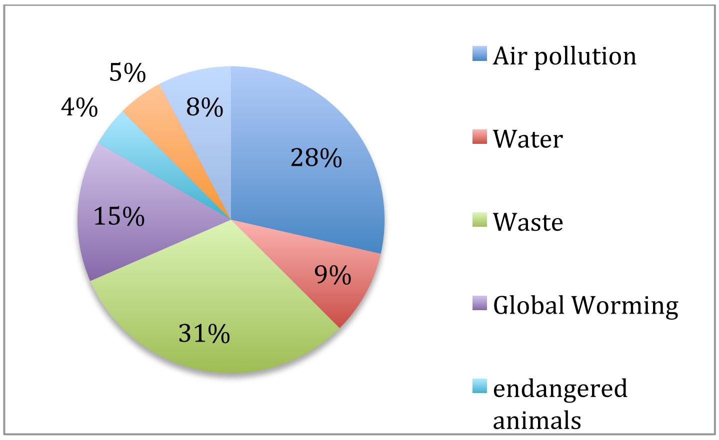
	Blue:	Yellow:	Red:	Green:	Brown:	Purple:	Black:	Other please write down:
General waste:								
General recycling:								
Recycling plastic bottles:								
Recycling paper								
Recycling Batteries								

14.2.2 Student questionnaire results

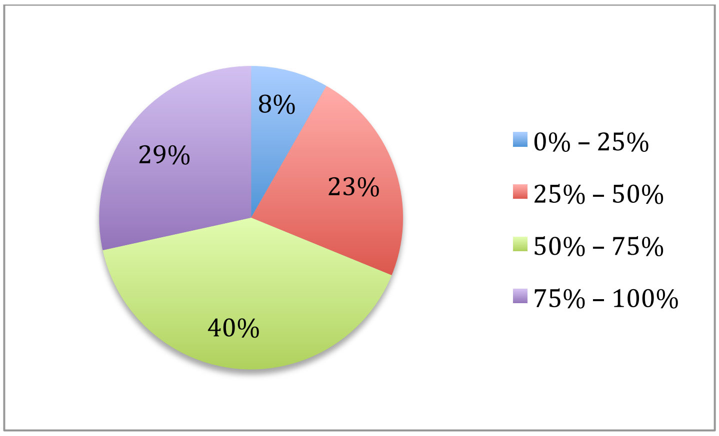
Question 1: How much do you care about environmental problems on a scale between 1 (0%) and 4 (100%)



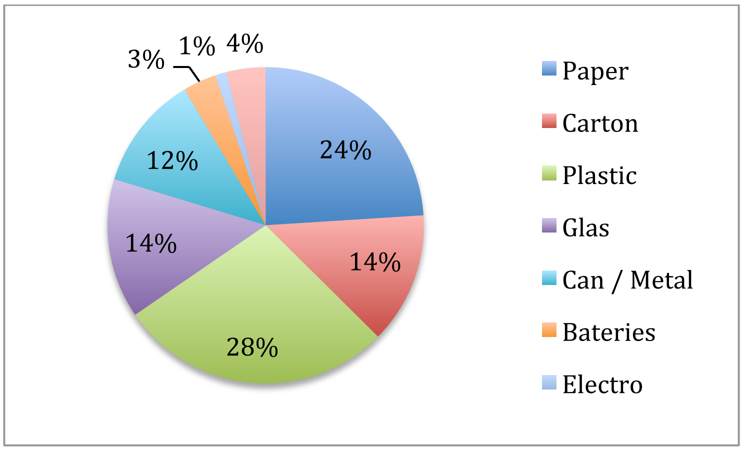
Question 2: If you care about environmental problems, which aspects are you most concerned about?



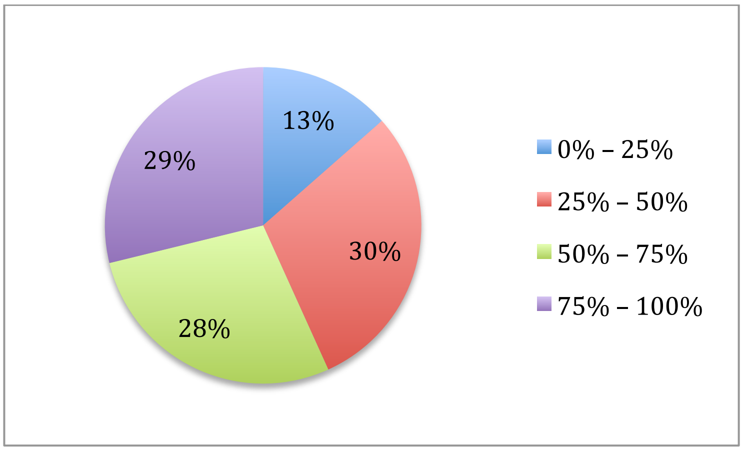
Question 3: How much do you recycle (separate your litter) on a scale between 1 (never) and 4 (always)



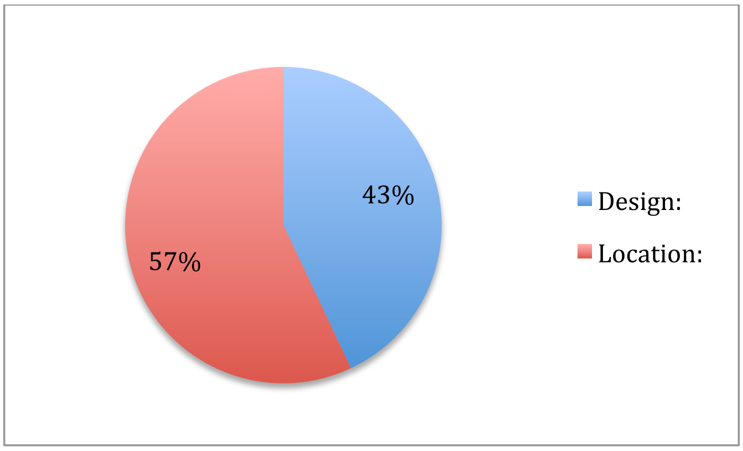
Question 4: What kind of litter (materials) do you recycle?



Question 5: How much do you recycle (separate your litter) when you are at Coventry University on a scale between 1 (never) and 4 (always).



Question 6: What would encourage you to recycle more when you are at Coventry University?



– What location would encourage you to recycle more?

– What features on current designs of recycling containers inhibit / restrict / discourage you for recycling?

Location:	Persons	Design:	Persons
More single stream recycling bins near student accommodation	3	A recycling reward system	1
More recycling bins	3	Big holes	1
More bins near working areas	1	Bigger bins	5
More bins near exit	1	Clear labelling	19
More bins near reception	1	Colour code	6
More bins near eating areas	3	Easy identifiable	6
More bins near classrooms	1	Eye-catcher	1
More bins in the library	3	More recycling containers	1
More bins in the front of every University building	1	R+W bin on one place	3
More bins in the corridor	1	Single stream recycling	2
More bins in student accommodations	1		
More bins	35		
Bins in classrooms	9		
Better positioned bins	5		
Better locations	1		

Question 7: What colour do you associate with?

Colour:	Waste:	General recycling:	Plastic bottles:	Paper:	Batteries:
Blue	12	19	48	26	4
Yellow	3	7	17	16	16
Red	2	6	8	5	20
Green	15	63	21	32	11
Brown	18	4	8	20	11
Purple	1	2	3	1	7
Black	51	2	1	3	19
Grey	4	1	0	1	9
White	0	1	0	1	0
Orange	0	1	0	0	0
Clear	0	0	1	0	0

14.3 Interview notes with Selina Fletcher

Question 1: It seams to be a trend for universities to care more about environmental issues (Carbon footprint reduction). Why?

- Governmental pressure and cost reduction

Question 2: Does the aim for a carbon footprint reduction influence cost reduction, increasing Image, governmental regulations?

- 2-3 million energy costs every year
- Focus on carbon reduction and waste reduction (recycling)

Question 3: Last year you achieved an ISO 14001 standard. How does this standard influence your waste management?

- At the moment the standard does not influence the waste management much. It gives a pressure to decrease waste. Coventry University starts with competitions for cleaning staff to increase recycling.

Question 4: What are your defined targets for the waste reduction?

- To increase the recycled materials up to 80% until 2015

- Situation at the moment around 45%

Question 5: Do you already know how your next future target looks like?

- The main focus for the next targets will be on reduce and reuse

Question 6: Could an optimised waste bin help you to reduce general waste, increase recycling and help to achieve your targets?

- The waste bin design has a high influence on how much students recycle.

Question 8: Would a detailed waste monitoring system be useful to achieve future environmental targets?

- At the moment Coventry University collects data from the overall amount of waste. It is difficult to detect the more problematic areas. Future plans include collection data from building areas.
- A brake down to every bin would make sense for a temporary observation.

Question 9: In your opinion what features does a good waste and recycling bin system need to increase the amount of recycling?

- Consistency, symbolic pictures, recycling and waste bin together and not on different locations, a practical mount for the waste bags, high quality material, round edges

Question 10: What is the maximum a new waste/recycling bin can cost for Coventry University?

- The bins for the new buildings cost around £380.
- The new trail from Leafield environmental costs approximately £150.

Question 11: I know that you have different usability needs for the different areas at the campus. An office is not the same as a students' accommodation and a students' accommodation is not the same as a public area of a University.

- The general need for all facilities is the same. Some places have extra need. E.g. oil collection in the garage.

Question 12: I know that you run tests with waste bins from the Leafield Environmental Company. With these bins where you able to increase the amount of recycling?

- Increase of recycled materials = 10%-15% with an overall contamination of the recycled material of 5%, which is acceptable.

Question 13: Coventry University collects only general waste and mixed recycling. Where is the trend going to?

- At the moment it is the most effective way. Many Universities which collected single stream recycling return to a mixed recycling.

14.4 E-Mail interview notes with Gary Mills

Question 1: Your waste bin, which Coventry University is testing, has a lid on the general waste bin section. What is the purpose for this lid? (Mixed recycling bin has no lid).

The idea was to create a barrier to depositing litter in a general waste aperture which generally implies that the waste is destined to go to landfill. In consultation with both Selina and Steve Twynholm who explained the waste contract that Coventry University has entered into, it is generally accepted that 5% contamination is an acceptable level for mixed recycling for the waste management company to deal with. Therefore whilst educating staff and students to deposit waste into the correct aperture was deemed to be important it was also considered that where there was uncertainty as to which aperture to use the depositor should be encouraged to use the mixed recycling aperture and this should be the most easily accessible.

Question 2: How important is the signing and the colour coding of the different bins for an effective waste and recycling collection?

The colours used are consistent with WRAP which is a government led initiative to standardise recycling and waste management. Lime green is the industry standard for mixed recycling, whilst white is the standard for general waste or landfill.

Question 3: I know that at Coventry University (the data collection is still running) the amount of the collected recyclable materials has increased since the use of your waste bin. Are there any more detailed studies or numbers available, which I could use in the research part of my project?

Coventry University are quite unique in the way they are monitoring their waste and how the recorded data shows increasing recycling rates in direct correlation to the date of installing our units.

Greenwich University also implemented a recycling scheme using our products and have been able to demonstrate significant improvements also. Centralised Recycling Greenwich Case Studies

Question 4: The whole movement to care about waste is quite new for Universities and today's standards and regulations could change in the future. What do you know about future trends, needs, regulations or standards, which could influence waste bin design and system for Universities?

The most notable future trends relate to the interpretation of European demands for total segregation of waste streams. As a business we've noticed that in Wales and Scotland this has been interpreted as meaning all waste streams are segregated at source e.g. cans are separated from paper as are plastics likewise. Meanwhile in England co-mingled or mixed recycling has been accepted as fulfilling the requirement for segregation.

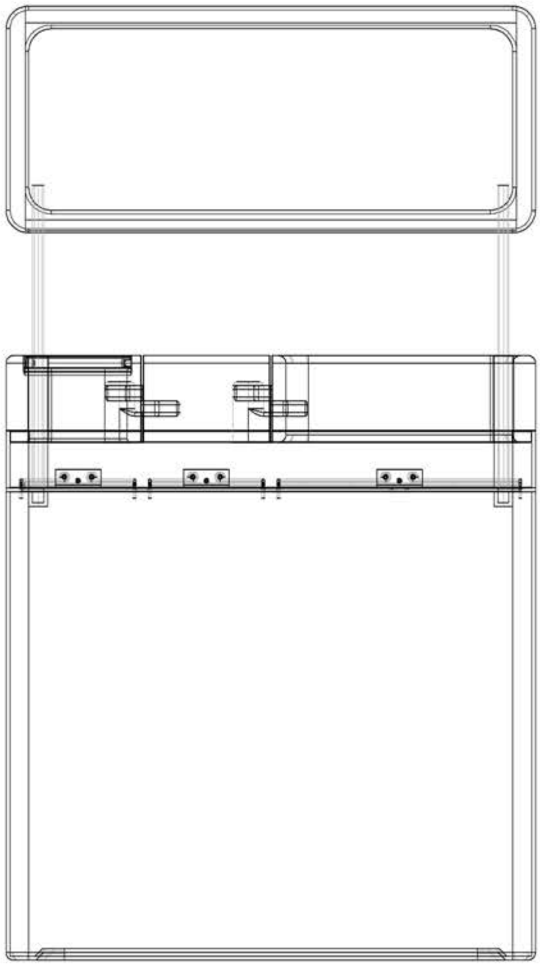
Furthermore Scotland has introduced at the beginning of 2014 new legislation surrounding the need for all food waste to be diverted from landfill and be used in power generation or composted. This has seen a growth in our sales of bins to manage food waste. The industry anticipates that it's only a matter of time before this requirement is rolled out to the rest of the UK although no time scale has been attached to this as yet.

Question 5: How does your product focus on future trends? Is your product modularly expandable?

As manufacturers and designers it is important for us to future proof our products as much as possible. Tracking trends and consulting heavily with our clients to understand the demands of the industry is of utmost importance. Most, if not all of our recent products have been introduced directly through customer led projects of which the Mini Meridian bin specified by Coventry is a typical example.

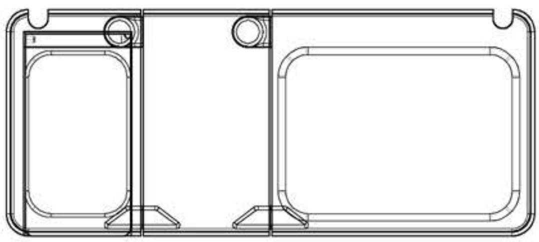
14.5 Concept design of the waste and recycling bin for Coventry University

Front view 1:10

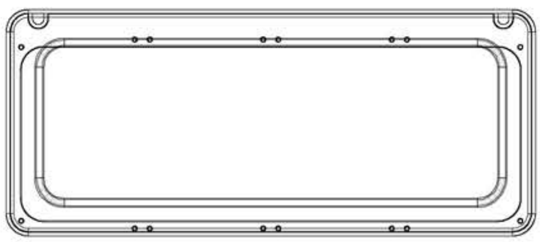


Top view screen 1:10

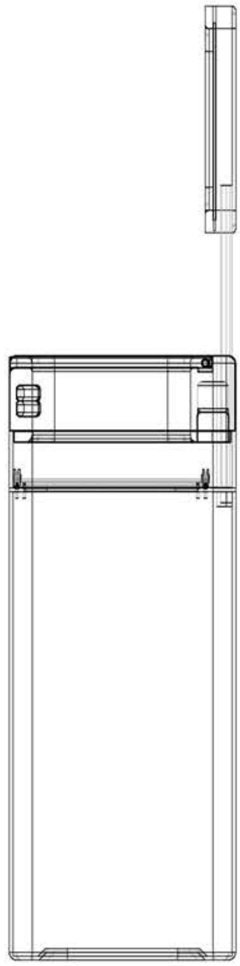
Top view bin top 1:10



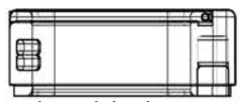
Top view bin 1:10



Side view 1:10



Side view bin-top 1:10



Side view bin bag mount 1:10

Side view bin 1:10