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Cleaning Africa through product design:

A field study regarding plastic recycling and sustainable product development in Zanzibar

Master of Science Thesis in the Master Degree Programme,
Industrial Design Engineering

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Abstract

This Master's thesis was carried out at the department of Product and Production Development at Chalmers University of Technology by Anna Engström and Ellen Österdahl, master students at the programme Industrial Design Engineering. The project was performed in cooperation with Zanrec Plastics, a small Swedish company aiming at introducing a scalable plastic recycling system in developing countries, starting in the island of Zanzibar, just outside the coast of Tanzania in East Africa.

The aim of the project was to utilise recycled plastic material as a basis for development of a new product, made partially or fully from recycled plastic. The aim was also to identify needs on the local market that could be fulfilled by this plastic product. The local market was defined as East Africa with a primary focus on the island of Zanzibar. The developed product should be a part of Zanrec Plastics' business concept, meaning that it should be a sustainable product, well adapted to the local society, and that it should be produced locally in Zanzibar.

In the first phase of the project, a theoretical pre-study was carried out and then followed by a seven week-long field study in Zanzibar. General cultural observations and several interviews with local people were performed during the field study, giving the project group new insights and knowledge regarding the East African culture. A number of interesting needs and areas for future product development was identified, and after consulting Zanrec Plastics and supervisors, school furniture was selected as the most interesting area. The current need for functional school furniture in Zanzibar is big, and it is need that most likely can be translated to other developing parts of the world.

The product development phase was carried out at Chalmers in Sweden. With respect to the gained knowledge regarding the local market and its environment, and with respects to other important considerations, such as ergonomics, several demands and requirements for the school furniture were defined. A number of concepts were developed and evaluated against these demands in an iterative process. The concept that best fulfilled the demands and the requirements from both the user, Zanrec Plastics, and potential investors, was then further developed.

The final result is a unique set of modular school furniture, made entirely out of plastic material. The furniture have been design to fit primary school children in East Africa, meaning that the furniture are ergonomically adapted to the children, providing them with better workspaces than the current furniture. As Zanrec Plastics wishes to educate the local community in terms of sustainability and recycling, these new school furniture will work as excellent educational products within an educational environment. The modularity of the furniture makes them easy to transport and thus facilitates export to other areas in need. The products can be produced locally in Zanzibar and assembled only using a few local tools. The result of this Master's thesis is consequently a sustainable outcome that includes both social and environmental sustainability aspects, as it provides work opportunities in the local community as well as introduces a life cycle opportunity for plastic material.

Keywords: recycling of plastic, Zanzibar, East Africa, field study, product development for developing countries, emerging markets, sustainable product development, school furniture.

Preface

This report is the final outcome of a Master's thesis; the final examination for a Master of Science in Industrial Design Engineering at Chalmers University of Technology in Gothenburg, Sweden. It was carried out during 2011 in cooperation with Zanrec Plastics. We would like to thank all of those who have, in one way or the other, contributed to the success of this project.

A special thanks to our examiner Örjan Söderberg and supervisor Thomas Nyström at Chalmers for supporting, guiding, and believing in us throughout this process. Also, we would like to express our gratitude towards Fredrik Alfredsson and Erik Gulbrandsen at Zanrec Plastics for all their valuable input and support, both in Sweden as well as in Zanzibar.

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Also, we would like to thank Yvonne Young, coordinator of the Minor Field Study scholarship at Chalmers, and the people at SIDA, Internationella Programkontoret as well as Sveriges Ingenjörer for supporting our project financially.

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Last but not least, we would like to thank our families and friends for encouraging us and bearing with us during this journey.

Anna Engström and Ellen Österdahl

Gothenburg, 2011

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Introduction

1. Introduction

In this chapter, the background and aim for this Master's thesis are described. The project time line and limitations are also presented followed by an explanation of the report outline.

This Master's thesis has been performed in cooperation with Zanrec Plastic, and comprises of two parts; firstly a field study, carried out in Tanzania, followed by a product development phase, executed in Sweden. This thesis differs somewhat from other Master's thesis performed at the programme Industrial Design Engineering, since big emphasis has been on the field study itself. This includes extra attention to cultural adaptation, as well as identifying and solving a local problem on the island of Zanzibar, in Tanzania, where the field study was held.

1.1 Background

As the population of the world grows, the need for more efficient solid waste management increases, especially in urban areas in developing countries. In these countries there is often a lack of knowledge regarding the consequences of not having a developed solid waste management system, which also is why there today often are no, or very inadequate, systems available. As the industrialism and consumer behaviour of the western society spreads to the developing countries, the lack of these resources grows to an even bigger problem. The environmental impact of not dealing with the waste is great which is why there is an imminent need for a sustainable solid waste management focus in the entire world. One step on the way to a more sustainable society is to reduce, reuse and recycle a lot of the materials and product used today. This is something that Zanrec Plastics have recognised and it is the reason they were initiated.

1.1.1 The company

Zanrec Plastics is a small Swedish company, founded in 2009, that has recognised the need for a better solid waste management system in East Africa. The company aims at creating and developing a scalable waste recycling system suitable for developing countries, starting on the island of Zanzibar just outside the coast of Tanzania in East Africa (Zanrec Plastics, 2011). Their work is built around three milestones; a collection system, a processing plant, and an educational package regarding future sustainable development. The educational package aims at securing the knowledge regarding the importance of recycling among the local population, thus creating an important foundation for the intended recycling system. During the time of writing, Zanrec Plastics had not implemented their business concept, but were initiating collaborations with local authority and Non-governmental Organisations (NGOs). As mentioned above, this Master's thesis have been performed in cooperation with Zanrec Plastics, with the intention to assist the company to identify interesting areas in the local society, where the recycle plastic material can be used, and thereafter develop this product.

1.2 Aim and goal

To substantialise the multifaceted aim of this project, the project group decided to divide it in three levels; effect goal, project aim, and finally product aim.

1.2.1 Effect goal

The effect goals comprises of the desired effect and impact that the future product should give. These are:

- Reduce plastic waste in Zanzibar
- Introduce a life cycle opportunity for plastic material
- Increase the insight regarding the life-cycle of plastic material among the local population
- Create work opportunities within the local community

1.2.2 Project aim

The aim of this project is to utilise recycled plastic material as a basis for development of a new product, made partially or fully from recycled plastic. The aim is also to identify a need on the local market that can

be fulfilled by this plastic product. The local market is defined as East Africa with a primary focus on the island of Zanzibar.

Finally, a third aim is that the product development process should result in a sustainable outcome that considers both social and environmental aspects. The social aspects mainly concerns the adaption of the product to local production methods, thus providing work opportunities in the local community. The primary attention regarding the environmental factor is about the plastic material, its availability and the possibility of a sustainable life-cycle.

1.2.3 Product aim

The product aim includes tangible aims for the product:

- Utilise plastic waste material as a basis for development of a new product (made partially or fully from recycled plastic)
- Conform the product to the East African culture in terms of aesthetics and behaviour
- Satisfy an observed need on the local market
- Enable a local production/assembly/disassembly of the product
- Facilitate future reuse and/or recycling of the product

1.3 Limitations

With respect to the huge existing market for developing countries, and the fact that Zanrec Plastics is a small, newly founded company, the following limitations for the thesis was set up:

- The thesis will primarily focus on the culture in Zanzibar, and somewhat on the culture in the rest of East Africa, whereas the possible implementation of the final result in other developing countries will be of lower priority.
- The idea generation will be guided and limited by the manufacturing possibilities of Zanrec Plastics.
- The project focus will be on developing a new product (made from recycled plastic) with a sustainable life-cycle, meaning that the entire plastic material flow in Zanzibar will not be designed.
- Considerations will be taken to the fact that Zanrec Plastics is a new company with limited resources.
- No detailed construction drawings or calculations will be made.

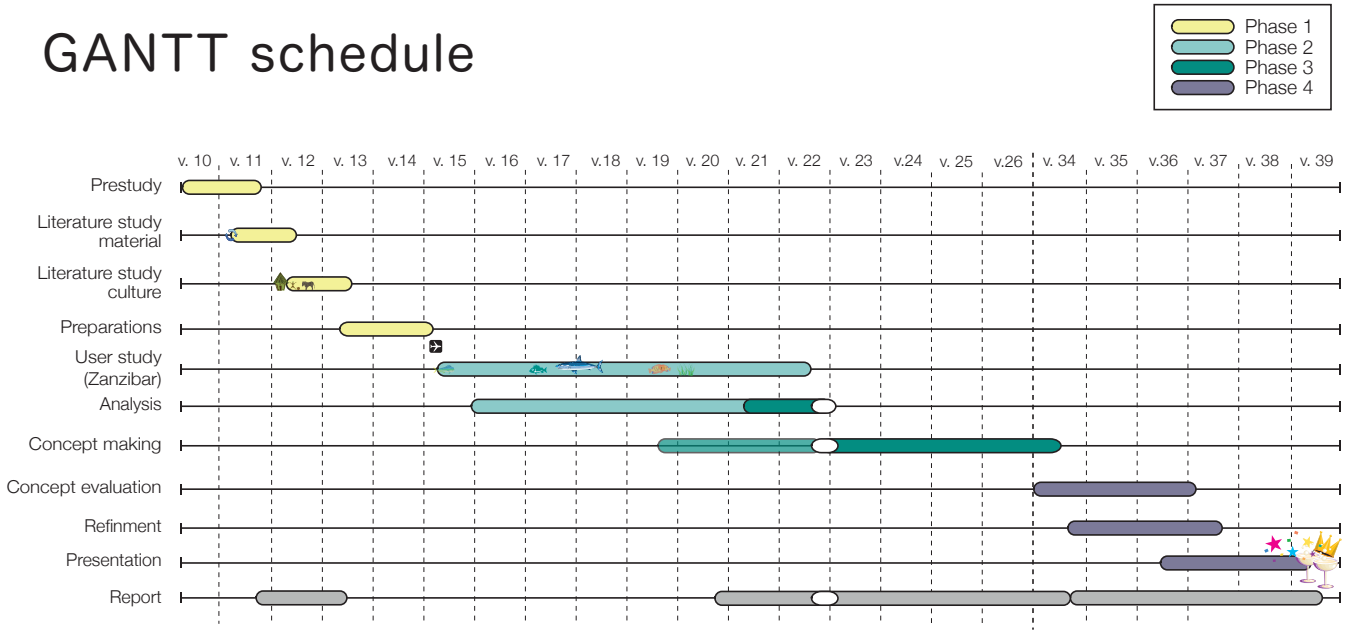


Figure 1. Gantt schedule, version 1

1.4 Project plan

As the project started, an initial time frame for the project was set up. The plan was divided in to four different phases: pre-study, field study, product development, and evaluation and finalisation. See Figure 1 for the entire time plan in its original version. After returning from the field study in Zanzibar, the plan was adjusted somewhat (Appendix 1) since the project group realised that more time was needed in order to accomplish and fulfil the aim of the thesis.

1.5 Report outline

The outline of this report mainly follows the way the project has been executed, see Figure 2. The following chapter, chapter 2, includes all theory and information that were gathered during the project and that have been used as a foundation for many of the decisions taken. The third chapter explains the different methods used during all four phases of the project. This is followed by the Field Study chapter, chapter 4, which includes information about the implementation of the study as well as the results and conclusion of it. In the fifth chapter, called Product Development, the ideation and concept development are described followed by the evaluation and selection of concepts, as well as the further development and refinement of the chosen concept. Subsequently the final result is presented in chapter 6. The different phases of the project, as well as the final result, are discussed in chapter 7. This chapter also includes recommendations for Zanrec Plastics regarding the result of this thesis. Finally, chapter 8 contains a conclusion of the project.

The report is structured so that readers do not have to read the report continuously from beginning till end. The Theory chapter and the Methods chapter, for instance, can be regarded as sections that includes supporting information for those readers who are unfamiliar with the terminology and methods, and they are thus not necessary to study before continuing with other chapters.

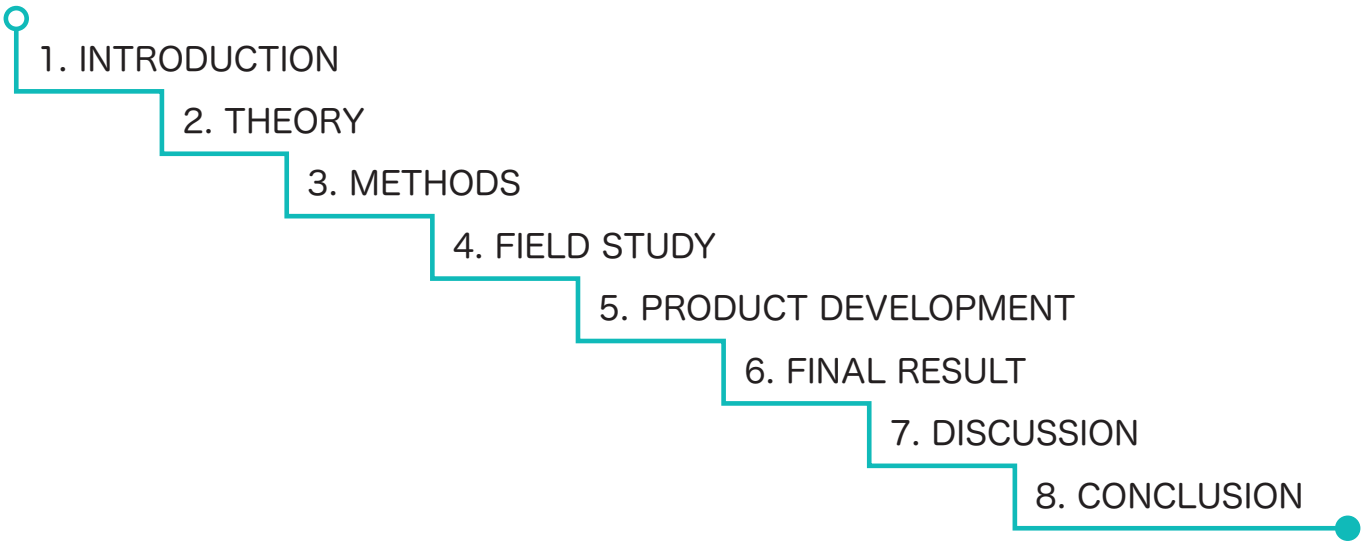


Figure 2. Report outline

Theory and Methodology

Flag of Tanzania

Flag of Zanzibar

2. Theory

In this section, the most relevant result of the literature study is presented. Firstly, the island of Zanzibar is examined, and the cultural and societal structure are presented. Following this is a cultural comparison between East Africa and Sweden, and some considerations when working in emerging markets. Later on, attention is taken to the technical specifics regarding plastic material and its recycling, as well as solid waste management and manufacturing processes. Finally, a section about ergonomics regarding sitting and writing is presented.

2.1 Zanzibar

Since this Master's thesis is partially carried out in Zanzibar, a deeper understanding and knowledge base regarding the area is necessary. In this section, this general background information is concluded.

Zanzibar is a semi-autonomous group of islands in the Indian Ocean, 35 kilometres off the coast, belonging to the United Republic of Tanzania (Finke, 2010). Zanzibar compromises a total area of 2 643 square kilometres (roughly the same size as the province Blekinge in Sweden). The two biggest islands are Unguja and Pemba, the former being the largest of the two and commonly referred to as Zanzibar. Zanzibar City is the capital of the region, with approximately 200 000 inhabitants, and consists of the two areas Stone Town and Ng'ambo. The region is known for its beautiful beaches, exotic wildlife and spice plantations. The main language in Zanzibar is Swahili, though English is also spoken widely and Arabic to some extent. The currency used is Tanzanian shilling (TSH), where TSH 10 000 corresponds to roughly USD 6 (Oanda, 2011).

2.1.1 History and politics

Zanzibar history starts sometime around the first millennium when the Bantu-people explored the archipelago (Fitzpatrick, 2008). Around the 8th century, the area became an important trading link between Arabia and East Africa, as the Shirazi traders from Persia settled in Zanzibar. The Arabic influence on the area has been great; the religion of Islam and the Arabic architecture commonly found in Zanzibar being two results of it. Traditionally, Zanzibar exported trading goods such as slaves, gold, ivory and wood to places as distance as India, and eventually the production of spices grew large. During the 16th century, the Portuguese conquered Zanzibar, which had damaging effects on the trading and the economy. The Portuguese were soon challenged by the British, and a few years later by the Oman Arabs who took over the rule, and eventually the trading flourished again.

In the end of year 1963, Zanzibar gained its independence, but just a few month later, in the spring of 1964, as a result of a revolution, the president of Zanzibar united the region with Tanganyika, forming the United Republic of Tanzania (Larsen, 2008). Since then, the political situation in Zanzibar has been turbulent, and from time to time even violent (Finke, 2010). Today, the two parties Civic United Front (CUF) and Chama Cha Mapinduzi (CCM – the Revolutionary Party), which also are big politic parties on the mainland, dominate this semi-autonomous area. There have been a fierce rivalry between the parties, but during the latest election in November 2010 the two parties came to an agreement and the election was peaceful, resulting in a democracy no longer as restricted as before (Tanzanian Affairs, 2011). The current President of Zanzibar is Ali Mohamed Shein from the CCM, and the First Vice President is Maalim Seif Shariff Hamad from the CUF. In the House of Representatives there are today 81 members, where 50 members are elected by direct popular vote, ten members are appointed by the President, five are reserved for government-appointed regional commissioners, and fifteen are filled by women on a party basis in proportion to the elected seats. Finally, one seat is reserved for the Attorney-General. The members, as well as the President, serve five-year terms (Zanzibar House of Representatives, 2010).

2.1.2 Population

The total population in Zanzibar is around one million, of which 650 000 inhabits Unguja and 350 000 Pemba (Larsen, 2008). The population density is

much higher than the rest of Tanzania, that is, about 400 person per square kilometre compared to 40 on the mainland (Fitzpatrick, 2008). Most inhabitants are Swahili or Shirazi, that is of Afro-Arabian heritage (Finke, 2010). Zanzibar's position as a traditional trading port has led to a fusion of the two tribes, both between each other and with people of other descent, and today, telling one a part from the other visually is practically impossible. However, both populations actually originates from the Zanzibar Archipelago and from Kenya's Lamu Archipelago, even though their language, Swahili, today is spoken all over eastern and central Africa due the former slave trade. The literacy in Zanzibar, approximately 80%, is slightly higher than on the mainland, according to the government of Zanzibar.

2.1.3 Religion

In Zanzibar, unlike the rest of Tanzania, a person's identity is not as dependent on what tribe he or she belongs to. Finke (2010) writes that "several millennia of interactions with foreigners [...] have created a rich synthesis of culture and history, language and literature, music and architecture". As mentioned earlier, the Arabic influence in Zanzibar over the history has been great, one example being the religion of the island, Islam, which dates back to the 8th or 9th century. Almost all Zanzibari are Muslim, most belonging to Sunni Islam. Many locals have less orthodox beliefs, incorporating traditional beliefs such as offerings to ancestors. The belief in spirits is rather widespread and important on the islands, though, especially on Pemba island, more fundamentalist Islamic beliefs have increased during resent years (Finke, 2010).

2.1.4 Etiquette

In Tanzania, greetings are very important. It is pivotal to allow greetings to take time, and to ask how the other person is doing etcetera, even if your sole purpose is to ask for directions. When greeting, one shake hands with the other, and sometimes, when appropriate, one can touch the right elbow with the left hand as this is a way to show the other person respect.

One should never eat or pass things with the left hand. Also, one should receive gifts with the right or with both hands. It is important not to criticise the government and to respect authority.

Also, since the Zanzibaris are Muslim, one should dress according to their standards and expectations, meaning one ought to cover shoulders and necklines, and that skirts and trousers should be at least of knee-length. Finally, one should not kiss or show very affectionate emotions in public. (Fitzpatrick, 2008)

2.1.5 Economy

Tanzania, and especially the area of Zanzibar, is poor. The gross domestic product (GDP) of Zanzibar was USD 548 year 2009, compared to Sweden's USD 43,903 (UNdata, 2009). Zanzibar's biggest sources of income are tourism and agriculture, which together contributes to approximately 75 percent of the total GDP (International Labour Organization, 2010). The GDP growth rate was 6,5% during 2007 (Ministry of Finance and Economic Affairs, 2009). A widespread and persistent challenge in Zanzibar is unemployment. The unemployment rate was about seven percent during 2004, and, according the Zanzibar Strategy for Growth and Reduction of Poverty (The Revolutionary Government of Zanzibar, 2007), the goal was to decrease this rate to four percent during the coming six years. This would be accomplished partly by establishing small and medium enterprises (SME's) and by improving the performance and competitiveness of the existing ones (Ministry of Finance and Economic Affairs, 2009).

2.1.6 Transportation

Zanzibar is reached either by plane or boat. Flying from the capital of Tanzania, Dar es Salaam, takes approximately 30 minutes, while a boat trip lasts for two and a half hours (Fitzpatrick, 2008). There is no public transportation system on the islands, but a network of daladala (mini buses or other delivery vehicles) exists. Also, taxis and pikipiki (motorbikes) are commonly used for transportation. The taxis are substantially more expensive, but also much safer than the daladala.

2.2 Cultural differences

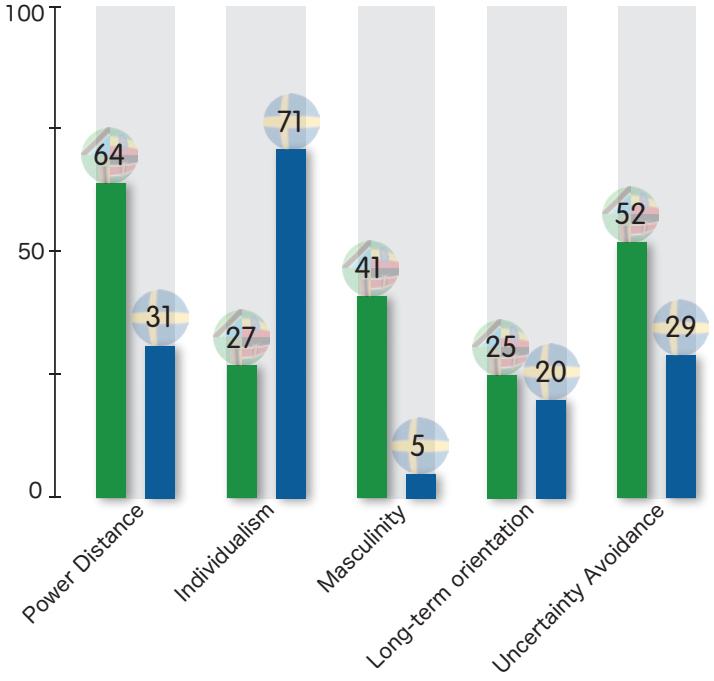
In this section, the cultural differences between East Africa and Sweden are assessed according to the theorem of Geert Hofstede, in order to create a deeper cultural understanding and enlightenment for the project group prior to visiting Zanzibar.

2.2.1 Cultural Dimensions according to Hofstede

Geert Hofstede is a Dutch social psychologist and anthropologist whose most notable work is the development of a theory, involving cultural dimensions to assess and differentiate national and organisational cultures (Baskerville, 2002). Four, of the currently five, national cultural dimensions were established in the 1970's, based on an attitude survey that the employees of a worldwide organisation (IBM) participated in, during a period of six years (from 1967 to 1973). These became the cornerstones of national cross-cultural research. The fifth dimension, long-term orientation, was added in 1991 after a greater consideration of Asia and the Pacific region. The dimensions have been widely accepted and Hofstede is now one of the most cited authors of social science (Mikov, 2011), but the usage of the dimensions is steadily spreading to other disciplines as well (Baskerville, 2002).

Followed is a comparison, of the five dimensions, between Sweden and East Africa. According to Hofstede, included in East Africa are Ethiopia, Kenya, Zambia and Tanzania. The score in Figure 3 represents Hofstede's ranking, and ranges from 1-100. The importance lies in the difference between the comparing countries, and not in the individual score.

Figure 3. An overview over the score of East Africa and Sweden in all five dimensions



Power distance

The East Africa ranking for Power Distance (PDI) is 64 versus Sweden's 31. A difference of 33.

Power distance is the extent to which the less powerful members of organisations and institutions (like the family) accept and expect that power is distributed unequally.

"A large degree of Power Distance means acceptance of a hierarchical order, in which everybody has a place and which needs no further justification. Whilst societies with a low Power Distance strive to equalise the distribution of power and demand justification for inequalities of power. It suggests that a society's level of inequality is endorsed by the followers as much as by the leaders. Power and inequality, of course, are extremely fundamental facts of any society and anybody with some international experience will be aware that 'all societies are unequal, but some are more unequal than others'"

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There is a significant difference in the comparing countries. In a cross-cultural cooperation it is therefore important to consider the fact that there is a major difference in the willingness and ability to question authority and to freely express ones point of view. In this particular situation Fitzpatrick (2008) states that not conforming to the more hierarchical East African culture produces a counter-active result, when for example one wants to negotiate something or get straight answers to questions. Thus it is important be polite and to keep in mind that some authorities and hierarchies are worth respecting. Also, in situations of collaborative group work, it's important to try and let everyone express themselves with out being "run over" by stronger individuals.

Individualism

The East Africa ranking for Individualism (IDV) is 27 versus Sweden's 71. A difference of 44.

Individualism is the degree to which individuals are integrated into groups or not.

"On the individualist side we find societies in which the ties between individuals are loose: everyone is expected to look after her/himself and her/his immediate family. On the collectivist side, we find societies in which people from birth onwards are integrated into strong, cohesive in-groups, often extended families (with uncles, aunts and grandparents) which continue protecting them in exchange for unquestioning loyalty. The word collectivism in this sense has no political meaning: it refers to the group, not to the state. Again, the issue addressed by this dimension is an extremely fundamental one, regarding all societies in the world."

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where the East Africa region and Sweden have the biggest difference. Most countries in the western world are strong individualists but on the other hand the amount of collaborative group work is something found to be more developed in this part of the world. This may sound like a contradiction, but it could actually be because of the high individualist score, which enforces the aptitude for an individual opinion, and which is one of the foundations for a constructive discussion amongst a group. This also relates to the hierarchical respect, or rather the lack thereof. In the collectivist culture of East Africa, the boundaries between family and village is rather fuzzy and a strive for collective achievement might be stronger.

Masculinity

The East Africa ranking for Masculinity (MAS) is 41 versus Sweden's 5. A difference of 36.

Masculinity versus its opposite; femininity, refers to the distribution of emotional roles between the genders which is another fundamental issue for any society.

"The masculinity side represents a preference in society for achievement, heroism, assertiveness and material reward for success. Society at large is more competitive. The femininity on the other hand, stands for a preference for co-operation, modesty, caring for the weak and quality of life."

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The values discussed in this aspect are reflected in group work as different expectations and presumptions regarding task divisions and expected feelings and reactions towards certain behaviours. It can be avoided by clearly discussing and arguing, but also keeping the different score in mind as a reference to the feelings/reactions in a certain situation. However, both countries are on the feminist side in this dimension, so the differences might not be particularly noticeable.

Long-term orientation

The East Africa ranking for Long-term orientation (LTO) is 25 versus Sweden's 20. A difference of 5.

Long-term oriented societies foster pragmatic virtues oriented towards future rewards, in particular saving, persistence, and adapting to changing circumstances. Short-term oriented societies foster virtues related to the past and present such as national pride, respect for tradition, preservation of "face", and fulfilling social obligations.

"Societies with a short-term orientation generally have a strong concern with establishing the absolute truth. They are normative in their thinking. They exhibit great respect for traditions, a relatively small propensity to save for the future and a focus on achieving quick results.

In societies with a long-term orientation people believe that truth depends very much on situation, context and time. They show an ability to adapt traditions to changed conditions, a strong tendency to save and invest, thriftiness, and perseverance in achieving results."

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Since the difference between the compared countries is very small, there is very little concern for a complete cultural clash in this dimension. However, it is always good to remember to respect their traditions and keeping in mind that it might differ.

Uncertainty Avoidance

The East Africa ranking for Uncertainty Avoidance (UAI) is 52 versus Sweden's 29. A difference of 23.

Uncertainty avoidance deals with a society's tolerance for uncertainty and ambiguity.

"Uncertainty avoidance indicates to what extent a culture programs its members to feel either uncomfortable or comfortable in unstructured situations. Unstructured situations are novel, unknown, surprising, different from usual. Uncertainty avoiding cultures try to minimise the possibility of such situations by strict laws and rules, safety and security measures, and on the philosophical and religious level by a belief in absolute Truth: "there can only be one Truth and we have it". People in uncertainty avoiding countries are also more emotional, and motivated by inner nervous energy.

The opposite type, uncertainty accepting cultures, are more tolerant of opinions different from what they are used to; they try to have as few rules as possible, and on the philosophical and religious level they are relativist and allow many currents to flow side by side. People within these cultures are more phlegmatic and contemplative, and not expected by their environment to express emotions."

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In this aspect, it is important to recognise that there are more rules and regulations in East Africa, written and unspoken, that need to be taken into consideration during the design phase. On a more social level, the religion plays a greater part, also with its own guidelines for behaviour and appearance.

2.3 Product development in developing countries

When developing products for emerging markets, there are four major areas that need to be taken into consideration in the local context; price-income levels, technology-developmental issues, capital constraints and finally; creativity (Chandra, 2008). The first factor is the most crucial one for a successful product implementation, much to do with the fact that the mean income level and purchase power is well below that of the industrialised world (meaning that most people would not be able to afford the products that are sold in the western world). This is one drawback for the big international companies when they want to launch a product in the developing world. The cost of actually constructing a new product so that it fits the developing market would be to high, so instead most companies tend to adjust one of their current product, resulting in a, far too expensive, product not well suited/adapted to the new environment. One suggestion that Chandra gives is to work backwards through the traditional product development process, thus starting with the limitations/constraints of the new product. There are two questions that could be asked, from a user/customer point of view, that works as a good starting point;

- At what price point would the low-income population be able to afford this product/service?
- What is the value-added element for the user? In other words, does the new product solve a user problem/need?

Starting with these answers, the development process could then work backwards, to generate products or services that would be adapted for these developing countries. To have this user driven approach, also known as a "market pull" (the opposite being technology push) is a foundation for successful product development and implementation in technological and capital deprived developing countries (Chandra, 2008).

In order to obtain these answers, the product developers need to spend some time in the intended culture to be able grasp the differences and possibilities for an effective development (Kandachar, de Jongh, and Diehl, 2009). Their mantra must be flexibility, communication and an open mind when visiting and engaging themselves within this new culture and context.

There is a market segment within developing countries, formulated by US business school academics Prahalad and Hart, called Base of the Pyramid (BoP) (Financial Times Lexicon, 2011). This refers to the people living on less than two dollars per day, which were about 2.6 million in 2005 (Shah, 2010). Prahalad and Hart states that companies can help eradicate poverty by providing goods and services for this, relatively un-targeted, market segment.

2.4 Plastics

Plastic is one of the most commonly used materials in the world, due to its wide range of properties and application possibilities.

2.4.1 What are plastics?

Plastics are combinations of polymers and additives. Polymers are giant molecules, constructed from long chains of monomers. There are three main classes of polymers; thermoplastics, thermosets and elastomers. Thermoplastics can be heated and formed, over and over again, and is most commonly used in consumer products. Thermosets, on the other hand, undergo a chemical change when they are heated, meaning that they can not be re-formed or easily recycled. Polymers are organic materials with properties that strongly depend upon the environment where they exist. In plastics, additives are combined with the polymers in order to change and/or strengthen the properties of the polymers. Additives can, for instance, prolong the life of the material or prevent it from degenerate under high temperature. Examples of additives are heat stabilisers, antioxidants, colorants and UV protection agents. (Lundquist, Leterrier, Sunderland and Månson, 2000).

2.4.2 Consumer plastics

In this report, consumer plastics refers to the plastics commonly used in consumer products. Most consumer plastics are thermoplastics; the most common being polyethylene, polyvinyl chloride, polypropylene, polyethylene terefthalate and polystyrene.

Polyethylene - PE

Polyethylene (PE) is a polyolefin and the most widely used polymer in the world, due to its low price and its many industrially important properties (Smith and Hashemi, 2006). The material is tough at room temperature, it has a good flexibility over a wide range of temperatures, it is corrosion resistant as well as odourless and tasteless. There are different types of polyethylene which derive from differences in the polymer chains, which results in variations in properties and thus also in application. These includes low-density polyethylene (LDPE), linear low-density polyethylene (LLDPE) and high-density polyethylene (HDPE). HDPE can be found in packaging, pipes, tanks, toys and bottles. (Goodship, 2007). Recycling homogenous HDPE is rather easy and the recycled material is attractive since it can be dyed into different colours. Recycled HDPE can for instance be used as plastic pipes, flower pots and trash cans. Low-density PE is somewhat softer that high-density PE, and is used in packaging, grocery bags, toys and lids. The recycling process of LDPE is similar to HDPE, with the exception that there are some special grinders used to handle plastic films made of LDPE. The recycled material can be used as trash bags, plastic tubing, agricultural film, etcetera (Lotfi, 2009).

Polypropylene - PP

Polypropylene is the second most commonly used consumer polymer. It is a semi-crystalline polymer, which makes the plastic white and milky. As a plastic film, the material is transparent and glossy, and therefore sometimes used as a bag and wrapping film for soft goods (Smith and Hashemi, 2006). The wide range of properties that the material has to offer makes it a very versatile material. It is stiffer and harder than polyethylene, which also makes it more brittle (Plastskolan, 1997). The material has a high heat resistance and rather good chemical resistance. According to Smith and Hashemi (2006), polypropylene is a high-quality material and is therefore used in, for instance, the automotive industry where the durability demands on the material are high. Other application areas of PP

are housewares, bottles of various types, rugs and battery casings (Goodship, 2007). Recycled polypropylene has similar properties to the virgin material (but of lesser quality), and is therefore also often used in similar products, such as in bottles, textiles, wraps and automotive products.

Polyvinyl chloride - PVC

Polyvinyl chloride is a widely used synthetic plastic that has been produced for more than 50 years (Brandrup et al., 1996). It is a vinyl polymer made by repeating vinyl groups. The material exists in many different varieties, both as homopolymer and copolymers, and has an unique ability to be mixed with a large number of compounds. Such compounds include heat stabilisers, lubricants, plasticisers, etcetera (Smith and Hashemi, 2006). The widespread use of PVC can partly be attributed to its high chemical resistance. The material also has good electrical isolation properties as well as a relatively high strength. Drawbacks with the material are for instance that it is brittle at low temperatures and that it poses a threat to human and environmental health by emitting dioxins, or other hazardous chemical compounds, when incinerated (Plastskolan, 1997). Application areas of the plastic are pipes, electrical wires, clothing, automotive interior parts, flooring, packaging, etcetera.

Recycling PVC is possible but expensive partly due to the high amount of additives in the material (Lotfi, 2009). The recycled material can be reused as for example pipes, profiles, bottles and packaging.

Polystyrene - PS

Polystyrene is the fourth largest thermoplastic in terms of tonnage (Smith and Hashemi, 2006). As a homopolymer, the material is crystal-clear, hard and glossy. Plastics made by this type of PS are often used for clear packages or disposable products (Plastskolan, 1997). Other applications of polystyrene include automotive interior parts, housewares, electrical devices, dials and knobs. Polystyrene has good electrical isolation properties but poor chemical resistance, poor UV resistance and it is relatively brittle unless modified. Such drawbacks can for instance be overcome by producing copolymers. Examples of styrene copolymers are SB (Styrene-butadiene), ABS (Acrylonitrile butadiene styrene) and SAN (Styrene-acrylonitrile).

Polystyrene has a high thermal stability which gives the material an advantage in the recycling of post-consumer parts. Brandrup et al. (1996) states that "To regenerate high-quality material, all that is needed is to clean it, separate foreign components and regrind it". Though, the level of purity of the regrind highly affects the scope for further using the regrind, meaning that the recycled material cannot be used for applications requiring bright colours or transparency. This applies to most recycled plastics. Recycled polystyrene is used as, for instance, flower pots, coat hangers, binders and as covers for the automotive industry.

Polyethylene terephtalate - PET

Polyethylene terephtalate is not as widely used as the previously mentioned plastics, but still an important consumer plastic. PET is a thermoplastic polyester and a very versatile material, thanks to its toughness, strength and easiness to shape and join (Smith and Hashemi, 2006). These properties are all favourable when it comes to reusing the material, meaning that recycling of PET is highly possible (CES EduPack, 2008). The most commonly known use of PET is as plastic bottles. PET bottles take less energy to produce than glass bottles and functions equally good, since the material is impervious to water and can withstand pressure from within, meaning it can be used for carbonated drinks. This crystal clear type of PET can also be found in films and as electrical isolation of high-voltage cables (Plastskolan, 1997). There is also an opaque version of PET that mainly is used for technical products, such as cog wheels and details in the automotive industry.

Recycled PET can be used to produced new plastic bottles or fibres and fleece material for clothing and carpets.

2.5 Recycling of plastics

The world's consumption of plastics is rising and so is the need for managing plastic waste (Practical Action, 2009). Throughout its entire life-cycle, plastic material affects the environment. For instance, most plastics are not biodegradable and could stay in nature for years after it has been thrown away, and it also produces unhealthy smoke when burned. To recycle the plastic is one solution to minimise these negative effects on nature. Another benefit with recycling is

that it minimises energy use and the need for nonrenewable resources. The charity organisation Practical Action (2009) also states provides a living for millions of people in developing countries, either through informal activities or formal employment, throughout the entire recycling process.

2.5.1 The process of recycling plastics

Goodship (2007) defines four different types of recycling:

- *Primary recycling* - mechanical in-house recycling where the waste material from the production is reprocessed. An economically smart recycling, since it reduces the production waste and the need for new raw material.
- *Secondary recycling* - mechanical recycling of single or mixed plastic materials from external sources. It can come in many different shapes and sizes and will most likely undergo a series of steps, for instance cleaning and regrinding, before it can be used as a raw material again.
- *Tertiary recycling* - chemical recycling, also called feedstock recycling, where the polymer is broken down in to smaller molecules, so that the material more easily can be separated in from impurities.
- *Quaternary recycling* - incineration, meaning that the plastic waste is burned.

This report will focus on the secondary recycling. In general, mechanical plastic recycling starts with the collection and sorting of the material from the different sources available, continuing with various washing methods as well as size reduction, see Figure 4. Throughout the process, the raw material increases in value due to the refinement.

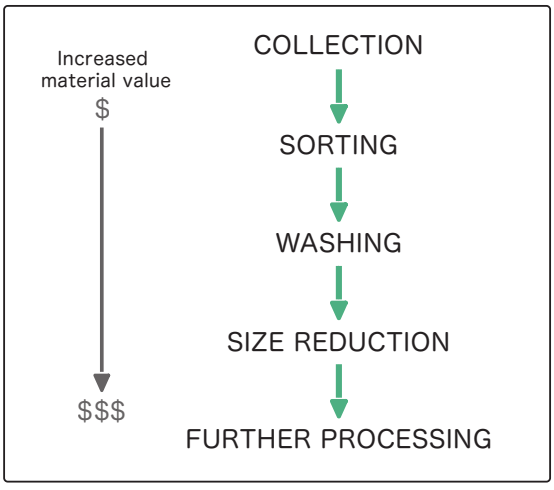


Figure 4. The process of plastic recycling

Collection

The importance of a well working collection system, with support from the locals, as well as an industrial acceptance, is the basis of a well working recycling system (Mustafa and Hansmann, 2003). Collection systems are most often locally adapted, meaning that depending on the scale and availability of plastics, different systems are used (Practical Action, 2009). There are for example formal systems of door to door collection, collection points and systems that depends on people collecting valuable material from the streets in return for payment.

Identification and sorting

After the collection of plastic material, it is necessary to identify the different plastic materials and sort them thereafter. Unfortunately, not all plastics are recyclable (Practical Action, 2009). A common problem is that plastic materials are often constructed out of more than one polymer, or that fibres are added to the material. It is possible to recycle such material, but the process becomes much more complex. The most commonly recycled plastic materials are PE, PP, PS and PVC (see section 2.4.2 for more information about the materials). If the plastic is not already marked, as in Figure 5, some simple tests can be made in order to identify - relatively accurate - what type of plastic it is. This type of identification is often performed manually, especially in developing countries, where labour costs are relatively low compared to machinery. Through water, burning and fingernail scratching tests one can examine the density, the melting point, and the hardness of the material. These simple tests are often enough to determine and sort the plastics. The value of the waste material increases substantially when the plastic has been sorted. By also sorting the plastic by colour or baling it the value can be further increased.

Washing

After sorting the material, it is necessary to clean it. Dirty plastic is a health risk and it impairs both the mechanical properties of the future recycled material whilst also wearing down the sharpness of the shredders in the following step of the recycling (Practical Action, 2009). Depending on the dirtiness of the plastic, different cleaning and washing steps are performed. For example, stickers are removed, remaining fluids are drained and both hot and cold washing is performed.

Size reduction

The next step in the plastic recycling process is the reduction of the size of the material. Brandrup (1996) states that the size reduction can also be done earlier in the process in order to reduce the volume of the plastic waste to a manageable size for smaller machines, or to make the material more dense for transportation/storage. In this later stage, it is performed in order to reshape the material into a form closer to the original raw material, which is beneficial for reprocessing. According to Brandrup (1996) there are different types of size reduction methods:

- *Cutting* with scissors, shears, saw etcetera. An initial size reduction of large objects, which can be a manual process.
- *Shredding* with a shredder, producing a pile of coarse irregularly shapes plastic flakes, which then can be further processed.
- *Agglomeration*, which is a pre-plasticising technique that consists of heating followed by rapid cooling. This process results in a significantly less bulky material, that only have been subject to thermal stress for a short time, but the method is costly and time consuming.

Further processing

When the material has been ground back to a suitable size, it can be reprocessed, creating new plastic products. If the waste stream is homogenous, it can be reprocessed on the same machinery as the virgin material is processed on (Goodship, 2007). Mixed plastic waste streams can also be processed, though it often requires some specialised reprocessing techniques, and the mechanical properties of the new product might be poorer than with a homogenous waste stream. In order to improve the mechanical properties, virgin material can be added to the waste stream.

Suitable reprocessing methods are for example extrusion and different types of moulding (Goodship, 2007).

2.5.2 The impact of plastic recycling

One reason for recycling plastic is for instance that it saves resources. By increasing plastic recycling one reduces the use of petroleum that is needed for new plastic products (Lofti, 2009). Another advantage with recycling plastic is that it decreases the amount of plastic that ends up in nature where it slowly degrades. In landfills, for instance, the polymers do not get sufficient UV exposure in order to degrade. The biggest problem with this though, might not be the polymer material itself, but rather the additives that have been added to the plastic material and that pollutes our nature. A disadvantage with plastic recycling, however, is that it requires a lot of energy to clean and prepare the material for recycling, which in some cases can be even higher than the energy needed to make new material. However, Mike Ashby (2006) claims that in most cases it is in fact the opposite, namely that the embodied energy of recycled plastic material is about half of the embodied energy for virgin material.

Not all plastics are easy to recycle (Lofti, 2009). Consumer plastics are normally marked by the numerical coding that was created in the late 1980's by the Society of the Plastics Industry, and which indicates what types of polymer a product is made from. There are six different types that are commonly used in consumer plastics, see Figure 5. Out of these polymers type 1 and 2, that is PET and HDPE, are the most commonly and most easily recycled.

Figure 5. Symbols for common consumer plastics

The most optimal recycling of plastic is achieved when the material is homogenous. If the polymers are mixed, the chance of a phase-separation is bigger (Lofti, 2009). This means that the different plastics separates, and sets in layers, like oil and water. The boundaries made over these layers causes structural weaknesses, meaning that the polymer blends are only useful in limited applications. In general, the mechanical properties of recycled plastic material decreases and the colour of the material tarnish (Plastportalen, n.d.). By carefully sorting the material according to the type of polymer and colour, this can be avoided to some extent, but in many cases one needs to add some virgin material into a product made from recycled plastic material in order to make it adequate.

2.5.3 Solid Waste Management in developing countries

Solid waste is defined as material that no longer has any value to its original owner and thus is discarded, according to the charity organisation Practical Action (2008). Plastic is one of the main constituents of solid waste, others being organic waste, paper, glass and metals. The handling of such waste is commonly referred to as Solid Waste Management (SWM).

As the population of the world grows, the need for efficient solid waste management increase, especially in urban areas in developing countries. Generally, the SWM in developing countries is less efficient and less developed than it is in developed countries. According to Practical Action (2008) most developed countries have formal door-to-door collection systems of solid waste, meaning that local authorities manages most, or all, household waste. In most developing countries however, the informal sector makes a significant contribution to the SWM. Practical Action have divided this informal contribution into the following areas:

- *Door-to-door waste collection*, which refers to when someone is informally contracted by the householder to collect, transfer and deposit the waste at transfer points. This is called primary collection. The secondary collection begins when the local authorities collects the waste from the transfer point and convey it to its final deposit.
- *Purchasing of valuable recyclable* items from households and small businesses, which reduces the overall burden of the SWM and recovers resources.
- *Waste picking*, referring to local people searching for recyclable material in the streets and on deposit grounds.

2.5.4 Recycling in developing countries

As mentioned earlier the amount of plastic waste in the world is increasing. This is true also in developing countries, even though the consumption of plastic is less than half in these countries, compared to the developed world. Practical Action (2009) however, states that ”there is a much wider scope for recycling in developing countries due to several factors”, one of them being that there is a wider range for the use of recycled plastic materials, such as for building materials, shoes, kitchen utensils etcetera. Also, in many developing countries there is an existing culture of reusing and recycling materials, making the recycling process easier within these cultures. Recycling in developing countries is also favourable since labour, transportation and raw material costs are low, giving a economical competitive advantage in the manufacturing world (Practical Action, 2009). Advanced recycling technology, on the other hand, is often not an option in developing countries due to limited funds, meaning that mechanical recycling is preferred in these countries.

2.6 Manufacturing methods

In this section, two relevant manufacturing methods are investigated. They are chosen for their simplicity of plastic manufacturing, alongside with a low tooling cost. The manufacturing method is a big concern during the concept development phase.

2.6.1 Rotation moulding

Rotation moulding is a process method ideal for hollow shapes. It is a simple and cost effective method to make larger components in low to medium series (up to 10.000 units) with a constant wall thickness (Thompson, 2007). The most commonly used material is polyethylene (PE), but other thermoplastics are also suitable. There is an option to add reinforcement fibres to increase the strength of the final product if needed. Tolerances are low compared to other plastic moulding processes, mainly due to shrinkage, cooling rates and the indeterminable wall thickness (Lefteri, 2007).

The process consists of four phases; powder distribution, rotation, heating, and cooling (Figure 6). Firstly, a predetermined amount of polymer powder is added to the mould. Then, while entering the heating chamber, the mould begins to rotate biaxially at a rate of approximately 15 turns per minute. The powder begins to melt and will start to tumble around inside the mould, where it builds up on the walls due to the centripetal force, thus creating a hollow shape (Lefteri, 2007). While the rotation continues, the mould is transferred into a cooling chamber. This final step is the most crucial for the quality of the product and also the determinable factor for the overall cycle time. If the cooling is done to hastily, the final product might build up internal stress concentrations. (Edshammar, 2006)

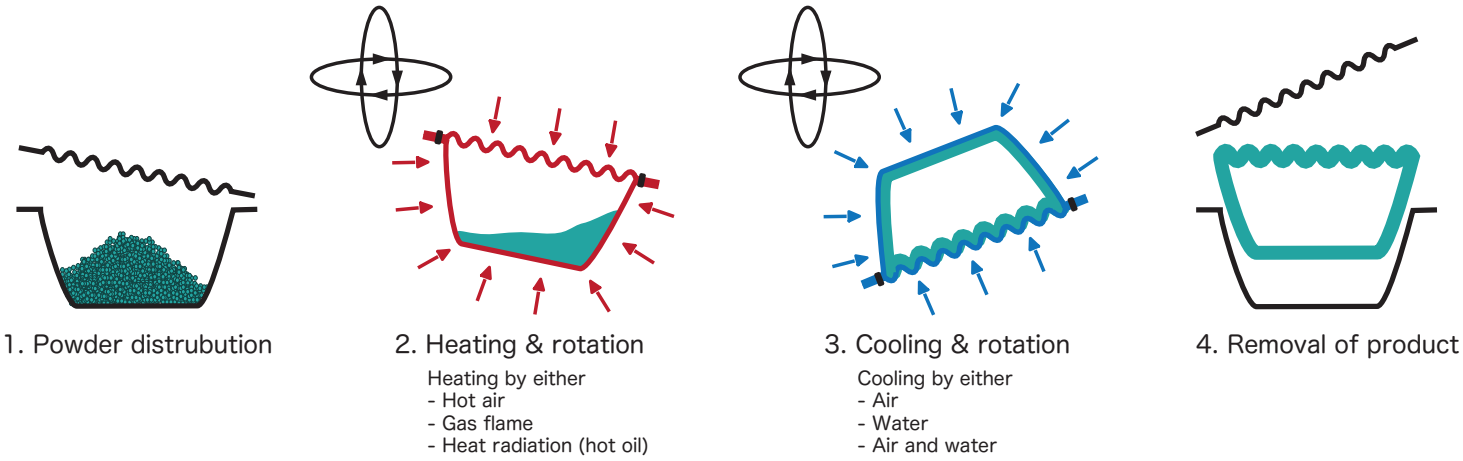


Figure 6. The four steps of rotation moulding

It usually takes about 30 minutes to 60 minutes to complete one full cycle, depending on the size and complexity of the product, and it is a semi-automatic process, meaning that manual labour is required. Since there is no pressure added in the process, the result is usually a stress free product, provided that the mould is constructed properly. That is, no sharp edges, small radii, or finer detail. Also, a glossy finish is hard to produce. The mould is most often made from metal; either casted aluminium or steel. There is no mechanical load on the form, only thermal. The main requirements for the mould are that it has good heat conductivity and can be able to sustain more than 300 degrees Celsius.

Some commonly rotational moulded products are canoes, water and gasoline tanks, toys and outdoor furniture.

2.6.2 Extrusion

Extrusion is a process to create bars with a constant cross section. Preferable materials to use are those with higher viscosity and low melting point such as most polymers, but aluminium, magnesium, copper and some ceramics are also possible (Lefteri, 2007). The size of the product can vary from a thin tread to big tubes (2000 millimetres in diameter) (Edshammar, 2005) and the extrusion speed can be up to 20 meters per hour (Lefteri, 2007).

The process starts with the feeder, where the material granulate is dispensed. A rotating screw feeds the material through a cylinder, containing heating and cooling elements. This thermal subjection in combination with the mechanical friction, between the screw and the inner walls of the cylinder, melts the granulate into a viscose liquid. At the end of the cylinder, a filter is placed, to sort out any remaining granulate, or other impurities, in the liquid before it exits through the cooled die. The material is solidified when passing through the die. The die is normally followed by some type of pull-mechanism with additional cooling baths and forming elements as a final process step. After this, the product is cut to desired length (Plastportalen, n.d.).

Important factors for a successful extrusion includes an even flow of material (Plastportalen, n.d.), the correct temperature and a durable and corrosion resistant screw. It is hard to maintain high tolerances due to wear of the die. (Lefteri, 2007)

Some examples of commonly extruded products are; toothpaste, rails, foils, tubes and hoses. So it is possible to make a lot of different products, but the machinery quickly becomes very complex and thus expensive (Edshammar, 2005).

2.7 Ergonomics

In this section, an introduction to the ergonomics of sitting and writing is presented. This theory is the foundation of some of the design decisions taken later during the product development process.

2.7.1 Sitting and writing issues

Sitting is not the most natural posture for our body, it is rather designed for upright positions and movements (Osvalder et al., 2006). Despite this, most people spend several hours each day in seated working positions. Prolonged sitting leads to several negative neurological and physiological problems. For instance, the vertebrae in the spine becomes more compressed during sitting than during standing, due to deviation from the natural S-shaped curve of the spine (Figure 7). Our breathing and digestion are also affected negatively by sitting, which in turn affects the attentiveness. Due to the discomfort caused by sitting, people tend to switch their sitting posture often, which is good for the body. Pheasant (1996) states that "In general, a varied working posture is better than a fixed working posture" and that prolonged static postures can lead to strain injuries and similar. When sitting in an upright posture, the muscular load is high, since only the musculature of the back has to carry and support the trunk of the body (Osvalder et al., 2006). A backrest deceases this load significantly and is thus preferred.

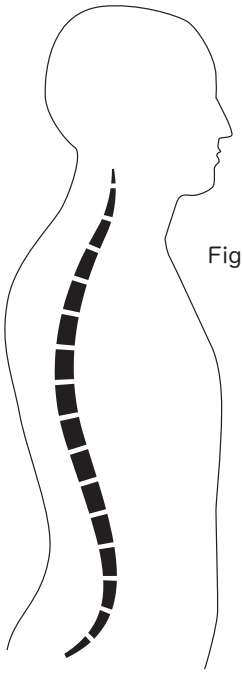


Figure 7. The S-shaped curve of the spine

When it comes to writing, good arm-support is important (Utriainen, n.d.). Unfortunately it is common to lean over to the passive side when writing, thus resulting in an uneven pressure on the sitting bones. Another important issue to consider is the readability. When we have our head in an upright position, our eyes will naturally assume a slightly downwards gaze of approximately 10-15° (Pheasant, 1996). To avoid having to bend our neck when sitting by a table and writing and reading, a slightly angled surface is preferred (Utriainen, n.d.). This will facilitates seeing and reading what have been written.

2.7.2 School furniture

School children remain seated in their school furniture several hours each day, many of them in bad sitting postures (Utriainen, n.d.). For instance, children have repeatedly been observed sitting without back-support, with the upper body bent forward, with hunched shoulders or slouched in the chairs. These static postures puts an extreme physiological strain on the muscles, the ligaments and in particular on the intervertebral discs (Panagiotopoulou et al, 2004). The students' sitting postures are affected by the activity performed in the classroom and by the design of the school furniture. For instance, too high or low desks or badly adapted chairs can be reasons for damaging postures. Ergonomically adapted furniture are even more important for children than for adults, since sitting habits are formed during young age. In order to design furniture that promotes proper postures, anthropometric data of the intended users should be studied and used as a basis for the design development. Figure 8 illustrates some of these data and measurements. For all suitable measurements for school furniture for children between 7-14 years, see Appendix 2.

Research have shown that besides ergonomically adapted furniture, the activity performed in the classroom and the attentiveness of the students also affects the posture of the students' bodies. Adaptable furniture and learning spaces can be used to facilitate this and have been shown to increase students learning and the seating comfort (HermanMiller, 2009).

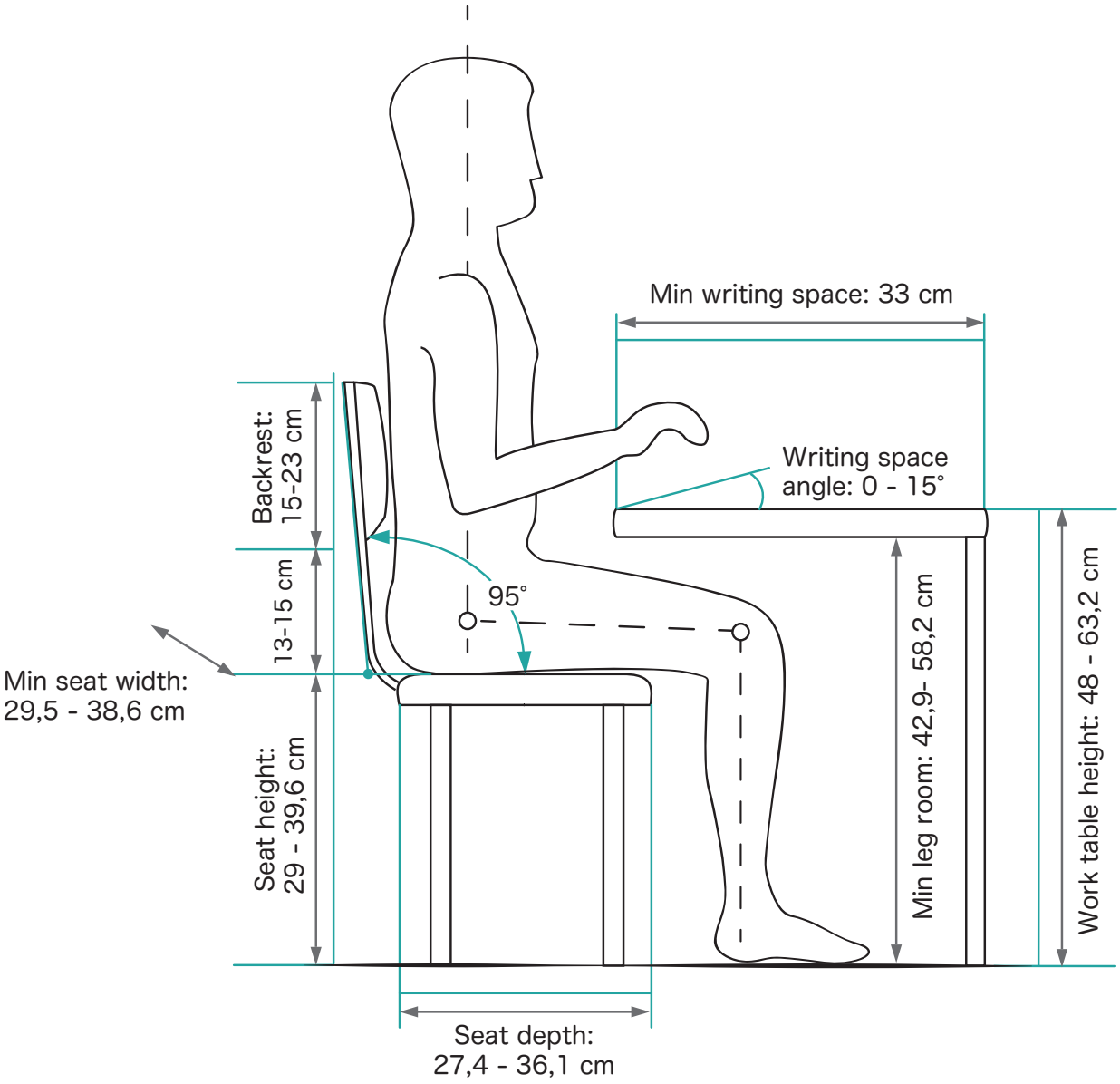


Figure 8. Ergonomic guidelines and anthropometric measurements for children, 7- 14 years, according to Diffrient, Harman, and Tilley (1981).

3. Methods

In this chapter, the methods and tools that have been used during the project are described in further detail. The methods are mainly presented in the order that they have been used by the project group, following the projects different phases.

3.1 Research and Design Methodology

A simple way to describe the design process is to divide it into two phases: analysis and synthesis. Industrial design engineering is a multidisciplinary field that bridges these two, by utilizing the result from the analysis as a knowledge base for the synthesis. The methodology in the analysis phase varies with the type of project, and thus borrows appropriate methodology from the relevant field. The synthesis phase originates in the analysis, as previously stated, and takes its methodology from the field of design, such as tools for ideation and creation.

3.1.1 Introductory methods

Introductory methods are those which sets the frames of a project. Both time management and group dynamics can be assessed during this phase.

Gantt-chart

A Gantt-chart is a type of a horizontal bar chart that runs along a time axis (Österlin, 2003). It is usually used for project planning in order to illustrate the start, finish and length of the different phases and elements that are included in the project. Some elements run parallel, called Concurrent Engineering.

3.1.2 Data collection

In this section the methods used during the data collection phase are described.

Literature study

A literature study is performed in order to find published information about subjects relevant to the project. The information can be found in books, articles and in Internet databases and should supplement the project research studies.

Interviews

Interviews are well-known methods used to collect opinions and information from and about users, customers, and other interesting parties. There are several types of interviews: personal interviews, phone interviews, and group interviews. An interview can result in either qualitative and quantitative information depending on its framing (Johannesson, Persson and Pettersson, 2004). A formal and structured interview, where the questions have been prepared beforehand, and where there are strict guidelines for the processing of the answers, results in mainly quantitative data. This data can later be analysed statistically. Qualitative data, such as emotional opinions regarding a product, are more easily obtained by semi-structured or unstructured interviews with open-end questions. These interviews can be either formal or informal, and allows for deeper understanding and discussions.

Observations

Observations allows researchers to gather information, draw conclusions, and document the process of certain situations (Lundequist, 1995). For instance, one can study user interactions with products in its true environment. Observation can be either direct or indirect. Indirect observations are hidden to the observed person, for instance trough the usage of cameras and other measuring devices. These types of observations often give a truthful result but the ethical dimension must be considered. During direct observations, the observed person normally know that he/she is being observed. These observations also include participating observations, where the observer joins in the observed situation, and self-observations. Direct observations are easily affected by the observer's presence but are still preferable since no ethical problems arise and since it is possible to learn about the observed person's reasons/motives behind certain actions.

3.1.3 Analysis

There are several methods to analyse the project as well as the objective and future product. Utilised in this project were the following.

Function analysis

The function analysis method is used to determine a product's main purpose and to analyse the functions of the product's different elements (Österlin, 2003). The analysis may result in a list of functions including main, partial, and support functions. To identify all functions of a product is very important, since the aim of product development is to establish the best possible way to accomplish these functions. The mapping of the functions is also an important prerequisite for the future specification of requirements of the product, as well as for the idea generation.

Specification of requirements

The specification of requirements is not really a method but rather a document based on the function analysis. The document includes the demands and requirements that the result of the product development process should fulfil, in other words that the future product should fulfil (Johannesson, Persson and Pettersson, 2004). The criteria are put together in a list and thereupon sorted, for instance in categories based on the different functions mapped in the function analysis. New demand and/or functions may be discovered during the course of time, meaning that the list of demands and requirements is a living document that can be updated and transformed during the product development process. The information in the specification of requirements can be used both as a starting point for the product development and as a reference when evaluating the future solutions, both individually and against each other. It is important that the criteria are clear, correct, and somewhat measurable in order to be able to perform these evaluations. Normally, the requirements in the list are divided in to ”wants” and ”needs”, where ”needs” are those that must be fulfilled by the final product and ”wants” are such that more or less could be fulfilled.

3.1.4 Creativity

Methods for creativity have been used in this project during the idea generation phase, to further spur the ideation, and to communicate a visual language.

Image board

Image boards are used to communicate an expression, feeling or attitude within a project group or to an external party (Michalko, 2006). It can also support the generation of ideas in product development by visualising the user, the context ,and the environment where the product will be used. The image board consists of a number of objects, most commonly pictures or photos, that visualises the desired expression. These pictures may include materials, colours, shapes, metaphors, etcetera.

Persona

A persona is a story about an intended user, that is created in order to relate more easily to this person, and to provide a focus for the design process (Jordan, 2008). The story gives an increased understanding regarding the entire life situation of the user, and can for example include information about goals, dreams, attitudes, work, and frustrations. The persona is based on interviews and observations of the intended user, which is then put together into a coherent story. Jordan (2008) states that it can be seen as an addition to traditional human-factors, since this is a discipline where most focus is on the human anthropometric and physical ability.

Brainstorming

Brainstorming was invented by Osborn in the 1930s and is today on of the most commonly used creativity method. Brainstorming sessions are performed in groups of minimum two people with the purpose of stimulating each participant to produce as many ideas as possible, during a short period of time (Österlin, 2003). One very important and characteristic principle of brainstorming is that no criticism is allow during the session in order to prevent inhibition. Crazy and unconventional thoughts are welcome in the brainstorming method, and combining, or developing ideas are encouraged. It is an advantage if the participants have different backgrounds, in order to produce as versatile ideas as possible. A brainstorming session can be design in different way and there are ways to facilitate more ideas or solutions, such as the technique brain-writing. During brain-writing each participant works on an own idea for a couple of minutes, after which the idea is passed on to another participator, who continues to develop the same idea and/or gets inspiration from this idea.

Morphology chart

A morphology chart is a tool that is used to produce different partial solutions, which thereafter are combined into several complete solutions (Johannesson, Persson and Pettersson, 2004). Different categories, or partial functions, of the product are distributed along the vertical axis in the chart, on which different solutions to each function is added horizontally (Wright, 1998). The solutions can be represented by either words or drawings, or combinations of both. When the chart is completed different complete solutions can be combined.

3.1.5 Visualisation

The following visualisation methods have been used in this project in order to produce presentable material that communicate ideas and solutions to external parties. Some of the following methods can also be considered as tools that facilitate the development of ideas, and that creates a common picture of what have been accomplished within the project group.

Sketching

Sketching is a tool that is used by product developers and designer to explore, communicate, visualise, and document ideas. A big advantage with sketching is that it is a quick and somewhat simple tool, which results in two-dimensional pictures. There are different types of sketches, with different levels of refinement, that have different purposes. Idea sketches, for instance, are ”quick and dirty” and used to quickly illustrate solutions. Photo realistic sketches, on the other hand, are quite accurate and used to for example promote the product, while technical drawings rather show hidden parts and other important technical information that is essential for manufacturing and assemblage (Österlin, 2003).

Physical models

The three-dimensional physical model is even more descriptive than the two-dimensional picture, especially if it is in full scale (Österlin, 2003). It is used to verify and evaluate shapes, functions, and solutions, but also to visualise and promote the final product to external parties. The physical models also have different characters with different purposes. For instance, the full scale, and not so detailed mock-up, is used to evaluate size and ergonomic parameters, while the prototype is a functional model of the final result.

CAD-models

Computer aided design, CAD, is a way to build three-dimensional objects by using computer software (Johannesson, Persson & Pettersson, 2004). There are several different CAD-software that assist during the phases of idea creation and product development. In the software, the product can be visually explored and tested. For instance, different shapes, colour, and materials can be experimented with, as well as the construction and strength of the product. In CAD-software, precise technical drawings can be produced, where the measurements with certainty corresponds to the physical product.

Different types of CAD-software produce different types of CAD-files. Some are surface models and others are solid models. Most CAD-software are however compatible with each other. In this project, the software Rhinoceros has been used to model the product. The result has thereafter been tested using the ergonomic analysis software called Jack.

3.1.5 Evaluation

Comparison chart

In a comparison chart demands and requirement are compared, two by two, in order to determine which are of greater significance (Johannesson, Persson & Pettersson, 2004). The demand that “wins” the most of the comparisons, scores highest and is thus the most important demand. The comparison chart results in the demands being sorted in order of priority, and can favourably be used to weigh the different demands in the specification of requirements.

Elimination chart

In the eliminations chart, different concepts and solutions are evaluated against a number of chosen requirements (Johannesson, Persson & Pettersson, 2004). The concepts are assigned either +, 0, or -, depending on how well they fulfil the requirement. All + and - are then summarised, and the concept with the highest total score is proceed with.

Pugh matrix

The Pugh matrix is a version of the elimination chart, where the different concepts and/or solutions are compared to a reference object, preferably the original solution or a competitive solution (Johannesson,

Persson & Pettersson, 2004). It is important not to use too many requirements in the evaluation, and rather choose the most important ones. When each concept is compared to the reference object, it will be assign a +, 0, or -, depending on whether the concept fulfils the requirement better, to the same extent, or worse than the reference object. After judging all concepts against all demands, the results is summarised and the concept that best fulfils the requirements advances. In the Pugh matrix, the different demands can also be weighted, so to that the most important demands play a more significant role.

EEA - Environmental Effect Analysis

EEA is a method which is used to map a product's, and all of its components', impact on the environment (Johannesson, Persson, and Petterson, 2004). The environmental impact in different stages of the product's life cycle is analysed and judged. These stages includes: resource utilisation, production, use, and end-of-life. Depending on the severity of the impact that a certain component has in a certain life-cycle phase, it is given different amounts of points, which then are concluded in a chart. Thereafter, the different environmental impacts and their consequences, which are summarised in the chart, can be concluded and judge in a lucid way.

Field study

Paje beach

Village life

City life

4. Field study

In this chapter, the field study performed in Zanzibar is explained and thereafter follows a summary of the observations made, and what they resulted in. Much of the information treated in this chapter is not directly connected to the future product development, but is of great importance for the understanding of the product context.

4.1 Introduction

This field study was supported by the Minor Field Study (MFS) scholarship, funded by SIDA, and took place in Zanzibar, Tanzania, during seven weeks (12th of April to 1st of June) in 2011. The scholarship also included a two-day preparation course, held by Internationella Programkontoret in Uppsala, which further prepared the project group for the field study and its challenges. The main purpose of the field study was to identify needs or problems on the island, which could be either solved or facilitated by a product made from recycled plastic material. Furthermore, another objective of the field study was to investigate the current waste management system in Zanzibar, including the local populations' understanding of it, and their perception of plastic as a material. The purpose was also to examine the possibilities of introducing a recycling system for plastics on the island. In order to achieve these purposes a deeper cultural knowledge was required, and thus constant observations and several interviews with the local inhabitants were carried out.

4.2 Implementation

Since the project group needed to get a deeper understanding of the culture and current organisational structure of Zanzibar, qualitative data was gathered through observations and interviews. The field study was guided by the suggestions from Kandachar, de Jongh and Diehl (2009), which are further explained in section 2.3. These suggestions, for instance, say that product developers need to spend time in the intended culture to be able grasp the differences and possibilities in order to have an effective development, and that they must be flexible and open minded when visiting and engaging themselves within this new culture and context. The project group tried to set their own cultural habits aside and keep an open mind, and seize every opportunity to participate in this new culture.

4.2.1 Observations

Observations were made continuously throughout the field study. The everyday life of the community was studied in the villages Paje, Bwejuu, Jambiani, Kitogani, Makunduchi and Nungwi, in and around the city Stone Town, as well as in Dar Es Salaam and Arusha on the main land. Also, more specifically, the project group was welcomed in to a few peoples' homes and joined Zanrec Plastics on study visits at local NGO's that handle plastic waste today. During these observations, the project group focused on identifying problem areas and needs, as well as on understanding the current waste management system.

The observations was documented by taking photos and by constantly taking notes.

4.2.2 Interviews

In the early phase of the field study, informal and unstructured interviews were held alongside observations and during conversations with local residents. Through these conversations the project group gained significant knowledge about the culture and norms in the society. Furthermore, three Scandinavian people currently living in Zanzibar, were interviewed (informally). These conversations proved to be very valuable since these persons had a viewpoint similar to the ones of the project group and they were able to describe interesting facts about norms and habits in Zanzibar in comparison to the Scandinavian culture.

Halfway through the field study, eight formal, semi-structured interviews were conducted in order to gather further qualitative data and thereby identifying points of interest for the future product development. A typical interview situation can be seen in Figure 9. These formal interviews were prepared in advanced, and the questions were used as guidelines for the interviews (see Appendix 3). The questions were sometimes altered in order to suit the current situation. In order to obtain qualitative data the interviewees

Figure 9. Interviews in Stone Town

were allowed to answer the questions openly. During each session, one group member acted as the interviewer, while the other took notes. The sessions were accompanied by Mr Rajab Ameir, Regional Agricultural Extension and Research Officer and member of the Seaweed Cluster Initiative, who helped with the translations and who also was the organiser of the interviews, meaning that he selected the eight participants. It was difficult for the project group to, on their own, arrange such sessions, and they thus utilised Mr Ameir's network. The eight participants were chosen for their different financial status (within the middle class segment), different occupation, as well as representatives for different districts of Stone Town. All interviews were held in the interviewee's home, in and around Stone Town, and the project group was allowed to document the houses by taking photos. With one exception, where the interviewee was a 23 year old man, all interviewees were women between 30-60 years old.

4.3 Result

Here, the general cultural observations of the field study are presented, followed by more specific results regarding plastic material and solid waste management. The recognised focus areas for possible future product development are described, with an in depth analysis of the final chosen focus area.

4.3.1 General cultural observations

In this section, general cultural observations that might influence the project, are concluded.

Politics

Since the latest election in November 2011, the political situation in Zanzibar has been stable. Throughout the island, campaign posters from the election can been seen, and people are free to show their political opinion. Clothes and scarves of the political parties are to be seen, and both men and women are allowed to visit political meetings. Even though comments regarding assumed corruption amongst politicians are sometimes overheard, the people in general seems satisfied with the political situation. This can probably be derived from the fact that the respect for authority in the country is very high, and questioning the government could have unwanted consequences. Furthermore, the inhabitants are presumably pleased with the fact that the violent history regarding politics seems to have come to and end.

Religion

The influence of the Islamic religion in Zanzibar is strong. This influence can be found in most situations and it truly permeates the everyday life of the population. Most people pray the five required times each day, the earliest praying session being around five in the morning, meaning that a majority of the population gets up early every day of the week. The men often pray in the mosques while the women pray at home. Before each praying session the body is cleaned.

Zanzibari women are dressed according to the Islamic culture in long dresses and veils, covering their entire body and hair. The clothing most commonly used in Zanzibar is the kanga, see Figure 10, consisting of two identical pieces of fabric with traditional East African design/patterns. Women of other religions, visiting or living in Zanzibar, should respect the dressing code

and wear clothes that cover at least their shoulders and knees. As in other Islamic societies, the dressing code of the men are not regulated in the same way as for the women. Men sometimes wears traditional shirts and kofia (Figure 10), especially if he is an elderly man, though the majority of the Zanzibari men are dressed in regular trousers and shirts.

The Islamic influence can to some extent also be traced to the food culture of Zanzibar. For instance, pork is never served. Alcoholic beverages can be found on the island but not in the Muslim homes.

As mentioned in section 2.1.3, the traditional East African belief in spirits exist in Zanzibar, but not to the same extent as on the mainland. However, traditional doctors, healing their patients through the extortion of spirits, can be found in some villages.

Gender equality

Since Zanzibar is a rather strict Islamic society, the gender equality is quite unbalanced, and women are often suppressed. It is common, especially in poor, uneducated families, that the women are responsible for the household and all the work performed in it, while the men are responsible of earning money for the family. In some of the visited families, this fact resulted in the women working for the family literally from dusk till dawn every day, while the men worked during approximately seven hours six days a week. The husband most often governs in the family, and it is common that he decides how the family's earnings and time should be spent.

Zanzibari men are allowed marry up to four wives, given that he has sufficient funds to support all wives. Women on the other hand, are only allowed to have one husband. Polygamy is an occurrence that is more common in the rural villages and amongst the more uneducated people.

Each village, or city district, in Zanzibar have a Shehe, a village chief. These chiefs are always elderly men, who together with the other senior men rule the villages.

In Zanzibar, socialising between genders is generally not accepted. Married women for instance, are sometimes not allowed to eat with other men if their own husband is not present. However, Zanzibar is slowly moving towards a more gender-equal society. Today, couples can get divorced and single working mothers are accepted, at least amongst the middle and upper class. There seems to be an ongoing change among the educated and the younger people.

The Zanzibari family, house and household

The Arabic history of Zanzibar has definitely put its mark on the architecture on the island. For instance, ornaments and typical arch-shaped doorways are common. Family houses often have the rooms arranged around a central courtyard. In this courtyard the families eat, socialise and relax. See Figure 11. The Zanzibari people interact a lot with their neighbours, they visit each others houses regularly and dinners are sometimes prepared jointly. Big families are common and there are often many persons and generations living together in the same household.

Figure 10. Kanga and Kofia

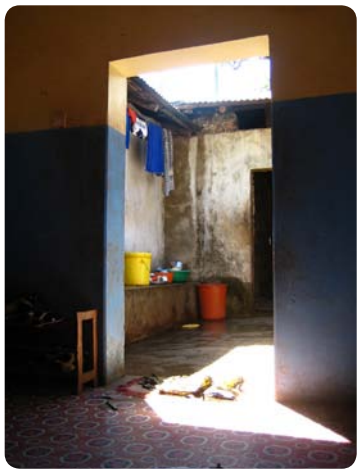


Figure 11. A typical courtyard

Figure 12. Swahili kitchen

Figure 13. From top; women cooking, a coconut grater, chapati stool, and typical Swahili cuisine

There are nursery schools for the younger children, but families must be able to afford the tuition in order have their sons and daughters there, so most children usually stay at home with their mother, or other relatives, until they start school at age seven. In school, boys and girls are in mixed classes and all children wear school uniforms. Normally, a child lives at home until he or she gets married.

As mentioned earlier, the husband most often is the provider of the family, although in some families other members also contribute. For instance, it is quite common that women prepare and sell different types of juices, or bake and sell breads. The Zanzibari people are very proud of their Swahili-cuisine. The food is prepared by the women who, most of the time, cooks on charcoal stoves on the floors in the traditional Swahili-kitchens, often outdoors or semi-outdoor (see Figure 12 and Figure 13). There are different kitchen tools, often made out of local materials such as different parts from the coconut-tree, that are used when preparing the food, see Figure 13. During dinner, the family is most often sitting on plastic carpets on the floor, either in the courtyard or in a special dining room. The Zanzibaris do not use cutlery when eating, instead they eat with their right hand and scoop up the sauce with the help of balls of rice and bread.

All the middle class families that the project group visited also had an additional western style kitchen, (indoors, stove, work bench, sink, cupboards) besides the traditional Swahili-kitchen, but these were almost exclusively used to prepare breakfast and simpler meals. The main part of the food preparations still took place in the Swahili-kitchen. Most likely, this is due to the recurring electrical shortages but also because of the strong presence of Swahili traditions.

Families with higher economic status often have housemaids that takes care of the household, or parts of it. Since the majority of families are very poor, compared to the western society, the amount of household tools and appliances in these families are very limited, meaning that the household work is mostly done by hand and is quite demanding and tiring. Furthermore, the Swahili traditions are not often questioned, leading to that the chores are performed in the same manner today as for a couple of hundred

years ago, with the exception/addition of some new material and smaller products. This equals quite undeveloped methods performed in straining working positions for the women. For instance, washing is generally done in basins on the floor, with the woman standing bent over the basin, see Figure 14.

Figure 14. Typical washing posture

Economy

The economic breach between the local population of Zanzibar and the visiting tourists is vast. An average monthly salary is about TSH 30 000, which is equal to less than USD 20 (Oanda, 2011). Few families can save money each month, and most people live on a day-to-day-basis, meaning that the money they earn during the day is immediately spent on food for the evening. Even some of the middle class families that the project group visited had a hard time saving money, and the biggest investment/expense for these families were often necessary reparations of their house or similar. Travelling is truly a luxury to the islanders and most people have hardly ever left Zanzibar and even fewer have travelled outside of Tanzania.

The consumer behaviour in Tanzania is quite different to the one in the western society. Even the more wealthy people of Zanzibar do not own the amount of products that the poorer people in western counties do. This is reflected in the homes of the Zanzibari, which are quite sparsely decorated (Figure 15) and where only the most necessary things can be found. Many of the interviewees claimed that they were not so affected by commercials. However, there are commercial slogans and logos painted on almost every house or roof, advertising for example local telephone companies or local beer, which the people are most likely subconsciously affected by. Also, the generally low income affects their purchasing behaviour. Since they have only limited money to spend, they really shop around before making a purchase decision, which often included a bit of bargaining as well. Information about new products are often spread by word of mouth. Most things are sold in the markets or through specialised shops (the plastic bucket shop, the meat shop, the fabric shop, etcetera) The bigger malls, where there is one big store that sells everything, has just started to arrive on the main land.

Figure 15. Plastic product shop and sparsely decorated livingroom

Aesthetics

What is considered to be beautiful is of course an individual measurement, but it is also affected by our culture and surroundings. The East African population is not as easily affected by trends in product design and clothing as the European population, since the consumption of products in East Africa is much lower. What can be said about the East African and Zanzibari aesthetics is that it is colourful and full of patterns, especially in terms of clothing. In Zanzibar, furniture are rather big than slim, and ornaments are very common, which most probably can be traced to the Arabic influence on Zanzibar. As mentioned previously, a reoccurring form element is the Arabic arch, which can mainly be found in typical doorways, but also in furniture and as graphical elements. Even though the homes of the Zanzibari are sparsely decorated, most people have a small shelf with small ornaments, or with their most fancy china. During interviews, most women expressed an affection for glass as a material. In Figure 16, a selection of photos depicting the Zanzibari aesthetics can be seen.

Figure 16. Zanzibari ornaments and aesthetics

4.3.2 Comparison to Hofstede

On a general note, the Hofstede assumption proved rather correct. East Africa is, as well as Sweden, short-term oriented, but maybe for a different reason. There is a national pride, respect for traditions and a strive for quick results. Not many save for the future, but not because they do not want to, simply because they can not due to the economic situation.

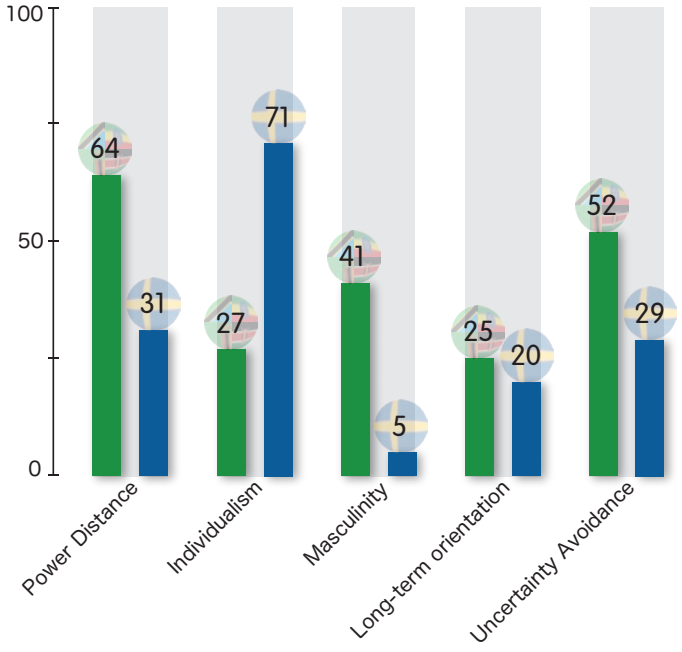


Figure 17. Hofstede-diagram

Zanzibar is a very hierarchical culture (Figure 17), which goes hand in hand with the higher power distribution score of East Africa. During the interviews it became clear that in order to make a change in their living behaviour, all interviewees wanted the initiative to come from above, from their Shehe or even the president. Furthermore they showed a reluctancy to question the authorities and they felt inhibited to freely express their point of view. After the recently initiated collaboration of the political parties however, the acceptance to express ones political point of view has become much freer. As the project group were viewed as an authority, being educated Westerners, this could in praxis mean that some were keen to gain the respect of the project group. However, the project group consisted of women only which, in their regard, is of lower status.

As mentioned previously, women do most of the traditional chores, such as taking care of the house and children while the men are at work. The men have a big say on what goes on in the family and the decide what to spend money on. This is directly in line with a more masculine society, where task division is not equally distributed between the genders. Although, it is generally more accepted in Zanzibar, compared to Sweden, for men to display their emotions, but this

is most often done without women present. It is also socially acceptable for men to hold hands in public as a way to show affection.

The collectivist culture of East Africa was also well rooted in Zanzibar, with a big loyalty towards your extended family. Cousins were often referred to as ”brother/sister” and a lot was done that could benefit the family as a whole. But on the other hand, there was a constant struggle to put food on the table every day, with the likelihood of a more individualistic approach where you fight for your own right to exist.

There are more rules in Zanzibar than in Sweden, especially originated from religion, that permeates the every day life on the island. This was noted in, for example, the five praying occurrences each day, that most Zanzibari followed.

As a conclusion, the project group felt more as spectators than participants in this culture, and were less involved than if the field study were to have taken place in, for example, an European country. The challenge for the project group was the mixture of trying to understand the culture, in combination with wanting to fit in and not upsetting the locals due to cultural ignorance.

4.3.3 Plastic and waste management

During observations, and mainly during the formal interviews, the project group gathered a lot of valuable information regarding the current waste management system in Zanzibar, but also concerning the local peoples’ attitudes towards it and their ideas about plastic as a material. This information is concluded in this section.

Solid Waste Management in Zanzibar

The interviews held by the project group showed that there are different ways that the private households deals with their garbage in Zanzibar, see Figure 18-20.

In the city the waste is first taken to a mini-dump, referred to as primary collection in section 2.5.3. The transfer of waste to the mini-dump is done either formally, by a contracted municipal employee, or informally, by the individual persons or by persons hired by the household. Thereafter the waste is collected with trucks and driven to the big dump just outside Stone Town, see Figure 18. This dump was initiated in 2007 and has grown tremendously since then. Every once in a while, the garbage pile is burnt in order to decrease it slightly. At the dump waste picking occurs now and then, meaning that people search the dump for valuable material. On the country side, the most common way of dealing with your trash is to throw it out on your backyard, see Figure 19. In one visited family, the children were allowed, and even encouraged, to play with the garbage before it “naturally” disintegrated into the nature. This behaviour is most probably connected to the belief that plastic can be treated as organic waste and that it will moulder in much the same way. According to Michael Juel, from NIRAS (an international multidisciplinary consultancy company, www.niras.com) who is currently working with environmental questions on Zanzibar, roughly 80% of the waste today is organic. The knowledge of dealing with other types of waste is limited amongst the general population. The plastic products that mostly exist in the every day life are, besides the occasional food-packaging, mostly bottles, containers, chairs, and buckets and thus not things that are thrown out every day. There is a culture of reuse in Zanzibar which, as mentioned in section 2.5.4, is common in developing countries and leads to even less plastic waste. For instance, PET-bottles are used over and over again, for instance as containers for water and homemade juices, and as pots, building material, scoops, etcetera. PET-bottles are currently one of the biggest plastic sources in Zanzibar, as many tourist visits the island and consume a multitude of bottles each day.

Figure 18. The waste management system in the city

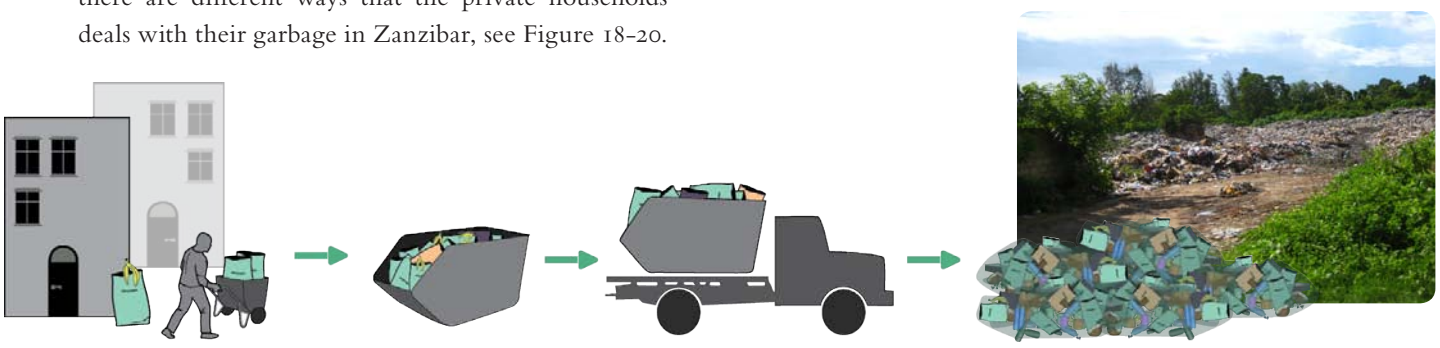


Figure 19. Waste management on the country side

Figure 20. Waste management in smaller villages

In some countryside villages mutual waste dumps exists, most of which are burned once in a while, see Figure 20. In the village of Paje, a garbage-house has been build by Scandinavian students from the Zanzibar Adventure School (www.zanzibar-hojskolen.dk). The idea was that the local hotels would pay a small fee for each of their guests, which in turn would finance a truck and employees, that would come and empty the house on a frequent basis, and thereafter transport the garbage to a "certified" dump. But this failed to settle in the local community, with the consequence that it now gets filled up but very seldom emptied. As shown in Figure 21, children now even use the house as a playing ground. This truly shows the importance of adapting and engaging a waste management system on a local level.

Solid waste management initiatives

There are currently small initiatives starting in Zanzibar regarding the waste management. Zanrec Plastics is one, as well as NIRAS, contracted by the local authorities to help with environmental issues. These initiatives are both indications on that the Tanzanian government is starting to realise the need for a more extensive environmental plan. Another example of this is a ban of plastic bags in Zanzibar that was initiated roughly five years ago and was successfully implemented. On the Tanzanian mainland, plastic bags exist, but only in some thicknesses and to a limited extent. Plastic bags have been the cause of some environmental issues, such as blocked drainage ditches and sewage systems, impaired land productivity and endangered livestock, which are the reason for this ban (Division for Sustainable Development, 2009). Instead, the government is encouraging industry owners and investors to produce alternative bags, such as paper bags. The UN Division for Sustainable Development (2009) also states that other, similar, solid waste management decisions have been taken by the Tanzanian government in the recent years.

There are currently two local Non-governmental Organisations (NGO's) that deals with different parts of the plastic waste chain. One in the town of Matembwe that collects garbage from some of the surrounding hotels and sorts it on a big field (see Figure 22). At this NGO, the glass is crushed and the plastic is pressed together into big plastic bundles. The materials are then transported to the mainland. Taking care

Figure 21. Children playing in garbage house

Figure 23. Zazi's shredding facility

of the waste from hotels seems to be quite profitable since the tourist consumes many PET-bottles each day. The other NGO is called Zasi and focuses mainly on processing plastic waste (see Figure 23). Zasi owns a small shredder for plastic that processes up to one tonne of plastic bottles per day, which is also shipped and sold to the mainland. Zasi buys some plastic waste from the NGO in Matembwe.

Zanrec Plastics' future initiatives

It is likely that Zanrec Plastics will start cooperating with both previously mentioned NGOs, and can thereby benefit from their local knowledge, networks and logistic. Since the knowledge regarding plastic recycling is low, or even nonexisting, in Zanzibar, Zanrec will start with very basic mechanical recycling, referred to as *Secondary Recycling* in the theory chapter. There are of course also other reasons for this, such as economic grounds. Besides handling the plastic waste, Zanrec Plastic aims at educating school children in Zanzibar regarding plastic material and the recycling of it, as this increases the knowledge base which will be an important foundation for the continuation and implementation of the recycling system.

At first, Zanrec will collect, sort, clean, and shred the plastic, and thereafter sell the material. Later on however, as declared in chapter 1 (section 1.1.1), Zanrec aims at starting the manufacture of new plastic products in Zanzibar by further processing the material locally. Initially, Zanrec will process approximately **one tonne** raw material each year, consisting of roughly one third PET, one third PE and finally one third PP. Since the knowledge level regarding plastic recycling is low, as stated above, the manufacturing method of this future product needs to be simple and relatively cheap. As the current manufacturing industry in Zanzibar is very small and basic, very little

Figure 22. Bundled plastic bottles ready for shipment to the mainland

knowledge regarding different manufacturing methods and materials exists. Also, as mentioned in section 2.5.4, advanced technology is not a favourable option in developing countries since the investment needed is rather high, while labour cost are rather low, meaning that mechanical and labour intensive methods are preferred. As Zanrec also wishes to enable income bringing activities to the poor, using a labour intensive manufacturing method is recommended. With respects to this, and to the facts that Zanrec Plastics currently have limited funds, the project group concluded that there are two interesting plastic manufacturing methods for the future product development, namely extrusion and rotation moulding. These methods are suitable for processing PP and PE, while PET are more uncommon. For more information regarding these two methods see section 2.6 in the theory chapter.

Local attitudes regarding plastic and recycling

During the formal interviews, the project group recognised that most inhabitants did not seem to have anything against separating the plastic from the rest of the household waste prior to throwing it, they did just not know *why* they should do it. In fact, very few of the local people seemed to know what recycling is or that it even exists. There is not even a Swahili word for recycling. Some interviewees said that they thought that one should separate the plastic because it was more healthy. Many people also stated that the biggest motivation for them to start sorting out the plastic would be an initiative ”from above”, that is from the government or another authority such as the local Shehe.

A problem with having the locals sorting the waste though, is the fact that not all people are familiar with all types of plastic material. During interviews it was discovered that the local people mainly consider buckets, containers, food-wraps, etcetera, to be plastic products. These are products that commonly are made entirely of plastic, often in bright colours. Most of the interviewees did not identify the plastic material in products such as TVs and stereos, where the plastic is combined or integrated with other material and/or has a metallic finish.

All interviewees considered plastic to be a cheap material, best suited in kitchens and other areas where fluids are used, see Figure 24. It was also considered to be a suitable material for children, as it will not break easily. One interviewee liked the fact that plastic can be designed and decorated in beautiful ways, but most participants considered the material to be non-luxurious and very basic. The fact that most interviewees only recognised buckets and similar as plastic products most probably affected these opinions. The project group have learned that even though plastic is considered to be cheap and basic, it is sometimes preferred over local, natural materials. For instance, plastic chairs were sometimes chosen over the traditional bamboo and cow skin chairs, a choice that most probably would be the opposite in a European country (Figure 25). This can most probably be derived to the fact that plastic chairs are considered more modern.

Figure 24. Typical kitchen appliances

Figure 25. Plastic chair versus cow skin chair

4.3.4 Identified areas of interest for product development

As the main purpose with the field study was to identify needs or problems at the island, which could be either fulfilled, solved, or facilitated by a product made from recycled plastic material, the project group constantly observed people in their everyday life in order to find such interesting focus areas. The formal interviews were also partly targeted at identifying such needs, see Appendix 3. After five weeks in Tanzania and Zanzibar the project group summarised the following areas of interest for the future product development.

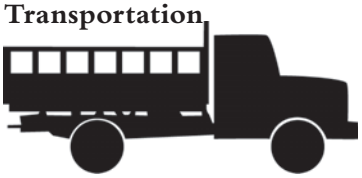
Laundry

Early during the field study the project group noticed that the women in Zanzibar perform most of the demanding everyday chores. By observing the women in the village of Paje, both at home and working at the local hotels, the project group could conclude that washing and doing the laundry seemed to be the most physically demanding duty. Laundry was also the activity that most women complained about during the interviews. Not only does laundry consist of demanding working positions, normally with the women bent over a basin on the floor (see Figure 14, earlier in the Field Study chapter). It is also a very heavy chore, as well as extremely time-consuming. As most families only own a few sets of clothes each, and since washing machines are a pure luxury that only few can afford, washing is basically performed by hand every day. Some women also complained about the detergent used during laundry. The complaints where either about that the detergent made their hands dry, or about that it had chemicals in it which hurt their hands. The project group stated that the fact that the women had wet hands during a long period of time also affected the skin of their hands. The observed and interviewed women did not own any specific washing tools which could help them with the laundry. Normally, they only used their own hands, water, detergent and a basin when doing the laundry.

School furniture

The need for new school furniture in Zanzibar was expressed both by the teachers working in the schools and by a government official, who met with Zanrec Plastics and who claimed that up to 30 000 school children needed new furniture. One reason for this big demand is that the amount of children attending school in Zanzibar is currently increasing, while the amount of furniture stays the same. The schools themselves have little, or no, funds to buy new furniture with, and the government contribution is low and do not seem to increase with the amount of students, resulting in the children having to share the existing furniture, as in Figure 27 on the next page. These tables, benches, and chairs have often been repaired several times by using material at hand. Another problem regarding school furniture is that most of the once used today are wooden furniture, made by rare types of wood. Since deforestation is a problem in Zanzibar today, to keep producing new wooden furniture would not be a sustainable option, and thus plastic furniture would be an interesting alternative.

Transportation



One can identify many problems regarding transportation issues in Zanzibar. Many different communication means hustle on the badly maintained roads, such as daladala, cars, motorcycles, bicycles, and cows with carriages, most of which are heavily loaded. This results in many dangerous situations, especially for the smaller, heavily loaded transportations, as well as for the pedestrians. There is also a need for assorted carrying aids for those who do not have access, or possibilities, to use vehicles. A product, or a series of products, that helps to minimise these problems and dangerous situations are consequently needed.

Plastic collection and recycling system

As the project group joined Zanrec Plastics on various study visits and business meetings regarding the future plastic collection and recycling system, they came to the conclusion that the scope for products within the system itself is huge, since the system is not yet fully developed. A product that support the system could most likely also be applicable in other solid waste management systems, and it would also give Zanrec a stronger business case.

Other areas of interest

The project group also identified other problems in the Zanzibari society, which most likely could be solved by a plastic product, but that did not fit the scope of this Master's thesis, or the business case of Zanrec Plastics. One example of this is building material, where the problem lies partly in the current rape of coral stone which is used in most village houses today (Figure 26). Building material made from recycled material has a big potential, but the aesthetic dimension of this concept was not challenging enough for the project group, and the area was thus not further investigated. Another area that the project group did not look further into, but still found important and interesting, was the problems that the fishermen and seaweed farming women encountered when working in the salt seawater during low tide (Figure 26), without shoes, and sometimes without any tools at all. The reason for not exploring the area further was that the user target group was too small to fit the business case of Zanrec Plastics.

Figure 26. From top; house base made from coral stone, seaweed farming at low tide on the beach in Paje.

4.3.5 Selected focus area

After discussing with Zanrec Plastics and supervisors at Chalmers, the decision to proceed with the school furniture was made. There were several factors that influenced this decision. Firstly, the need for new and/or better school furniture could be translated to a global level, since this is an occurring problem in most of the developing countries, and not just in East Africa. Locally, deforestation was an expressed concern from several parties, and as the current furniture are mostly made from wood, it would be a step towards sustainable development to introduce recycled school furniture. Also, this was an area where two of Zanrec's milestones merged. It both incorporates a marketable product to showcase their production process for further investments, as well as acting as an educational product in an educational environment.

Another reason for proceeding with the school furniture, as opposed to, for example, something for laundry, was that the choice needed to be a product that did not have to compete with the millions of "China-plastic-products" that are currently on the market today. Referring to all the buckets and plates, and other mono-polymeric objects that are produced in millions, and sold very cheap on the markets. The competitive edge, in this case, is that the selected product would be made from recycled plastic, but this is yet not a selling argument in East Africa, especially when considering that most do not even know what recycling means. However, the school furniture would most likely be financed by an organisation, such as the United Nations, which might appreciate the environmental action that the furniture represents.

A supporting product to the recycling system would be in line with Zanrec's business idea, but to work through the trial-and-error-based development process, as would have been necessary here, was not within the time frame of this Master's thesis. Also, this product would not fulfil a need that is current, but rather create and support a future demand, and consequently the school furniture were preferred.

Figure 27. Many students have to share the same bench, due to limited furniture

4.3.6 Education and schools in Zanzibar

After choosing school furniture, the project group focused on further investigating local schools and their furniture. Several schools in different villages as well as in Stone Town were visited, and the project group was able to interview two teachers, three Danish volunteers working in one school, as well as two principals. The information that was gathered during these visits and interviews, and from some additional research, are concluded below.

The educational system

The educational system in Tanzania consists of early childhood care, primary education, secondary education, and finally a higher education at University level. The seven years of primary school, plus the first three years of so called lower secondary education, is compulsory for all children from age 7 to 17. In the Tanzanian mainland only the first seven years are compulsory. In 2000 there were just over 200 government schools in Zanzibar (Sacmec, 2010), but lately there have been a number of private schools introduced into the educational system (Zanzinet, 2004). All government schools are administered and managed by the Department of Education. All schools are closed one month each year during December, and also during shorter periods on national holidays and the Ramadan.

Etiquette and rules

A normal school day in a primary school in Zanzibar starts at 8 o'clock in the morning and ends at 13.30. During this time, the students have one recess for 10 minutes. There is normally one teacher and one classroom per class. The layout of a typical classroom is as shown in Figure 28. The educational atmosphere and hierarchical culture in Zanzibar are reflected in a teacher-oriented teaching style. The students are to greet the teacher with respect, which means to stand up when answering or asking questions, and otherwise be quiet. The children are also required to wear a school uniform, which often are trousers and shirts for the boys and dresses and veils for the girls. These usually have bright colours and represents each school.

Furniture

The most common type of furniture is a longer wooden bench attached to a writing surface as in Figure 29. The furniture are mainly made of wood, sometimes

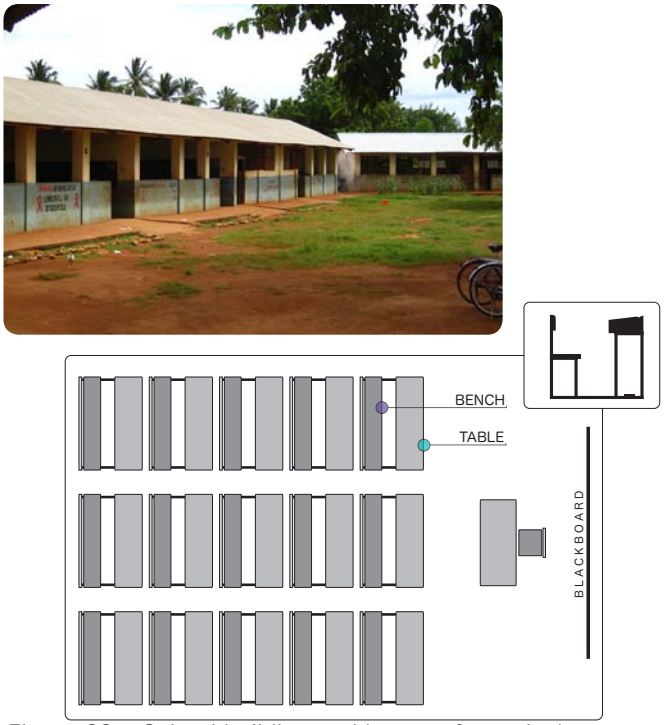


Figure 28. School building and layout of a typical classroom

Figure 29. Wooden bench

with a metal framing. In some schools the furniture exist in two different sizes, in order to, somewhat, accommodate for the differences in size of the children from age 7 to 14. For the smaller children, up to four or five can be seated on one bench, whilst the bigger students can fit three (a comfortable writing space would rather be three younger students and two older). Since the students must stand when greeting the teacher, and answering questions, the bench is seated at a distance from the writing desk which makes standing possible, but it leads to that the students sit in very straining postures when writing, see Figure 30. It forces the children to sit only on the front edge of the bench, and they do thus not often utilise the backrest. Many of the school furniture used today are not ergonomically adapted to the children. For instance, most of them have backrests in a 90° position, though a 95° position is preferred, and the furniture are often too big for the small children which forces them to raise their shoulders in order to reach the desk when writing. In one school visited, several benches had broken and were instead replaced by chairs. These chairs were far too big for the children, also resulting in them sitting only on the edge of the chair in order to reach the desk. In some classrooms there were not enough chairs or benches to seat every student, and because of this some girls were sharing chairs, meaning that some of them had to sit in between two chairs.

The number of children attending school is constantly increasing in Zanzibar, which has led to bigger and more classes and even more schools, which in turn has led to less governmental funding per child, and consequently less money to buy new furniture. A typical school furniture set costs around USD 45-50 to purchase today, according to the principals interviewed by the project group. Thus the type of furniture that can seat many students at once were preferred by the principals during the interviews, but at the same time they explained that a reason for the younger students having a hard time to learn how to write, is because there are so many students on every bench, so that they do not have enough space to practice properly. Also, in most cases, the students do not own pen and paper, so they do not have an opportunity to practise at home either.

Figure 30. Girl sitting on the edge of her seat

4.4 Conclusion of field study

During the field study the project group gained a large amount of information and knowledge regarding the culture and structure of Zanzibar, and to some extent also about Tanzania. This knowledge have been truly necessary in order to identify the needs and problem areas in the society, and it will also be the base for the product development and is thus indispensable for the project group. Much of the information which is stated in this chapter, however, is not explicitly connected to the chosen product but still of great importance since it includes a lot of implicit cultural indications for the product and the development of it. The knowledge regarding the current waste management system in Zanzibar, and the local peoples perception of plastic, will also be of great importance to Zanrec Plastics in their development of a plastic recycling system, and since the future product will be a part of this system, this information will most likely affect the product development as well.

4.4.1 Base for product development

As mentioned in the theory chapter, section 2.3, important questions to consider when designing for developing countries are whether the product really fulfils a need in the society and if the intended users can afford it. As fulfilling a need, or solving a problem, always have been a requirement for this project, one can conclude that the selected product will do so. When it comes to price-income levels and capital constraints it is, as of yet, hard to ascertain whether the new school furniture will be cheaper or more expensive than current school furniture. But since the furniture will not be purchased by the individual user, but most likely from some organisation or government, this is not a quite as important question to answer. Though, keeping the price of the future product(s) low is of course still an extremely important success factor.

Before starting the product development in Sweden, the project group compiled a list of prerequisites and demands for the future product development, see Figure 31. These are mainly cultural, qualitative, considerations that needs to be reflected upon and considered when creating new school furniture for East Africa. Other, non-cultural, demands on the product(s) will be generated in the product development phase.

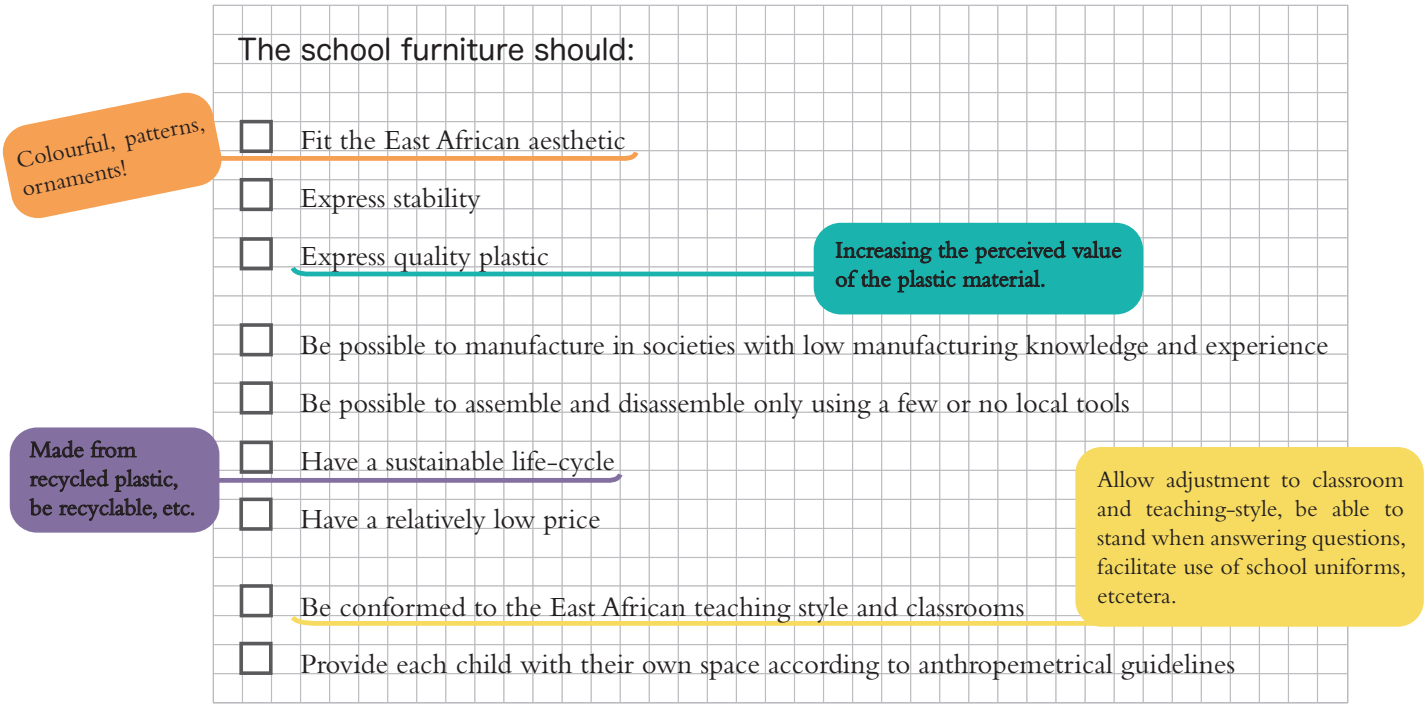


Figure 31. List of prerequisites for the product development phase

Product development

5. Product development

After returning to Sweden, the product development was initiated. Presented in this chapter are the implementation and execution of the development, as well as an explanation of the concepts that were developed followed by the concept evaluation and selection. Finally, further development of the chosen concept is presented. All methods used during the product development are described in chapter 3.

5.1 Definition of product

During the field study in Zanzibar it was decided that the project group should develop school furniture made from Zanrec Plastics' recycled plastic material. Before starting the product development, the concept of school furniture was further clarified, and the demands and requirements on the product(s) were defined.

5.1.1 The user and the context

The user for the school furniture are East African children attending primary school, normally between the ages of 7-14. The primary schools in Zanzibar are of different standards. Many of them are semi-outdoors, meaning that there are open windows and doors, or that there only is a roof/shelter above the classroom. Earth floors, or hard concrete floors, are common. Newer, more equipped schools, do also exist, most of which are private schools. In Zanzibar, most schools are centred around a courtyard where the children spend their time during recess. The number of children in each class and school varies somewhat, but most schools in Zanzibar have somewhere between 20-40 children in each class, that are taught by one appointed teacher. For more information, see Field Study chapter section 4.3.6.

In order to communicate who the intended users for the furniture really are, and in what type of environment they live, the project group put together a persona. The story behind the persona is based on the observations and interviews that the project group performed during the field study.

Persona

Dina is 12 years old and her brother Abel is 9 years old (Figure 32). They live outside the small village Kitogani in southern Zanzibar, together with their parents, their grandparents, and one older brother. They both attend the same primary school in the village Kitogani. In order to reach the school, Dina and Abel have to walk three kilometres along a paved road. Dina can sometimes borrow her fathers bike to school, but Abel always walks as he does not yet know how to ride the bike. Most days the siblings bring chapati-bread that their mother has prepared for them earlier in the morning. They eat the bread in between lessons, but if they do not have any with them, they can buy some from the local women that comes to the school to sell it. Besides the chapati, Dina and Abel do not bring anything with them to school. In school they each have a book to write in, which the teacher collects at the end of each day and stores in school over night. All school children wear school uniforms. Dina has a blue dress with a white veil, and Abel blue trousers and a short sleeved white shirt. Blue and white are namely the colours of their school. There are eight identical classrooms in the school, one for each class and one that functions as a combined library and study room. In Dina's class there are currently 30 students, and in Abel's there are 40. During recess, which occurs one time each day, the siblings mostly play around with their school mates on the small school courtyard and eat their snack. After school, the children jointly walk home to their mother.

Figure 32. Dina and Abel

5.1.2 Image board

To further set the visual aesthetic of the final outcome, an image board was put together, see Figure 33. The intention with the image board is to communicate the perceived feeling of Zanzibar, both internally and externally, as expressing aesthetics in terms of words are rather hard. The image board visualises typical colours, forms, patterns, as well as the intended user context. Above is a collage of patterns which represents some of the typical textiles, whose colour, shapes and ornaments can be found throughout East Africa. In the artboard below the project group have combined representative images, with pictures showing the user and user context, as well as images representing the origin of the future product (i.e. plastic waste) and the desired expression of the final product. In this artboard, the Baobab-tree and the coloured cube are metaphors for the desired expression of stability. The latter, in combination with the image showing a puzzle, also represents a wanted modularity of the furniture. The image board has been used by the project group as inspiration and as an aesthetic guideline, and in a later stage as a communicative medium.

5.1.3 Function analysis

In order to further clarify the functions and the main purpose of the school furniture, a function analysis was performed. At this stage, the concept of school furniture was divided into school bench and school desk. As furniture are low-tech products, the functions are clear and quite simple, and often somewhat abstract. In order to ensure that all functions of the furniture were mapped thoroughly, the analysis was divided into seven different categories; base function, expression, ergonomics, safety, production, construction, and marketing. The base function for the bench was identified as *Permit sitting*, with support functions such as *Offer backrest*. For the table, the base function was defined to *Permit writing*. The entire function analysis can be found in Appendix 4.

5.1.4 Specification of demands

The function analysis, the requirements from Zanrec Plastics, as well as the cultural demands that were concluded in the field study, together built the base for the specification of demands for the school furniture. The identified demands have been weighed against each other in a comparison chart, in order to identify which demands are of greater importance and, should be prioritised in the development phase. Some of the most important demands for the school furniture are that:

- They should provide seating and writing surfaces that are ergonomically adapted to the users.
- They should able to be manufactured and assembled locally, using the intended machinery of Zanrec Plastics', which takes considerations to the low level of skill in the society, etcetera.
- They should be able to be disassembled for transportation and repair, which also facilitates reuse and recycling at the end of product life.
- Students should be able to stand when answering questions.

The entire list of demands can be found in Appendix 5. These demands have been used to evaluate and select a concept, and have also been important guidelines in the concept refinement phase.

5.1.5 Designing for the Base of the pyramid

When developing for the Base of the pyramid (BoP, see definition in section 2.3), Prahalad (2005) has assembled some design principles to consider. These are loosely interpreted below, and have been used as a guide for the project group throughout the product development.

- Start in functionality, not form
- Focus on price performance. Serving the BoP is not just about lower prices.
- Do not be afraid to make hybrid solutions and incorporate new technology.
- Reduce resource intensity! Conserve resources.
- The product must work in an hostile environment (noise, dust, abuse, electric shortage, etcetera)
- Deskilling work. Take into consideration skill levels, poor infrastructure and difficulty of access.
- Scalable and transportable solutions for shipping, that also facilitates transition to similar Base of the Pyramid markets.
- Distribution methods should be designed to reach both highly scattered rural areas as well as highly dense cities.
- Focus on broad architecture – easy to adapt to new features and functions at a later stage.
- Educate customer of the product usage.

Figure 33. Image board

5.2 Concept development

After defining the product specification, and user context, the work continued with concept development. This included several idea generation iterations, that resulted in five concept principles.

5.2.1 Idea generation

The concept and idea generation started with a wide initial brainstorming with no limitations in terms of feasibility of the final product. For example, surrealistic ideas of using magnets and force fields was discussed. This was done in order to produce new, innovating, solutions to seating and writing in a school environment.

To further expand the view of the project group, a brainstorming session was held with seven other students from Industrial Design Engineering at Chalmers, where the problem was loosely described, and inspirational pictures were shown, in order to make the brainstorming group get the gist of Zanzibar. This session produced a lot of ideas, that acted as inspiration for the project group when the limitations of manufacturing technique and material was taken into consideration. A morphological chart (see Appendix 6) was conducted, to generate solutions for the smaller part solutions, which was not treated to any greater extent during the brainstorming session.

Initially, only extrusion was considered as a possible manufacturing method for the furniture. This however, limited the type of concept to such extent, that the project group felt inhibited by this. Since the extrusion method produces long planks, it does not give much freedom in the overall design. For instance, dynamic and organic shapes are very hard to accomplish without adding a lot of finishing work. Thus, a secondary manufacturing method was investigated; rotation moulding. This method is on a par with extrusion in terms of costs, and have a lot more freedom regarding the form creation, shapes, and aesthetic appearance. This new possibility made the project group iterate the idea generation again, but from a new perspective. Another set of ideas, to accompany the first extrusion-set, was produced. The different ideas included module-based concepts as well as one-piece furniture. For some of the ideas generated, see Appendix 7. There was not an alternative to combine the two manufacturing methods, due to the financial restraints from Zanrec Plastics.

The different ideas were all judged, with basis in the list of demands and the Base of the pyramid-list, and thereafter combined into five concept principles. Each principle can later adopt different forms and expressions. Also, a group of the most promising part solutions, which could be adapted by several of the principles, where compiled. The five different principles embodied the different directions that the concept development had taken, and merged several ideas from the same direction into one single principle.

5.2.2 Concept principles

The five different concept principles were; Extrude concept, OnePiece, TwoPiece, Y-bench and the Wedding stool. Each concept represent different techniques of modularity, joining possibilities and manufacturing techniques, and are further explained in this section. All concept can be further developed in terms of form, shape, and design, and are rather to be seen as different principles of modularity.

Extrude concept

This concept is the only one based on extrusion as a manufacturing method, meaning that all plastic parts are made from extruded recycled plastic. Since extrusion produces long boards of the same cross-section, several boards, or planks, have been combined together to form a long bench and table, see Figure 34. As extrusion initially was the only considered manufacturing method for the furniture, a big set of extrusion based ideas were generated, some of which are included in Appendix 7.

The advantages of the extrusion concept is the modularity. It is possible to combine as many of the planks as you want, thus the length of the furniture is possible to customise. It is also very stable, due to all the legs. Another advantage is that the planks can be combined with the current school furniture that have a metal frame, thus directly replacing the wood used today.

The disadvantage is that it requires a lot of material, which is not in line with the design guidelines mentioned in section 5.1.5. Also, the amount of legs may hinder the children to have sufficient space for their own legs. The fact that the writing surface consists of

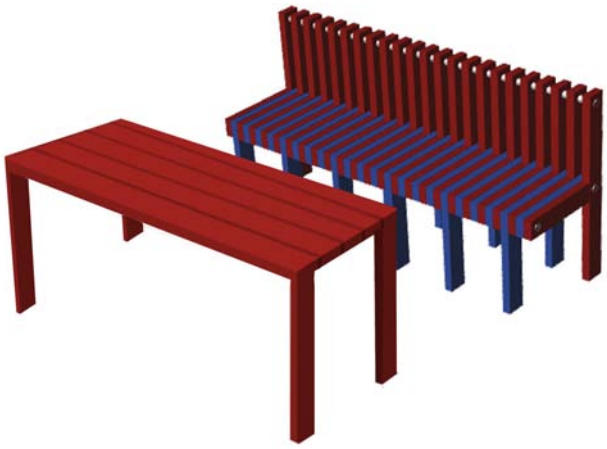


Figure 34. Extrude concept

Figure 35. OnePiece

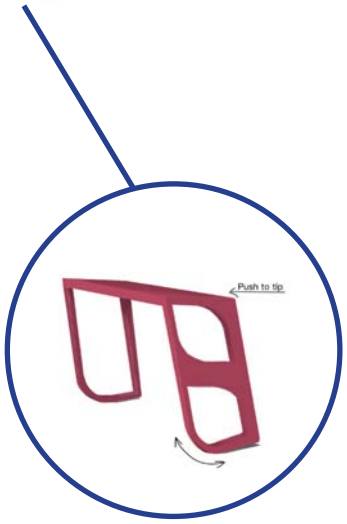


Figure 36. Part function

lengthways planks results in parting lines, which is not optimal for a writing surface. Yet another disadvantage is that the concept requires other details to fasten the planks together, which may or may not be plastic, and may or may not need other tooling. This could have the implication that the necessary tools might not be available in all assembly situations.

OnePiece

This concept consists of one rotational moulded piece per function area; one for the bench and one for the table (Figure 35). Part solutions that were discussed included having chairs instead of one long bench, and incorporate a possibility for the table to rock slightly back and forth, thus enabling students to push the table away from them in order to have the sufficient legroom to stand up, as in Figure 36.

One advantage with this concept is the stability of the product, since no parts need to be assembled, with the immediate disadvantage of not being able to disassemble it for shipping and repair. This concept requires a low amount of material compared to the created volume, though slightly less in the case with the chairs.

A disadvantage regarding the manufacturing of this concept is that the mould would be very big, and consequently bigger heating chambers and more complex and expensive tooling are required. With regards to the length of the sitting surface, there would most probably be some type of spring back in the surface if no internal structure is present underneath. This could create a feeling of instability.

An advantage with rotation moulding as a manufacturing method, is the possibility to incorporate patterns into the mould. This could help subdue the plastic material expression whilst also being used to increase the stability and decrease the contact surface of the plastic material for the user - which is desirable in such warm countries. The feeling of skin against plastic in a very warm and humid environment is not very pleasant.

TwoPiece

This concept constitutes of two moulds, one for the sides of both bench and table, and one for the sitting and writing surface (Figure 37). These can be highly varied in their form aesthetic, as well as joining possibilities. Some ideas that were explored was to cut the

side module in half and use it as support for the sitting bench. This would have the added benefit of being able to pour sand, or other readily available material, into the legs, giving them the extra weight and stability needed so that the children can not move the furniture, which was an explicit wish from the principals. The side module could also be designed to accommodate the different levels of both sitting and writing surface.

If a third module is added to the concept, that merges the sitting and backrest, it opens up for the possibility to have individual chairs instead of a bench, giving the students the freedom to move the chair, as necessary when standing up.

The advantage here is the extreme variation of forms and expression, plus the modularity of the furniture that enables easy transportation and repair. To open up the form and fill it with, for example, sand, does not only give added stability but also a connection to the nature and hopefully an added awareness of what the furniture are trying to preserve. The part solution seen in Figure 36 can also be incorporated in this concept to facilitate standing.

A disadvantage, or rather design challenge, with the concept is the joints and the ability to make them entirely out of plastic material, whilst still ensuring the stability of the furniture. Also, the joints need to be assembled securely, without being to complex, since that would make them very hard to manufacture.

Y-bench

The idea behind this concept was to utilise the height/width ratio of the bench and table. If the same module is either on its long or short side, it would support either the bench or the table, see Figure 38. In order to conform to the anthropometric data, with regards to the table height, the bench has been shortened to seat two children, whereas the other concepts are based on three children per bench to conform to the cultural standard in the schools today.

This concept also has many form opportunities. The fact that the bench is for two students facilitates the possibility to alter between sitting and standing, and it also promotes the possibility to arrange the furniture in a different arrangement.

Figure 37. Variations of TwoPiece

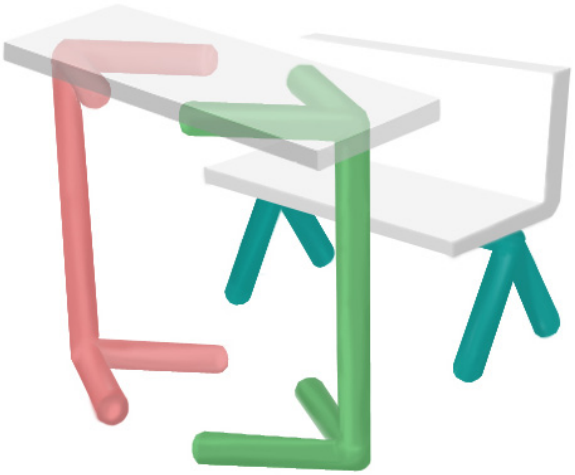


Figure 38. The Y-bench

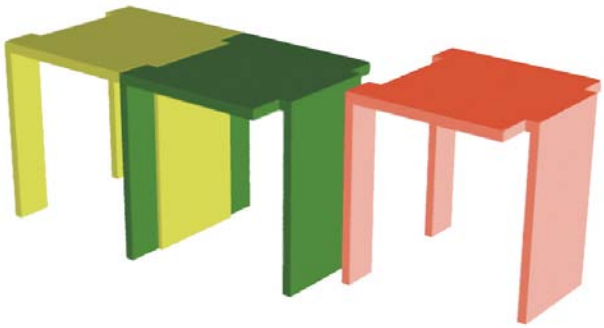


Figure 39. Wedding stool that fit together like a puzzle

The joining of the different modules in this concept is not yet solved, as well as whether it can meet the requirements of stability etcetera. Another disadvantage with the concept is that the backrest requires a special mould and that the close packing of the modules is not optimal.

Wedding stool

Another idea was the option to place the chairs closely together, to create the illusion of a bench but with the alternative to still be used as chairs (Figure 39). This is accomplished through a puzzle-like joining, that originates from some of the puzzle ideas that were generated during the extrusion-development. This is a principle that can be incorporated into some of the other concepts as well.

An advantage is that the students have their own chair, and if they want to create a bench, in order to get extra seating places, no one have to sit in the - normally uncomfortably - space between two chairs. A disadvantage, however, is that the freedom to move the chair in order to stand up is limited by the puzzel-lock. Also, in this sketch, the backrest has no solution as of yet, but is possible to incorporate in a later stage.

5.3 Concept evaluation

After outlining all the concepts, they were evaluated by using the Pugh matrix, meaning that the different solutions were evaluated against the most important demands, with the current school furniture as a reference object, see Appendix 8. In this evaluation, the Pugh-matrix gave a weighted result, since the different demands weighed unequally. This means that if the first concept scored high on a demand of low priority, and the second concept scored high on a demand of high priority, the latter would be favoured. Besides the base functions of offering sitting and writing spaces for the students, the possibility to easy assemble and disassemble the furniture only using very basic tools, was considered to be some of the important demands.

The concept that scored the highest in the evaluation was the TwoPiece-concept, with the chair as sitting module. The chair was preferred over the bench since it provides the children with the freedom to move and stand, but the bench also scored well and is thus also an interesting option. The demand that the furniture should ”obstruct redecoration by students” were the only demand that the TwoPiece concept did not fulfilled better than the existing school furniture, but this demand was considered to be of lower priority. The OnePiece concept also scored high in the evaluation as it constitutes of stable furniture, that can be well adapted to fit the school environment. The other concepts performed inferior mainly due to the fact that the assembly and disassembly of the furniture was either uncleared or not possible, or because the freedom to stand was hindered.

5.4 Concept selection

In a meeting with Zanrec Plastics' the different concepts together with their advantages and disadvantages were presented and discussed. Zanrec pointed out the importance of being able to closely pack the furniture for transportation, as this reduces the carbon dioxide emissions, and thus further supports the sustainable life-cycle of the products. Zanrec also thought this would be a demand from potential investors. For these reasons, Zanrec Plastics preferred the TwoPiece concept and since the concept also scored high in the concept evaluation, it was selected for further development. The project group also decided to go with the chair instead of the bench, because they wanted to somewhat challenge the current furniture arrangement and instead offer a possibility to vary the furniture and classroom layout. As mentioned in the theory chapter, adaptable spaces can assist the learning process and increase the students attentiveness. Another, even more important, reason for going with the chair was that the individual module can be moved when the student needs to stand up when answering questions. In order to avoid the, sometimes, occurring situation, when some children have to sit in between two chairs due to lack of furniture, the chair must be designed so that it allows close connection with other chairs.

5.5 Further development

After choosing the concept principle TwoPiece, with focus on the chair-track, it was further developed to a more feasible concept. Important features to specify were the exact form of the different modules and how they should be assembled and joined to each other. The development was, at this stage, very much guided by

the manufacturing possibilities and limitations of rotation moulding.

5.5.1 Form development

The form development was based on three starting points; manufacturing considerations, aesthetic expression and ergonomic measurements. Each part has its own demands and requirements on the final product.

Manufacturing considerations

The main considerations and affecting factors regarding the rotation moulding were that:

- The number of moulds should be minimised.
- The product will be made up of hollow shapes
- Preferable wall thickness is between one to five millimetres. This is determined by the amount of powder added in the first step of the process.
- The distance between two parallel surfaces have to be four to five times the wall thickness.
- It is not possible to produce sharp corners and edges due to the angle of release in the mould. The radii should be minimum of two millimetres.
- The statement above also implicates that finer detailing is difficult to incorporate.
- If possible, vertical partition planes should be avoided as these constitutes a weakness in the form.

After consultation and discussion with Håkan Lorentsson at Storuman Plastindustri, a company that manufactures rotation moulded products and tooling, it was concluded that there is a possibility to seal off parts of the mould. This opened up to further possibilities in terms of shapes and was a positive revelation for the project group, as the mould could be altered prior to manufacturing. Regarding material selection, Håkan Lorentsson expressed that the preferred material for rotation moulding is polyethylene, due to its elasticity qualities. At Storuman Plastindustri they manufacture a product for road-safety, made partially from recycled polyethylene. However, the recycled material are ground more coarse than the virgin material, which has the effect that during the heating of the form, the more coarse plastic flakes takes longer to melt. This results in the finer, virgin, material spreading out on the mould in a first layer, with the recycled material added as a second layer from the inside (thus not visible in the final product), acting as a kind of reinforcement.

Further ideas were constructed and evaluated using sketches, physical models and CAD-models (for some of the physical models; see Appendix 9). In view of the mentioned considerations above, the concept steered towards an H-shaped side-module as the bearing frame, as in Figure 40. If a part of the mould is sealed off, an h-shaped module can be produced, which would function as a bearing frame for the chair. This idea would require three moulds; on for the side module, one for the table surface and one for the sitting surface/backrest. The fact that the moulds can be sealed off is appreciable from a sustainable perspective, as it saves material in the manufacturing process. However, as the side-module no longer is cut open in some way, as mentioned in the concept description of the TwoPiece, the possibility to fill it with sand is removed.

Figure 40. The same H-shaped side-module is used in both table and chair/bench.

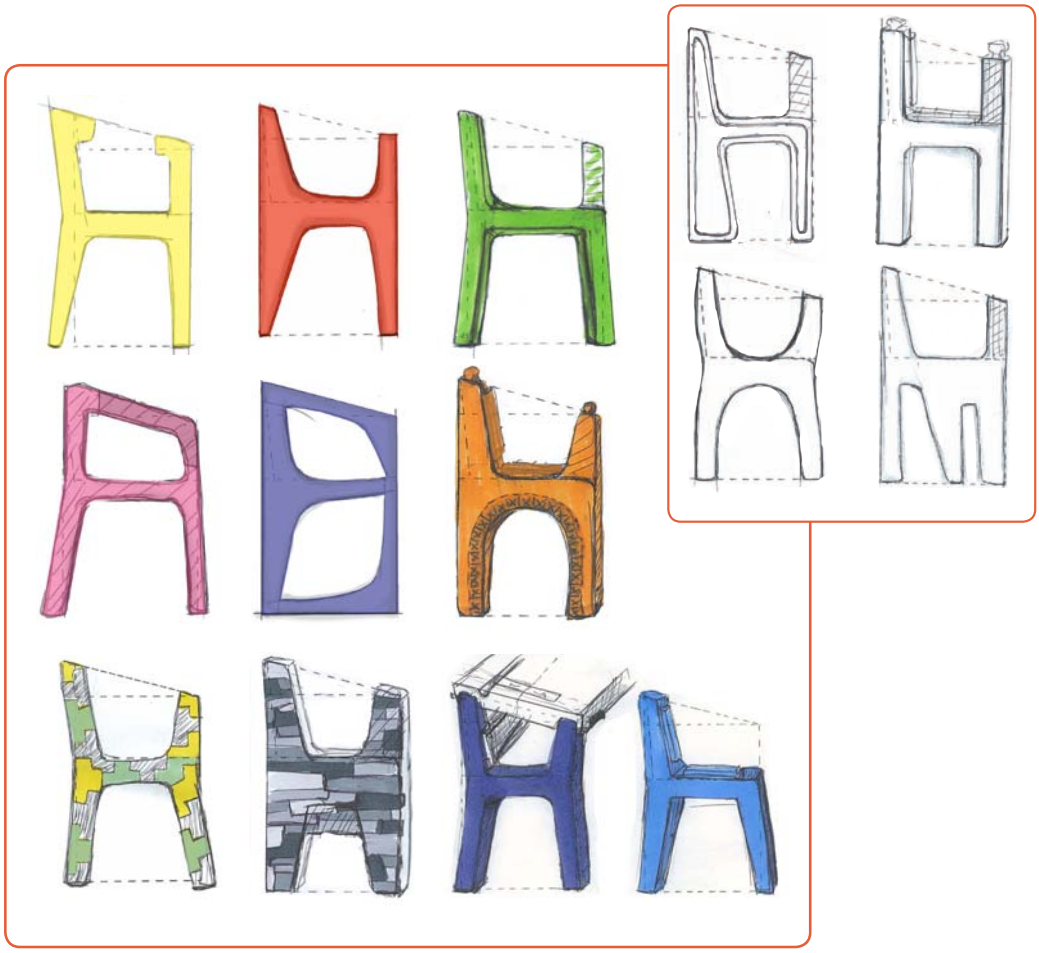


Figure 41. Different form variations of the H-shaped side, for example the typical Zanzibari-arch and meetings between soft and hard shapes

Aesthetics and expression

The aesthetic expression of the furniture was centred around the visual communication of Zanzibar, converged in the image board (see Figure 33, section 5.1.2). Main foci was different colour possibilities, patterns and form elements, that would articulate East Africa, whilst at the same time clearly stating its character as a school furniture. One function from the Function analysis (Appendix 4) that was of greater importance for this part, was that the furniture should give a stable expression.

The H-shaped side was explored with different aesthetic aspects in mind, see Figure 41. Since finer detailing was difficult to manufacture, the form language was directed to more round forms with bigger radii. This was no disadvantage in this project, as these forms are common among other products for children. The project group concluded that slightly tilted, A-shaped, legs contributed to a stable expression and that the arch-shaped cutout communicated of Zanzibar. Adding different patterns and ornaments to the mould were also explored, as well as using chamfers.

Ergonomics

The ergonomic part guided the measurements on the H-shaped side, in the regard of seat height and table height, as well as the slope of the writing surface. From these measurements, the backrest was optimised. The sitting surface was adapted, width wise, to the anthropometric measurements seen in Figure 8, section 2.7, and the width of the table was then adjusted to hold three chairs, which was a conformity to the classrooms used today.

5.5.2 Joining and assembly

The biggest challenge with the TwoPiece concept was to solve how to assemble the different modules. Since the furniture will be used almost everyday in a school environment, they must sustain a lot of wear and tear, and the stability of the furniture is therefore extremely important. In order to make the final products as economically and environmentally sustainable as possible, the project group decided to minimise the amount of different materials used in the products, meaning that the joinings should preferably only be made of plastic

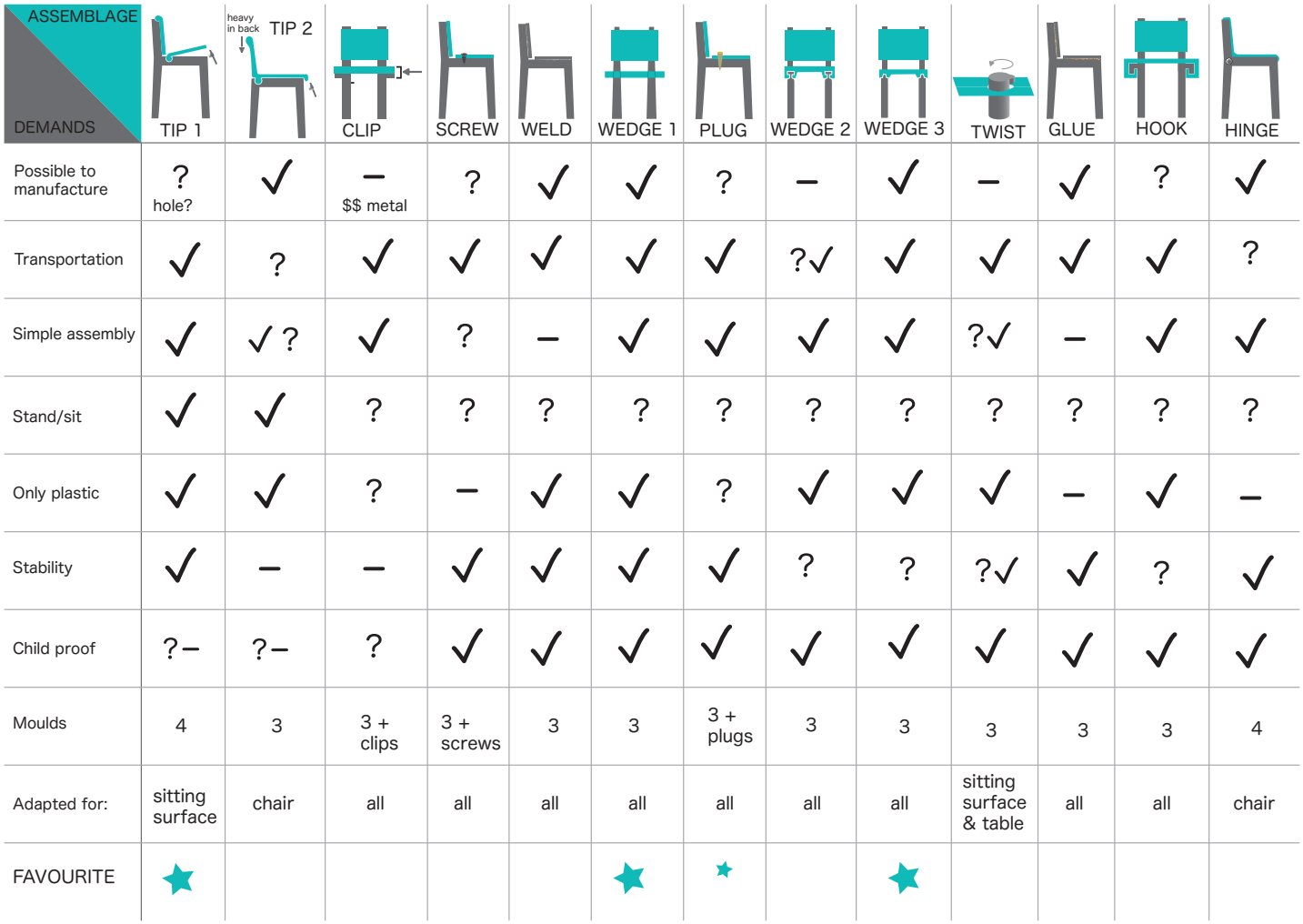


Figure 42. Assembly comparison chart

as well. This decision also takes into consideration the limited resources available in the manufacturing environment. For the same reason, as mentioned previously, another demand for the assembly was that it should be possible to assemble the parts with only a few or no tools at all. Also, since the skill and knowledge level is low it is important to indicate how to assemble and disassemble the products. Both of the former demands corresponds well with the design principles stated in section 5.1.5.

After concluding the demands for the assembly, the project group used CAD-software and physical models to test different ways of connecting the modules. Conventional solutions, such as using regular screws, were tested, but also more experimental solutions such as varying wedges. The different solutions were then compiled and evaluated against important demands in the comparison chart, see Figure 42. In the evaluation the project group also considered whether the specific solutions were adapted for joining all modules and if that would constrain the amount of moulds needed for producing the modules. For instance, the solution called Tip 1 would most likely need an extra mould as the sitting surface and backrest would probably be different modules. The project group realised that many of the solutions would not be possible to manufacture, either because they were to intricate, meaning that the mould would be too costly to produce, or because they could not function with the angle of release needed in the mould. Ultimately, after testing the solutions on small scale physical models, the project group decided to continue with a combination of the solutions called Wedge 1, Wedge 3 and Plug (Figure 42). These wedge solutions can easily be manufactured and the assembly of the parts, when using such wedges, is quite obvious. Other advantages with the wedges are that the assembled furniture becomes rather stable. Since stability is such an important requirement for furniture, the project group decided to further ensure the stability of the furniture by adding plugs to the joinings. As mentioned previously, the plugs should preferably be made from the same plastic material since this would facilitate recycling at the end of product life. The

holes needed for plugging the modules together will furthermore re-open the possibility of pouring sand, or similar, into the modules in order to make the furniture heavy and more stable.

Another favourite of the project group was the tipping solution, Tip 1, which enabled standing for students as they could lift the seat in order to stand. This solution, however, has some quite obvious disadvantages, namely that there is a risk of pinching, and a question as to whether the solution would be stable enough. Unfortunately, the tight time frame did not allow for further investigations and due to the importance of the safety demands, it was not carried on with. The concept, however, remains as an interesting possibility for Zanrec Plastics to further develop.

During the development of the joinings it became evident that some kind of supporting cross-bar was needed for the table. Only using two sides and a writing surface would make the table too unstable, and thus a cross-bar was added to the furniture. This requires an extra mould, thus making the furniture a bit more costly than previously expected.

5.5.3 Opening up for co-design

With a modular furniture system, the possibility for user involvement, so called co-design, increases. The user can adapt the furniture to better suit their own likings. In this concept one option, for example, could be to choose colours on the different modules, maybe adapting them to the school colours to create a more cohesive school unity and strengthen the school spirit. The supporting cross-bar could be an optional mould, and instead local material such as wood or bamboo could be used, preferably from scrap pieces, so that it does not add to the local deforestation in Zanzibar. Also, one idea is to utilise the plugs to fasten fabric around the chair in order to create a more pleasant sitting surface for the children.

Final result

6. Final result

The aim with this Master's thesis was to utilise recycled plastic material as a basis for development of a new product, made partially or fully from recycled plastic, which would fulfil an identified need in Zanzibar. In this chapter, the final result of the product development is presented; new school furniture made from recycled plastic.

6.1 PlastikiRafiki furniture

The final result is called PlastikiRafiki furniture, and constitutes of a unique set of modular school furniture, made entirely of plastic material. The furniture have been designed to fit primary school children in East Africa, meaning that the furniture are ergonomically adapted to the children, providing them with better workspaces than the current furniture. The name, PlastikiRafiki, is Swahili for Plastic Friend, and aims at increasing the local perception of what can be done with plastic as a material. As Zanrec Plastics wish to educate the local community in terms of sustainability and recycling, these new school furniture will work as excellent educational examples within the educational environment itself. The modularity of the furniture makes them easy to pack closely and thus facilitate transportation and export to other areas in need. The products can be produced locally in Zanzibar and assembled by only using a few tools. The result of this Master's thesis is consequently an outcome that includes both social and environmental sustainability aspects, as it provides work opportunities in the local community as well as introduces a life cycle opportunity for plastic material.

6.1.1 Manufacturing and material

The manufacturing process selected for the school furniture was, as previously stated, rotation moulding. This manufacturing method has been the main consideration and constraint during the product development, as it puts limitations on both form aspects as well as material selection.

Modularity

PlastikiRafiki is made out of modules which originates from four different moulds. The table is made out of four parts; one writing surface, two H-shaped sides and one cross-bar. The chair is also made of four parts; two h-shaped sides as well as a sitting surface and a backrest. The h-shaped side is produced in the same mould as the table's H-shaped side, but one of the "arms" of the H has been sealed off, see Figure 43. The backrest and sitting surface is also produced in the same mould, but the backrest module have been shortened somewhat to facilitate the assembly of the chair and in order to better fit the anthropometric demands. In other words, the four moulds that are needed to produce the furniture are one H-shaped mould for the sides, one for the table surface, one for the cross-bar and finally one for the sitting surface/backrest.

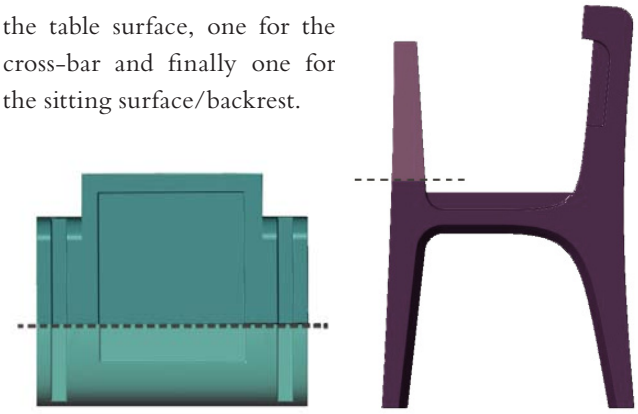


Figure 43. The sitting surface and backrest are produced in the same mould, as is the two h-shapes.

A big advantage with this final design is the simplicity of the modularity. The modules are easy to manufacture through rotation moulding, using only the four, previously mentioned, moulds. Since no advanced shapes are included in the design of the different modules, the moulds themselves will be easy to manufacture thus making the moulds inexpensive to produce. According to Håkan Lorentsson at Storuman Plastindustri, each mould costs from 20 000 SEK up to 500 000 SEK for very specialised moulds. Depending on the size of the machinery, several modules can be manufactured simultaneously. In fact, it might even be possible to attach all moulds to the same spindle, meaning that they all can be processed in the rotation machinery at the same time. This will however need further investigation, and might not be proven necessary, as time will most likely not be a constraining factor.

As rotation moulding is a relatively simple and cost effective method, the production of the school furniture can preferably be done locally at Zanrec Plastics recycle processing plant. Rotation moulding is normally used to make larger components in low to medium series, and is thus suitable for these new furniture. The method is a semi-automatic process, meaning that manual labour is required, which supports one of the effect goals with this thesis; to create work opportunities within the local community.

Material selection

The modules will preferably be made by some type of polyethylene, as this material is favourable to use in combination with rotation moulding. The material has many other advantages, such as good flexibility and fracture toughness. Also, as mentioned in the theory section 2.4.2, recycled homogenous high-density polyethylene can be dyed into different colours, which is an aesthetical advantage when it comes to creating products for children. In order to ensure sufficient durability of the furniture, virgin material will be needed in the products. It will also be important to make certain that the same type of polyethylene will be used, in order to facilitate recycling at the end of the product life. When manufacturing the furniture, Zanrec Plastics can favourably undertake the same process as Storuman Plastindusti, that is ground the recycled material more coarse than the virgin material, so that the recycled material creates a layer on the inside of the product, thus acting as reinforcement.

For each table, approximately 4,8 kg of polyethylene is needed, and for each chair 2,1 kg is needed, see Appendix 10. The amount of plastic available in Zanzibar is by current estimation sufficient to produce 72 000 tables and 216 000 chairs per year, given that Zanrec Plastic will purchase 50 percent virgin material and that the recycled material is of sufficient quality.

6.1.2 Assembly

The simplicity of the design of the furniture also facilitates the assembly of the modules. How to assemble the modules are rather clear thanks to the bevels and accompanying bevel holes, see Figure 44. The assembly can easily be done in areas with low skill levels and few resources, as basically only human strength is needed to wedge the parts together. The tight tolerances of the bevels will squeeze the modules together, but as some shrinkage of the plastic is likely to occur, plugs have been added to the final design in order to ensure that the furniture will be completely stable. These can be found on the side of the table, underneath the seat and on the backside of the backrest. As mentioned in section 5.5.2, the plug-holes have an extra functionality since they will be used to fill the modules with sand or soil which will give the products extra weight and stability. This will help fulfil the demand that the products should obstruct redecoration from students. Furthermore, the plugs are designed as knobs, and can thereby be used to hang personal belongings. The plugs will be made from the same material as the rest of the product, in order to facilitate future recycling, but they can also be made from locally available material, meaning that local carpenters can produce plugs from scrap material or similar,

Figure 44. Exploded view of PlastikiRafiki showing how it is assembled.

if needed. The plugs are, and should be, designed so that they can be removed by manual force in order to facilitate disassembly.

PlastikiRafiki can be disassembled for repair and transportation. If a module is worn out it can be replaced, either by a new plastic part or by a module made from other locally available material, as the simplicity allows for several types of connections. The cross-bar in the table can preferably be an optional part, and instead added during the assembly by the local carpenters, thereby supporting them in their work.

6.1.3 Ergonomics and usage

Since the furniture are to be used by children in the age between 7-14 years, they must fit a wide range of bodies. The final shape of PlastikiRafiki have therefore been adjusted so that the furniture, in the best possible way - with manufacturing constraints in mind, fits as many of the intended users as possible. The ergonomic design has been guided by the anthropometric measurements that can be found in Appendix 2.

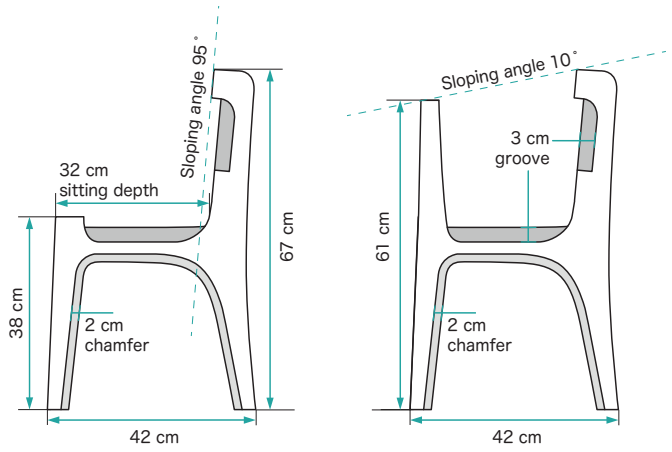


Figure 45. Measurements of the side

Figure 45 shows the measurements of the chair. For all measurements of PlastikiRafiki, see Appendix 12 and Appendix 11. The table surface of the furniture have been angled approximately 10° in order to offer the children an appropriate sitting posture when writing. The backrest of the chair is also angled, at a degree of 95°, so that it supports the natural curve of the spine. The height of the chair is lowered, compared to normal chairs (that are adapted to adults), in order to avoid the children having their legs dangling in the air, as this put pressure on the soft tissue of the thighs, which may cause tingling and numbness. As each child will get an individual chair, it is possible for them to move it backwards when standing up. This will also help them to keep a correct posture, since they can seat the chairs in a way that best suits their bodies. In order to facilitate gripping of the chair when moving it backwards, an edge is placed on the bottom side of the seat.

The design of the table is somewhat adapted to the current classroom layout and teaching style of Zanzibar, as three chairs are fitted to one table (see Figure 46). The reason for this is that furniture that supports the current layout are more likely to be accepted by the schools than those who do not. Another reason for not giving each child their own writing desk is that it saves material, since fewer legs are needed in a big table than in three small, meaning that this further supports the environmental sustainability aspect of the furniture. Furthermore, the fact that PlastikiRafiki consists of tables and chairs opens up for the possibility to alter the furniture layout of the classroom (Figure 46). Structuring groups of furniture is highly possible, and it is encouraged by the project group, as changing the layout can increase the attentiveness and thus also the learning of the students. If there is a shortage of furniture, it is possible to seat more than three children

Figure 46. Alternative placement of the furniture

Figure 47. Approximately 45 seats can be fitted into a regular classroom

Figure 48. PlastikiRafiki fit excellent into the current classrooms in Zanzibar

Figure 49. PlastikiRafiki has a stable expression and clearly fits into the the school environment

on three chairs as the chairs are designed so that they allow close connection with each other. This however removes the possibility for the students to stand, and is thus not recommended by the project group. The older children should ideally be seated in pairs for each table in order to get sufficient writing space.

Most school children in Zanzibar do not bring personal items to school, many of them do not even own a pen. Nevertheless, some of the older students have backpacks, and some children bring snacks or food to school. Since each child gets their own chair, they can use it for hanging their backpacks and bags. The plugs can also be used for hanging things.

During classes the school children are normally provided with a writing book and pen. Since the table surface is angled, a groove have been added where the pen can be placed when not use.

6.1.4 Product identity and expression

PlastikiRafiki is designed to give a stable expression, clearly stating that it is school furniture for children, see Figure 49. The H-side part is slightly angled outwards, giving it a somewhat A-lined shape. This increases the desired expression of stability. To further emphasise the Zanzibari cultural heritage, an arch form is build into the lower part of the legs. The form of the arch has been altered somewhat to give the side module a stronger base and a sense of direction. The soft curves, enclosing the sitting surface and backrest, frames the seating area on the chair and makes it into a unit. The chamfers on the legs have been added to increase the arch-expression as well as making PlastikiRafiki look more delicate. The softer curves in combination with the solid modules, the material and the choice of colour enhances the expression of children's furniture, which in combination with the classic form element of a groove in the table, makes the furniture clearly articulate that they belong in school.

The fact that PlastikiRafiki will be produced in an, for the Zanzibari, modern manufacturing method could make the design of the furniture appear as rather modern by the locals. This can, in turn, help to increase the users perception of plastic material in a positive and desired way.

Furthermore, patterns can easily be added in the mould, to further emphasise the Zanzibari cultural heritage with its ornamented style. The project group, however, decided not to add such ornaments to PlastikiRafiki, in order to keep a more cultural neutral design, thus facilitating acceptance of PlastikiRafiki in other cultures. Also, as previously stated in the development section, PlastikiRafiki allows the users to alter and further broaden the expression of it, as the users can select colour and for instance add fabric to the furniture, see Figure 51. Adding textile to the seats, for example by tying it around the plugs, will not only alter the aesthetic of PlastikiRafiki, but it will also make the furniture more comfortable.

6.1.5 Need in other areas

As stated in the field study section, there is a big need for PlastikiRafiki in Zanzibar. When browsing the internet for more information regarding school furniture, it becomes clear that this is a need that can

Figure 51. Examples of possible colour variations and other alterations to PlastikiRafiki. The textile, in the figure to the left, is tied around the knobs/plug underneath the seat.

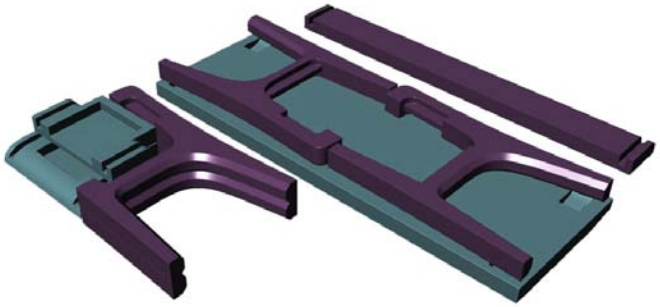


Figure 50. The different parts of PlastikiRafiki can easily be closely packed for transportation

be found in several parts of the world, mainly in the developing countries. Therefore, it is the project groups belief that Zanrec can export PlastikiRafiki to many other places, after the need in Zanzibar has been fulfilled. However, this would require further investigation and may also include some design alterations.

Although the aesthetic expression has its origin in Zanzibari aesthetics, it is not unaffected by the project group's background from Sweden. Thus, the final appearance can be considered to be a merge of two cultural spheres, the East African/Zanzibar and Sweden, which one could argue, would make it a more cultural neutral design, thus also suitable in other markets.

6.2 Evaluation of result

In order to verify that the final product result meets the product aim and fulfils the demands of the product, an evaluation was conducted. Besides fulfilling the specification of demands, there are three areas of importance that affected the final product outcome; cultural demands, sustainability and ergonomics.

6.2.1 Fulfilment of demands

In the first step of the evaluation, the project group investigates how well the final product meet all of the requirements in the specification of demands, see Appendix 13. In the evaluation, the different demands have been given a grade according to how well they are fulfilled. If a demand is fulfilled completely it is given 5/5, and if the furniture fails entirely to meet the demand it is given 1/5.

Most of the demands have been fulfilled completely, one exceptions being that the furniture are not optimised so that the students can stand easily. It is possible to stand, but whether the children really will sit in a correct posture and then push the chair backwards in order to stand, is unclear. Thus, the demand is given 3/5. The demand that PlastikiRafiki fulfils the least, is the demand that states that the furniture should be sold at a lower or equal price as the current school furniture. This demand has been hard to evaluate, as all price figures are not known, but PlastikiRafiki will most likely be more expensive, initially, than the current furniture, as the manufacturing of it will be more advanced. However, the demands of higher priority are fulfilled to a greater extent as those of low priority. The cultural demands are harder to evaluate as most of the are based on perception meaning that a validation would have to take place in the intended culture. However, the project group believes that PlastikiRafiki meets these demands rather well. Overall, the furniture fulfils the specification of demands in a satisfying way.

6.2.2 Sustainability

With the basis from an Environmental Effect Analysis, PlastikiRafiki was evaluated against four different life-cycle phases; resource utilisation, production, use, and end-of-life. Since PlastikiRafiki only constitutes of different plastic modules and no other components and materials, the environmental impact of the product is narrowed. Because of this, performing an entire EEA in detail was considered an excess, and instead of filling in an EEA-chart, the environmental advantages and disadvantages was discussed. See Figure 52 on the next page, for a summary of the most interesting factors.

The main environmental advantage of PlastikiRafiki is its modularity. That is, that it enables reparations, transportation, and also opens up for the users to co-design and add pieces of other material as well. If the user can get a personal connection, and a sense of caring for the product, its product life will most likely be longer. The measurements of the modules are adjusted, not only to cultural and ergonomic requests, but also to facilitate packing and transportation of the product, as can be seen in Figure 50. Since the production is initially intended to a local market, instead of a global, it has the added benefit of providing work opportunities on a local level, throughout the entire process - from collection of waste to final distribution and assembly of the product - and it can be a good foundation for increasing the skill level in the community. At the time of writing, the number of employees needed for the production was estimated to just over 60, spread out over the entire process.

6.2.4 Ergonomic evaluation

The time frame of the project did not allow for the project group to revisit Zanzibar in order to verify that the furniture truly fits the intended users. Instead, the ergonomic design of PlastikiRafiki was tested

Resource utilisation

+ mixing it with recycled material, thus decreasing the amount of finite resources
+ design and material are adapted to the manufacturing method
+ one type of material
- finite resource

Production

+ adding work opportunities to the society
+ increasing skill level by education
+ no energy required during assembly
+ can be packed closely
- hollow shapes equals transportation of air
- requires energy during production phase
- electricity shortage will require a diesel generator

Use

+ has no specific environmental effect during the usage phase

End-of-life

+ if near a Zanrec processing plant or similar, the furniture can be recycled there
+ easy to mark the furniture with material type or instruction on how to act when it should be recycled
- if the furniture needs to be transported far away in order to recycle
- requires grinders and other tools to prepare the material for another life-cycle

Figure 52. Concluded environmental effects of PlastikiRafiki

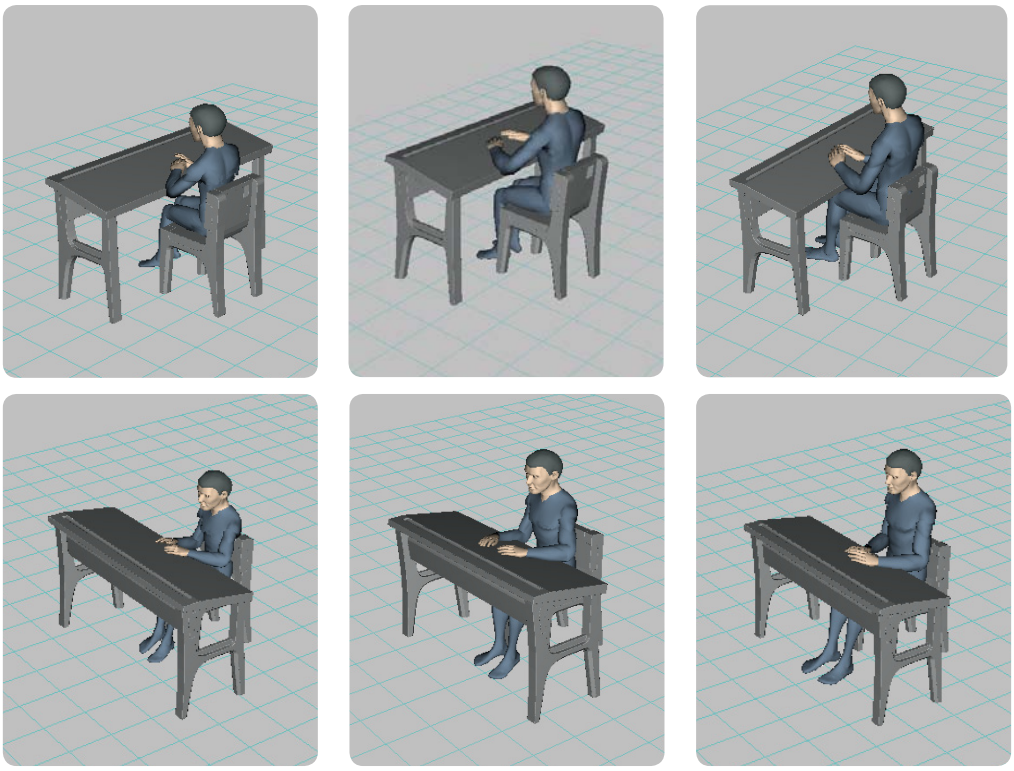


Figure 53. Different sizes of the Jack manikin according to the anthropometric measurements. From the left; small, medium, big.

using the ergonomic analysis software Jack, in which the project group was able to get a rough estimation of how well the new furniture fits the users physically. The extreme users, meaning the smallest and the biggest intended user, as well as one in between the former, were placed on the modelled chair by the modelled table. As seen in Figure 53, PlastikiRafiki gives all the three children a correct posture for the upper body when writing. For the bigger children, the backrest of this furniture is unfortunately a bit lower than optimal. This is due to the fact that the side-module for the table and the chair are the same, and in order to provide the children with a height-adjusted table, the backrest had to be lowered a few centimetres. As having few moulds was considered to be an important requirement for keeping the cost down, and as a correct table height was considered more important than the backrest, this adjustment was necessary. The very smallest children will not be able to reach to the floor when sitting, but otherwise the chair meets the ergonomic requirements.

Discussion and Conclusion

7. Discussion

In this chapter, the Master's thesis is discussed in its entity; whether the aim was fulfilled, how the different methods and tools worked during the different phases, the importance that the field study has played on the project, and of course the final outcome.

7.1 Mission of the thesis

The aim and limitations with this Master's thesis was initially set very wide, as it was unclear of what the actual outcome of the field study would be, and as Zanrec Plastics was interested in research in several diverse areas. We envisioned three different possibilities; looking at the entire waste management system and material flow on the island, looking at a product for the local market, and looking at a product for the western market. After arriving in Zanzibar, the system-approach was removed from this list as this would have to be on a trial-and-error basis, which would not have been executable within the time frame of the field study. However, a product for the local and the western market still remained. In hindsight, it would have been beneficial to narrow it down further, to only one focus area, as this dual focus took a lot of time and effort. Our level of ambition and will was not helpful in this thesis as it made the work straggling, up until the summer break, when we took the decision of focusing solely on a product for the local market, which enabled us to go more in depth, as opposed to continue going wide.

7.2 Fulfilling the aim

The project aim was divided into three levels; effect goal, project aim, and product aim. To divide the aim into these three categories worked well in this project, since the scope of the project initially was very broad. To further emphasise the different levels on which the final result should succeed, facilitated the product development phase and established a focus for us. These different levels will now be discussed in turn.

7.2.1 Effect goal

The effect goal is considered to be fulfilled in its entity. It was written on a more holistic level, and concerned the society at large, specifically the knowledge regarding waste management and plastic recycling. To fulfil these aims, several factors have to interplay and one of these factors is the new furniture. It acts as a visual communicator, both for the local society as well as for bigger charity organisations interested in supporting the product.

7.2.2 Project aim

The project aim has been fulfilled completely, as the final result is utilising the recycled plastic material whilst also solving an identified need on the local market. Regarding the product sustainability, we feel that it has been accomplished, since the product truly takes environmental and social aspects into consideration. The local production skills and knowledge has been considered in the choice of manufacturing methods, also including work opportunities. The life-cycle of the material is more on a system level which is more under the control of Zanrec Plastics, to get a functional closed loop from cradle to cradle, but the new furniture tries to facilitate this by incorporating recommendations for how to recycle the product as well as marking the type of material used.

7.2.3 Product aim

The product aim is a more straightforward version of the two previous aims, most closely relating to the project aim, and is thus consequently considered to be fulfilled completely.

7.3 Limitations

The limitations was at first set very wide, in order to not hinder whatever may come out of the field study. This affected the different aims of this thesis, in a way that made it hard for us to specify them, and thus would have made it hard to actually see whether the aims had been met or not in the end. When the project went into the developing phase, these limitations

were further constrained to more revolve around cultural aspects, and the possibilities and limitations of Zanrec Plastics as a new company, which in turn restricted the different aims.

7.4 Project plan

In the first version of the project plan, the attached Gantt-schedule was set at a very ambitions level. However, as we returned from the field study, this was quickly realised, and a second updated version was made. This also relates to the fact that, as suggested by the examiner, we did not specify the second phase to any greater extent in the beginning of the project, since the field study was considered to be of such importance for the project outcome and would most likely steer the future product development. Another favourable action, was that we took a break during the summer. This made us come back with renewed energy and two pairs of fresh eyes. Before the break, the ambition was to both make a school furniture, as well as either furniture for a western market or furniture that could be sold to the middle class households in Zanzibar. This was restrained after the break, to exclusively focus all energy on optimising the school furniture.

7.5 Field Study

In the following section the field study has been discussed in terms of preparation, implementation and result.

7.5.1 Preparations

The literature study carried out before travelling to Zanzibar was a good time-investment as our knowledge regarding the Zanzibari society truly increased. In addition to the literature study, we participated in a two-days long field study preparation course, held by Internationella Programkontoret that administrates the MFS-scholarship. The course included both lectures and discussions regarding working in other cultures and in developing countries, which further prepared us on what was to come, and it also made us reflect upon likely situations and cultural clashes that might arise in Zanzibar. The literature study in combination with the preparation course, and the fact that both of us have previous experiences in travelling in developing countries, contributed to us being well prepared for the field study.

7.5.2 Implementation and result

During the execution of the field study it became obvious that the language barrier between us and the local people was a big obstacle, especially during interviews and encounters. Most people in Zanzibar, first and foremost the poor people, do not speak English and as we only mastered a few words of Swahili, poor communication and misunderstandings characterised the initial time in Zanzibar. As learning Swahili fluently was not possible to master during the time of this project, not much could have been done differently to prevent this. We however focused on learning the basics of the language, which together with knowing common customs and greetings, contributed to us being quite well accepted by the Zanzibari people. It became apparent that trying just a little to fit in was truly appreciated, and for instance wearing the traditional Kanga was really respected and valued by the Zanzibari women.

During this initial time we acted a bit too cautiously, and had some difficulties with stepping away from our own cultural habits and customs, instead of ”throwing” ourselves out in the Zanzibari society. This behaviour also was somewhat affected by the fact that the Zanzibari people’s hospitality was somewhat moderate in the beginning. The big difference in religion and culture, but also in skin-colour, made it obvious that we were outsiders, and not part of the Zanzibari society. However, by building relationship and trust, we were slowly introduced to the culture. It took longer time than we had expected, making us somewhat frustrated, but in the end it payed off as we were invited to the real lives and homes of the Zanzibari. It is important to mention, that the Scandinavian people, temporarily living in Zanzibar, that we met through Zanzibar Adventure School or through Zanrec Plastics, helped us in the early phase of the field study by providing us with valuable information and setting up meetings with local people. It was truly valuable for us to meet these people, that understood both cultures, and that thanks to that could help us to integrate with the Zanzibari society in a quicker and more natural way.

As mentioned in the field study section 4.3.2, Zanzibar is a rather hierarchical society, which affects the local peoples' perception of Westerners. We were thus viewed as an authority, being educated Westerners, which sometimes resulted in that some people were keen to gain our respect and did so by said yes even though they could not or should not. However, since we were aware of this clash, it did not affect our work too much. Furthermore, the fact that the gender equality in Zanzibar is rather uneven also influenced the peoples' view of us, and resulted in that we only got to interview and accompany women in their homes. This have most probably affected which types of potential product development areas that have been identified during the field study, and it is likely that others would have been discovered if we would have been able to formally interview men as well.

The eight formal interviews that was conducted halfway through the field study were, as stated in section 4.2.2, accompanied by Mr Rajab Ameir, who also arranged and acted as an interpreter during the interviews. Before the interviews, we were under the impression that all interviewees would speak English. This however was not the case, at least not when Mr Ameir was present in the room. It seemed that the interviewed women had much respect for him and did not dare or did not feel comfortable with speaking English with him present. Instead, Mr Ameir acted as an interpreter, but as he is not trained to be one, the interviews and its' questions were clearly affected by this. For instance, Mr. Ameir had the tendency of providing the women with examples before they found their own ways of replying to a question. In other words, the outcome of the interviews were clearly affected by the language barrier and lack of a competent interpreter. However, without Mr. Ameir the interviews would not even have taken place, as he arranged the interviews, and consequently we own him a big thanks.

Despite the language difficulties, the interviews resulted in much valuable information regarding the current waste collection and waste management system in Zanzibar, as well as regarding the women's perception of plastic. These interviews also, somewhat, guided us in identifying needs, but it is our opinion that needs and problems would have been more easy to identify during informal interviews, for example if we were to join in daily household situations. So to say, it would have been beneficial to live with or shadow a family for some days. A problem with this however, is that due to the great respect of authorities in Zanzibar, and since we were considered an authority, it would likely result in us only observing and not participating in the household chores anyway.

To conclude the field study, it has been absolutely necessary for the project success. Without the study, identifying needs, understanding the users and the user context, would have been practically impossible. The culture and the economic situation in Zanzibar is truly contrasting to the Swedish, and consequently are also the needs and demands for products completely different. To develop a product for such a different society, without visiting it, would most likely result in products that are not rooted in the actual user demand and that will be hard to implement in the real user context. However, we feel confident that we have developed a product that truly fulfils a need and that will fit the intended environment, thanks to the genuine result of the field study.

7.6 Product Development

During the product development phase, the function analysis proved very valuable to state the "regular" demands for a sitting furniture. In addition to this, the cultural and contextual demands were provided from the field study observations as well as recommendations when working with The base of the pyramid. These, jointly, provided a good basis for the specification of requirements.

7.6.1 Product development in developing countries

We found it challenging, but not impossible to perform product development in a developing country. It would, however, not have been possible without the field study, as mentioned earlier. The theory states that one should start in the user needs and capabilities during development, which we feel have been accomplished. The other important factor to consider when developing for developing countries was the economics, which is also a contributing factor as to why the school furniture was chosen. It was evident that Zanrec Plastics could not compete with other regular plastic products, such as buckets and bowls that were

made by the dozen in China, in terms of economics. Since the school furniture is targeted to be purchased by a bigger charity organisation or similar, and not by the intended user themselves, the economic issue was put aside slightly in this project. Other factors, such as cultural conformity was of bigger concern. The tips and tricks for The base of the pyramid (section 5.1.5) states that a broad architecture preferable, since it makes the object easily adaptable to different cultures, as well as prepared for incorporation of new elements and open to alteration. We also stated the evident need for a school furniture on a global level, which further emphasises this. However, the final concept has had a stronger focus on adopting the Zanzibari aesthetic expression. The reason behind this was, first and foremost, that this was an aesthetic that we had come to know and recognise. However, the, for the Zanzibari, modern manufacturing technique will add to the modernity of the final expression. We feel that we have succeeded in merging the two aesthetic spheres of Zanzibar/East Africa and Sweden, and have obtained a result that we feel could be appreciated in several cultures.

7.6.2 Idea generation

The idea generation was iterated, in its entirety, twice, due to the change in manufacturing method. Extrusion that, a first, gave the impression of being a fixed prerequisite, later turned out to be interchangeable, as rotation moulding emerged as an opportunity. Although this meant some double work for us, it still proved valuable, and many of the solutions generated for extrusion could be translated to rotation moulding as well. The combination of the two methods opened up to new directions of thought and was very inspirational. When the time came for the concept selection, and external parties were to take part (Zanrec and supervisors), we found it hard to visualise only the concept principles, without letting the current design affect the selection. We tried to keep the sketches at an equal level of completion, but there is always the risk of a biased opinion.

7.7 Concept Selection

The concept selection was done in collaboration with Zanrec Plastics, and with the support of some methods for selection; the PUGH matrix and Comparison Chart. These methods were of great aid for us in order to substantialise our thoughts and opinions, as well as producing a good overview of the generated ideas. The PUGH matrix was altered slightly, so that it took the weighted demands in to consideration at the time of execution. This meant that the best scoring concept was the one which had the most improvements regarding those demands of higher priority. This was an alteration that we felt worked well for this purpose. The comparison chart were used at a later stage, when different joining methods of the furniture needed to be evaluated. This became a perspicuous overview, which, in combination with our judgements, acted as an excellent foundation for the joining selection.

7.8 Final result

As stated in previously in the discussion, we consider the product aim of this Master's thesis to be answered. However, there a some features of the final product subject to discussion.

7.8.1 Manufacturing

It is evident that the constraints of the chosen manufacturing method for PlastikiRafiki, for instance rotation moulding, have affected the product development and product design of the final product. We are pleased with the fact that we chose this manufacturing method, as rotation moulding allows for more form variations and bigger design challenges than extrusion. At the same time, even though we believe in the benefits and success of our final design, it is hard to verify whether it is optimal or not.

PlastikiRafiki originates from four different moulds, as four moulds was considered to be a good trade-off between keeping manufacturing cost and the environmental impact of the transportation down, whilst also ensuring the stability of the product and at the same time offering work opportunities through the assembly of the product. By adding a few more moulds, more design variation would have been allowed, but it would also have contributed to a costlier manufacturing and an increased production time. Since keeping the cost down is a crucial demand when designing for developing countries, further variations in the design was considered to be of less importance. Moreover, only having two moulds - one for the table and one

for the chairs (as in the OnePiece-concept) - is also possible in rotation moulding. But, as mentioned in the evaluation of the concepts, it is likely that two such moulds would be more expensive to manufacture than four, as they would be more complex and furthermore the modules would occupy more volume, consequently increasing transportation costs and add to the environmental impact.

7.8.2 Assembly

During the product development, big emphasis was put on finding a suitable solution for the assembly and joining of the modules. Initially, the goal was to find a solution that required no other parts than the modules themselves. Anyhow, we had to adjust this wish, as the stability of the furniture is of extreme importance, and we did not feel confident in that the wedge solution could ensure this alone, and thus the plugs were added. Plugs were chosen as they are details that easily can be manufactured from almost any available material. Also, the fact that the plug holes allows for the furniture being filled with sand, further made us appreciate them. The idea of letting the plugs act as hooks for storage and fasteners for fabric was thereafter added, which further increased their function.

7.8.3 Ergonomics and usage

The PlastikiRafiki furniture are designed according to the anthropometric measurements and ergonomic guidelines that we found during the literature study. The measurement are mean measurement from North American school children. Since we unfortunately could not find equivalent measurement of East African children, the American was used, but with the knowledge that the African population is slightly smaller than the American, kept in mind. Since no physical evaluation of the furniture have been made, it is hard to verify that the design truly fits its user, but as we have followed the ergonomic guidelines, this is most likely so. One exception, though, being the backrest which is slightly too low for the oldest students. However, as mentioned in the ergonomic evaluation, it is only a matter of a few centimetres, and we regarded the correct height of the table and keeping the number of moulds to a minimum, as more important demands.

In section 5.4, it is mentioned that chairs were chosen for the furniture, instead of benches, because the chairs facilitates rearrangement in the classroom and they also give the children freedom to stand up. Whether or not the children truly will adjust their seat, to keep a correct posture, is hard to tell. They might end up sitting far away from the tables, as some were observed doing when sitting in ”adult” chairs today, just so that they can stand more easily. It is, nonetheless, our wish and belief that these smaller and lighter furniture will facilitate correct sitting posture and encourage the movement of the chairs instead.

7.8.4 Evaluation

The evaluation of PlastikiRafiki was performed in order to verify that the final result meets all of the ergonomic, cultural and sustainability demands set on the product. Overall, we are satisfied with the result of the evaluation, as it showed that PlastikiRafiki fulfils the most important requirements in the specification of demands. The demands that not have been completely fulfilled, are of such nature that they could be met in the future, after more development and testing have been performed.

Since sustainability has been a constant focus in this thesis, it also permeates the product development result. The Environmental Effect Analysis, that was performed in order to evaluate the product in terms of sustainability were, however, not a very suitable method. The EEA is better adapted to evaluate existing products, in order to identify areas of improvement, rather than judging the product as a whole. Also products of a more technically advanced nature would be better suited for such an evaluation, which PlastikiRafiki is not. Nonetheless, the tool helped us to consider all life-cycle phases in the evaluation of PlastikiRafiki.

As mentioned earlier, a real physical evaluation of the furniture would have been truly beneficial. The ergonomic evaluation in the Jack software was not at all optimal, as the figure in the programme seemed to be adapted to adult bodies only, and the software seemed more adapted to evaluating more straining postures, rather than static sitting. Our moderate knowledge regarding the software did most likely contribute to this. Nevertheless, the evaluation was still worthwhile, as it gave an indication regarding how well PlastikiRafiki fits its users.

7.8.5 Social consequences

The fact that PlastikiRafiki utilises a big amount of the plastic waste in Zanzibar, might have some social consequences. For instance, there is an existing culture of reuse, especially among plastic bottles, that could decrease, if the monetary incitement gets big enough. On the other hand, as Zanzibar is a well visited tourist attraction, the shear amount of plastic waste coming from the hotels can be considered to be constant, as it lies outside of this reuse-culture today. A positive consequence that we, as well as Zanrec Plastics, hope for is that the level of awareness regarding plastic as a finite resource will increase when a recycling system is implemented. Yet another positive consequence is that more work opportunities will be created, and when people can earn money being ”waste-pickers” the island will also get cleaner. However, as the plastic waste increases in value, the risk of theft might follow.

7.9 The project as a whole

This thesis differs from the types of projects that we previously have done, as it has included a greater emphasis on the cultural challenges and differences, something that is not taught specifically at the programme Industrial Design Engineering. It was, initially, hard for us to fathom that the end result would be on a different level of completion, compared to our fellow students' projects, given the overall time constraint of 20 weeks, as a bigger emphasis in this project has been on the analysis as opposed to the synthesis. However, this is not something that we wish to change, as this project outcome would not have been the same, had not the field study and deeper analysis been made. Also, the subject of developing for developing countries was deliberately selected for just these cultural challenges and differences stated above. We have the wish to contribute to a more sustainable society and future, and thus found this project subject of uttermost interest. To conclude, this Master's thesis has been a great learning experience for us, and something we would gladly do again. We believe in and are proud of the final result that we have created.

7.10 Recommendations

Recommendations for future development of PlastikiRafiki mainly concerns the investigation and establishment of sufficient plastic waste streams. A proper user test should be performed, in order to justify the ergonomic design. An evaluation and refinement of the joinings have to be done in order to ensure product stability. Here, an investigation regarding the joining solution called Tip 1 is also suggested. Zanrec Plastics could also further develop the exact implementation of how the furniture could act as an educational feature regarding plastic waste and recycling. Finally, after implementing the product, a survey to confirm the user satisfaction is recommended.

8. Conclusion

The project group has developed school furniture that well fulfils the project and product aim; to identify a need in Zanzibar and to develop a sustainable product, made partially or fully from recycled plastic, that would fulfil said need.

This has been accomplished, as the developed product concept, PlastikiRafiki, is a school furniture made partially from recycled plastic, which can be manufactured and assembled locally. PlastikiRafiki is well adapted to the anthropometric measurements of primary school children, and will contribute to a better school environment for the children in Zanzibar. Furthermore, the modular design of PlastikiRafiki facilitates the transportation of the furniture, thus enabling export to other areas in need of new school furniture. PlastikiRafiki will also help Zanrec Plastics to implement their educational package regarding future sustainable development, by acting as a conversational piece about recycled plastic. It will function as an excellent educational feature within the educational system itself. The project group has consequently delivered a concept that contributes to a more sustainable society which is fully possible to implement in Zanzibar today.

Figure 54. The project group with the two principals

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Oral source

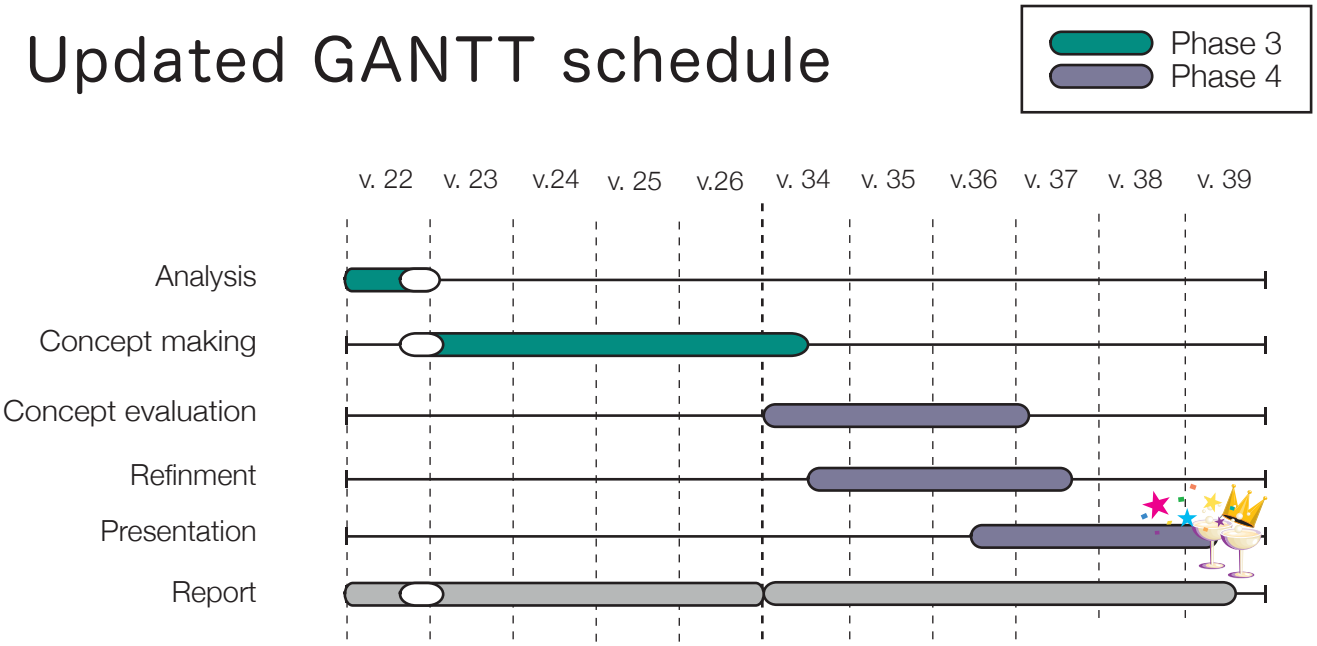
Håkan Lorentsson, Storuman Plastindustri

Michael Juel, NIRAS

Appendix

List of Appendixes

Updated GANTT schedule



Appendix 2 - Anthropometrical data

Anthropometrical data for school children

Mean measurement (50 percentile) per student 7-14 years according to Diffrient, Harman, and Tilley (1981):

Seating

Depth: 27,4 - 36,1
Width; 29,9 - 38,6
Height from floor; 29 - 39,6
Min. leg room (table structure) ; 42,9 - 58,2

Backrest:

Angle 95 degrees
Lower height; 13 -15
Support height; 15-23
Total height; 28 - 38

Writing surface:

Angle 0-15 degrees
Minimum writing space; 33 cm
Normal work distance: 16,3 - 20,6 (to support the arm whilst writing)
Worktable height (from floor); 48 - 63,2

Body measurements

From hip-joint to knee-joint; 27,7 - 38,6 (+13,5 to buttocks)
Height; 123,4 - 163,1
Shoulder width; 27,4 - 40,4
Hip width; 21,6 - 34,7

* All measurements are in centimeters (if not otherwise stated) and represent North America school children. The East African population is slightly smaller according to DINED (2009).

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Interview VII

FAMILY AND HOME

- Name, age and occupation?
- Husband?
- Children? Age? Living at home? Going to school? Helping with household?
- How many live together in your house?
- How long have you lived here? Do you rent or own?
- Where are you from originally?
- How many rooms?

FAVOURITES

- What's your favourite colour?
- What is the most beautiful thing you have? Why?
- Do you have any favourite thing (not a person or family) that you own?
- Products (kito) that you can't be without?
- Is there any product in the house that break often? Why/what?

A NORMAL DAY

- Times – waking up, eating breakfast, lunch, dinner, pray, going to work?
- Is there something that you really don't like to do or that is hard for you to do? So that you rather ask someone to do it for you? Get pain in body?

WORK AND MONEY

- Can you save any money each month?
- What do you spend your money on? Biggest expense? (Groceries, rent, shopping, clothes, car, school etc.)
- What was the last product you bought for the house and why?
- Where do you go to buy your stuff – one store for everything or several?
- How do you find out about new products?
- How about advertisement? Do you take notice of commercials? And where do you see/hear them most?
- Is there a product that you have seen others have (ex on TV /your neighbours/friends) that you wish that you had?

TAKA & PLASTIKI

- Where do they keep the garbage in the house?
- Where do you throw your garbage?
- Do you sort it beforehand? (compost/plastic/metal)
- Would it be hard to sort the plastic beforehand?
- Do you know why people would want to separate garbage?
- What would make you start to separate the garbage?
- How much of the garbage is plastic (for each bag/empty)? And what type is it?
- Do you consider Zanzibar to be clean or dirty? What do you compare it with?
- What do you think of the material plastic? Is it good or bad? When/why?
- Is it cheap or expensive? Luxurious or basic?
- Do you have any plastic prod in this room?
- What is the most beautiful material?
- Do you know of any products that are made from many materials ex plastic and something else?
- Have you heard the term recycling and what do you think when you hear the word?

Function analysis - school bench

BASE FUNCTIONS
MAIN FUNCTION: Permit sitting
- Allow connection (with other units)
- Offer backrest
- Offer flexibility
- Facilitate position-change
- Facilitate organisation
- Express stability
- Express quality
- Permit closeness (between units)

EXPRESSION
MAIN FUNCTION: Express stability
- Express quality
- Express recycling
- Express East Africa
- Express sturdiness
- Offer colour variations

ERGONOMICS
MAIN FUNCTION: Permit sitting height
- Maximise firmness
- Facilitate cleaning
- Express reliability
- Facilitate position-change

SAFETY
MAIN FUNCTION: Posses strength
- Minimise risk of pinching
- Sustain rough use
- Prohibit overturning
- Offer quality
- Prohibit risk of falling

PRODUCTION
MAIN FUNCTION: Facilitate manual labour
- Facilitate assembly
- Minimise waste

CONSTRUCTION
MAIN FUNCTION: Facilitate production
- Express assembly
- Maximise stability
- Possess strength

MARKETING
MAIN FUNCTION: Promote social responsibility
- Offer colour variations
- Express stability
- Express quality

Function analysis - school desk

BASE FUNCTIONS
MAIN FUNCTION: Permit writing
- Allow connection (with other units)
- Offer writing surface
- Offer flexibility
- Facilitate organisation
- Offer storage (of personal belongings)
- Express stability
- Express quality

EXPRESSION
MAIN FUNCTION: Express stability
- Express quality
- Express recycling
- Express East Africa
- Express sturdiness
- Offer colour variations

ERGONOMICS
MAIN FUNCTION: Permit writing space
- Maximise smoothness
- Offer arm support
- Offer flexibility
- Facilitate cleaning
- Express reliability

SAFETY
MAIN FUNCTION: Posses strength
- Sustain rough use
- Minimise personal injury (cut wounds etc)
- Offer quality

PRODUCTION
MAIN FUNCTION: Facilitate manual labour
- Facilitate assembly
- Minimise waste

CONSTRUCTION
MAIN FUNCTION: Facilitate production
- Express assembly
- Maximise stability
- Possess strength

MARKETING
MAIN FUNCTION: Promote social responsibility
- Offer colour variations
- Express stability
- Express quality

Appendix 5 - Specification of demands

WEIGHTED LIST OF DEMANDS AND REQUIREMENTS

The different demands were weighted against each other to determine the most important ones, and consequently got different scores. The demand with the highest score were the most important one.

19 p Provide seating for students 7-14 years old.

- *with measurements according to the anthropological appendix 2*

19 p Provide writing space for the students

- *with measurements according to the anthropological appendix 2*

18 p Possible to manufacture parts using Zanrec's intended machinery

16,5 p Contain at least 45% recycled plastic material

- *with optimised material usage*

15 p Provide backrest for the students

- *with measurements according to the anthropological appendix 2*

14 p Possible to disassemble for shipping and reparations

- *using local tools, minimise shipping volume*

14 p Provide work opportunities in the local community during production, manufacturing, assembly and disassembly

13,5 p Facilitate reuse/recycling at the end of the product life

13 p Enable students to stand when answering a question

12 p Possible to assemble using local tools and machinery

10,5 p Use standard measurements for non-manufactured parts, if needed

- *fasteners, rails or equivalent*

9 p Allow arrangement according to East African educational standard

- *all students facing the teacher*

8 p Be sold at an equal, or lower, cost than todays market price for existing school furniture

- *wooden benches cost approximately 70 000 TSH/unit*

6 p Enable adjustment to varying classrooms and class size

5 p Indicate correct assemblage

- *a brief or no instruction manual should be needed*

4,5 p Express stability

- *7/10 should find it stable*

4,5 p Permit a high students/classroom ratio

- *~ 5 students /m2 furniture area*

3,5 p Enable a place to store personal belongings for the duration of a class

1,5 p Obstruct redecoration of furniture by the students

1,5 p Increase the perceived value of the plastic material

- *6/10 should find it more valuable than material in common plastic products*

1,5 p Communicate environmental action taken by Zanrec

Also, the furniture should preferably:

- Facilitate cleaning of the furniture
- Correspond to the East African aesthetic
- Express school furniture
- Minimise risk of injury for the user

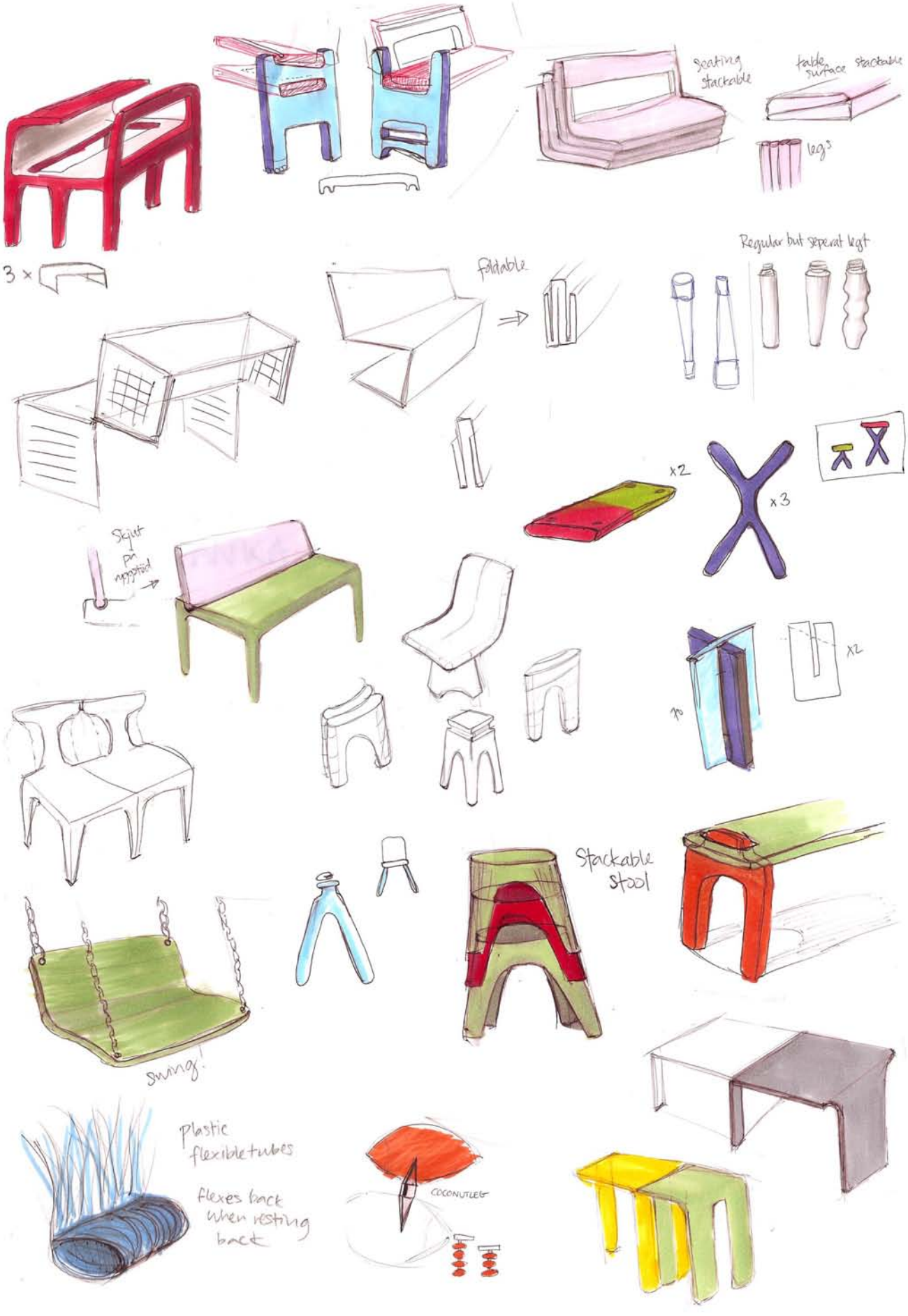
- *pinching, falling off, sharp edges*

Appendix 6 - Morphological Chart

Appendix 7 - Sketches Extrusion

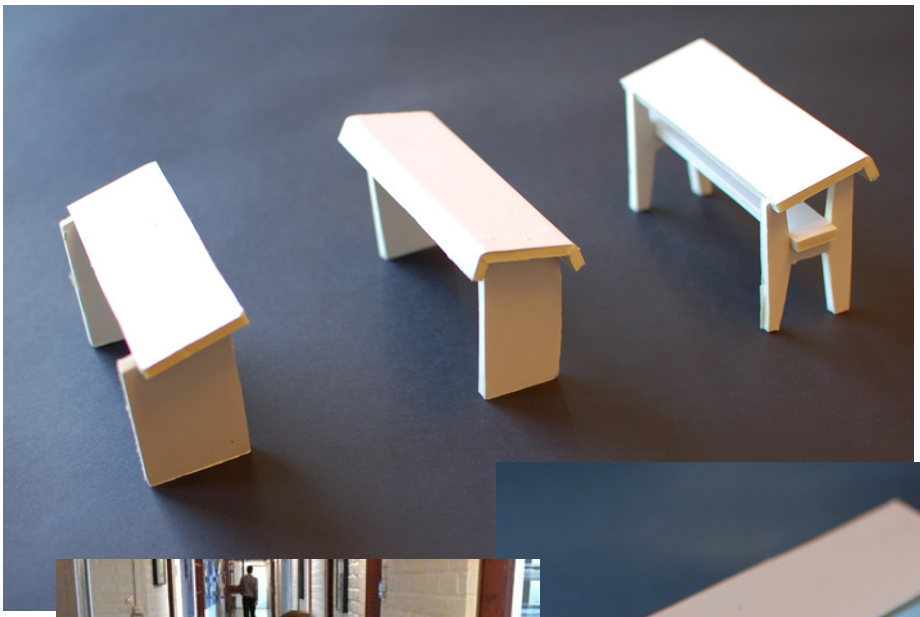
Sketches: Rotation moulding and part soulutions

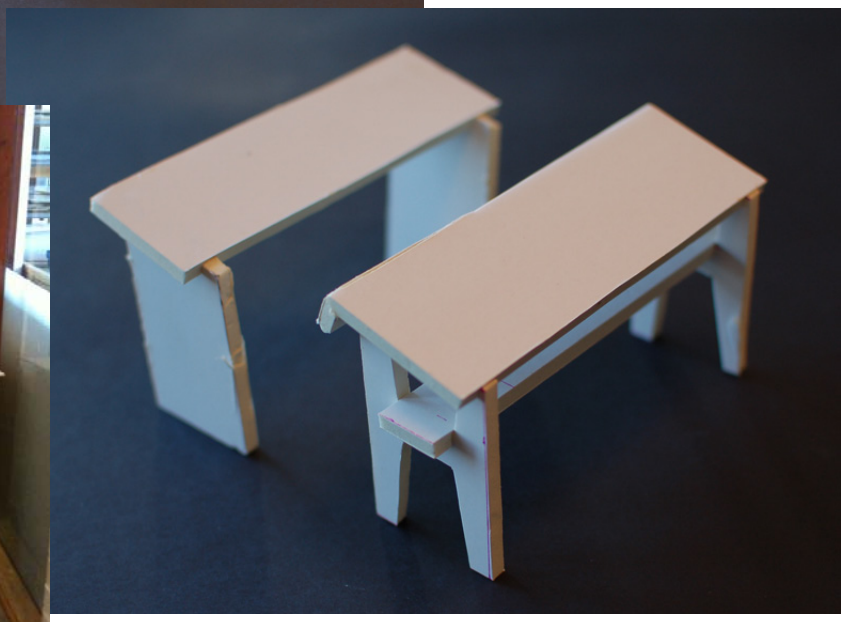
Sketches: Rotation moulding

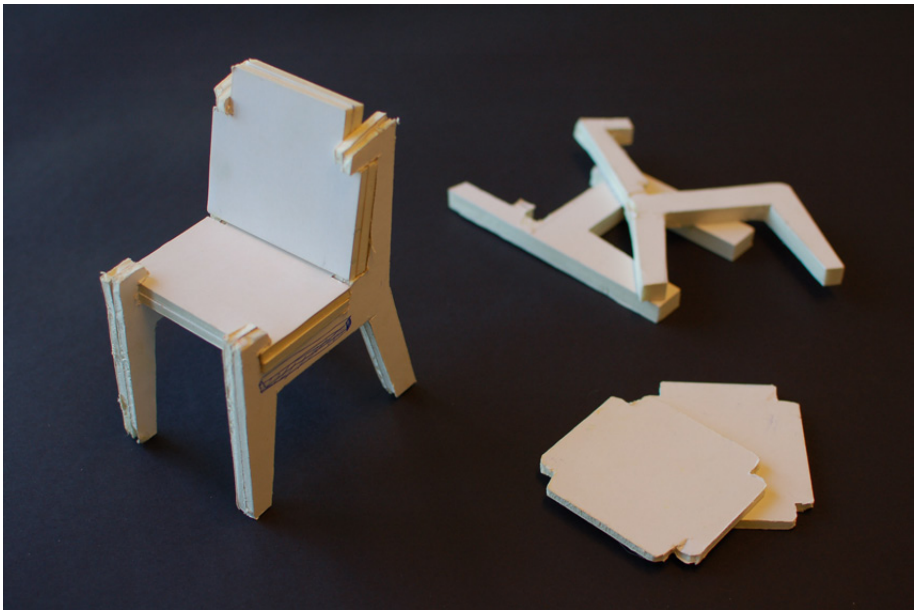


Requirements	Pts	Current	ONE-piece Bench	ONE-piece Chair	TWO-flip or cut chair	TWO Flip or cut Bench	X	Extrude	TWO&TWO bench	Wedding stool
Seating	19		0	0	0	0	0	0	0	0
Writing	19		+	+	+	+	0	-	0	+
Manufacture	18		+	+	+	+	+	+	+	+
Plastic 45%	17		+	+	+	+	+	+	+	+
Backrest	15		+	+	+	+	+	0	+	-
Disassembly	15		-	-	+	+	+	+	0	-
Standing	13		+	+	+	0	0	0	0	+
Assembly	12		+	+	0	0	0	-	0	+
Adjustment	6		0	+	+	0	0	+	+	+
Indicate assembly	5		+	+	+	+	+	-	0	+
Express stability	4,5		0	0	0	0	0	-	-	0
Storage	3,5									
Obstruct redecoration	1,5		0	-	-	0	0	0	-	-
TOTAL +		**-**	**6**	**6**	**7**	**6**	**5**	**0**	**2**	**4**

Appendix 9 - 3D-models in capa board







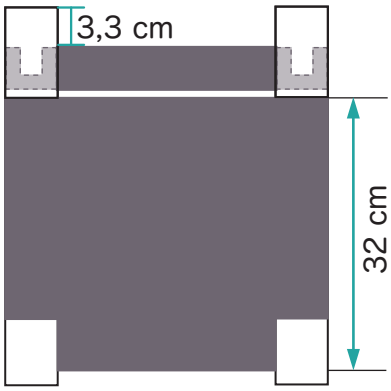
Appendix 10 - Calculated material use

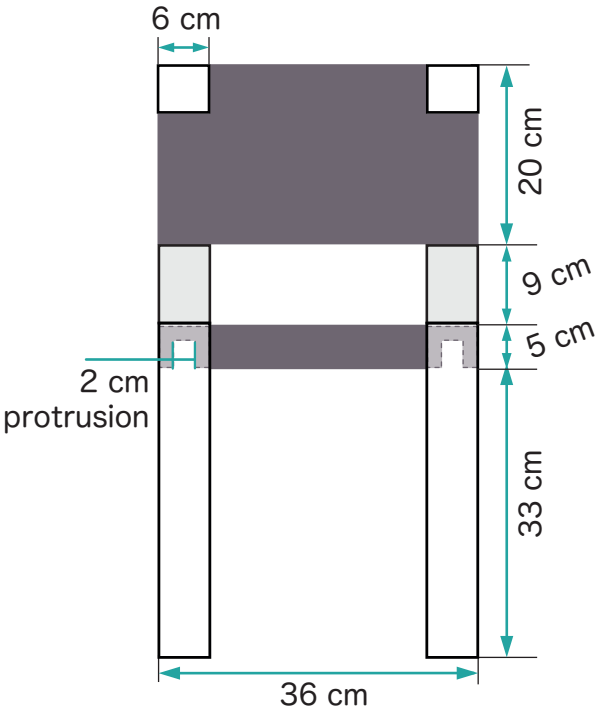
Part	Area [cm2]	Thickness [cm]	Volume material [cm3]	Weight [0.94g/cm3]
H-side	3592	0,2	718,4	675
h-side	3116	0,2	623,2	586
Backrest	2069	0,2	413,8	389
Sitting surface	3102	0,2	620,4	583
Writing surface	13409	0,2	2681,8	2524
Cross-bar	4803	0,2	960,6	903
TOTALT				**5660 g**

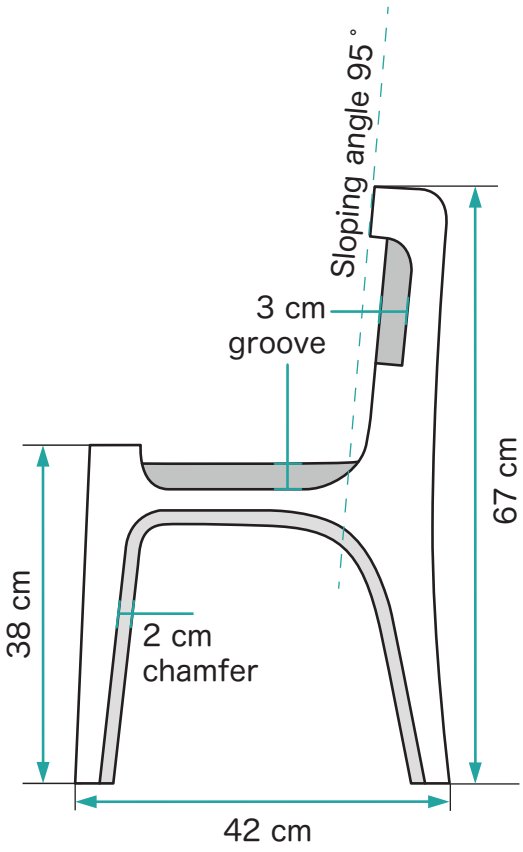
1 Table	Weight [0.94g/cm3]
H-side x2	1350
Writing surface	2524
Cross-bar	903
TOTALT	**4777 g**

1 Chair	Weight [0.94g/cm3]
h-side x2	1172
Sitting surface	583
Backrest	389
TOTALT	**2144 g**

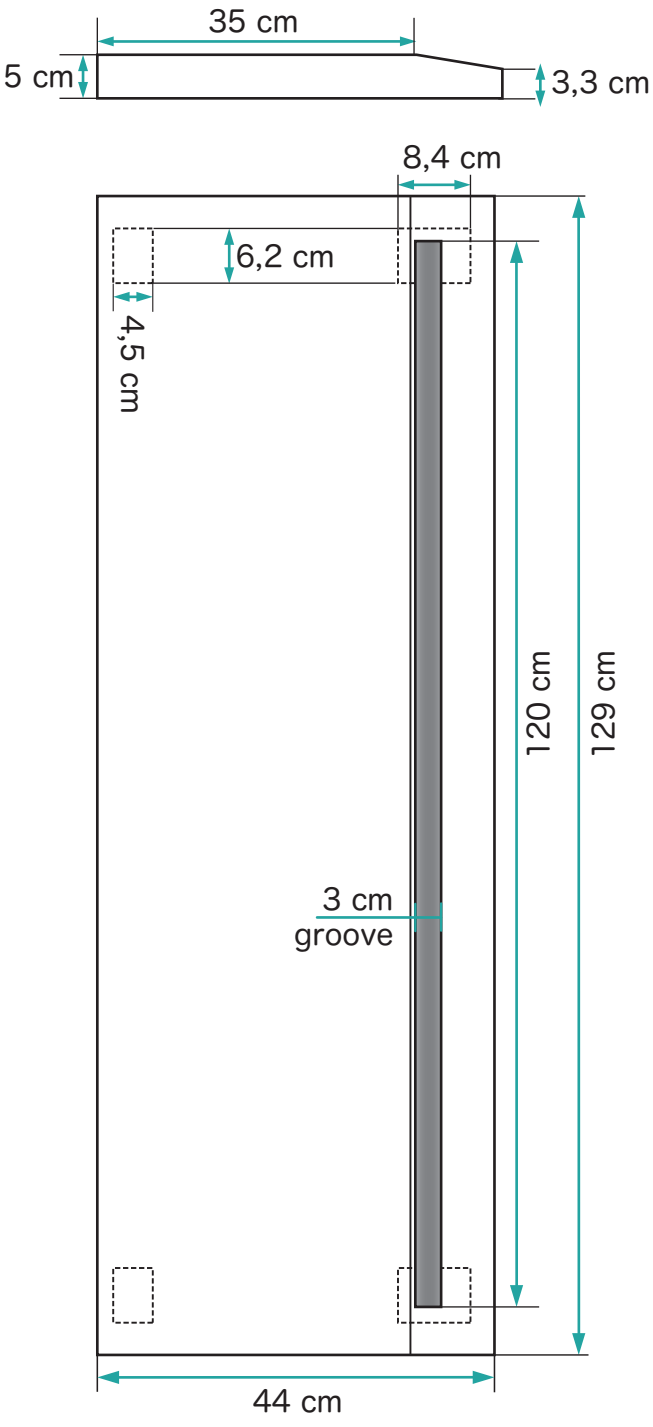
MEASUREMENT - chair;
sides, sitting surface and backrest

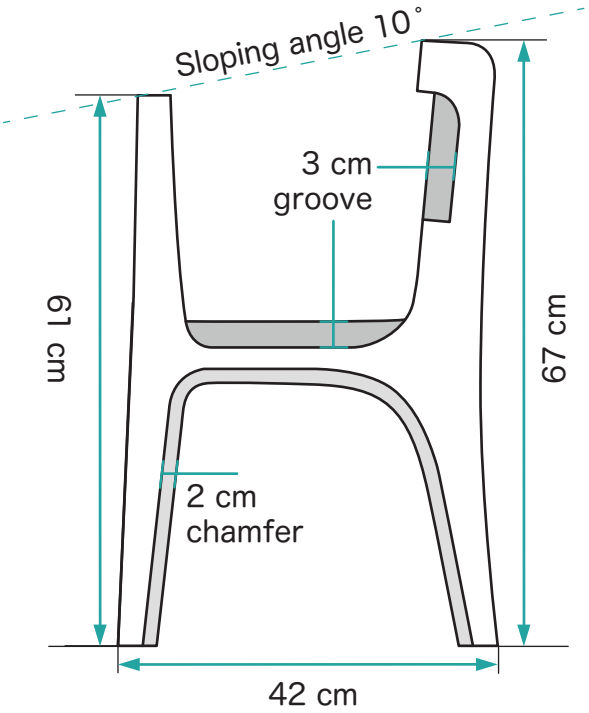






MEASUREMENT - table;
sides and writing surface





EVALUATION - DEGREE OF FULFILMENT

5/5 Provide seating for students 7-14 years old.

- *with measurements according to the anthropological appendix 2*

5/5 Provide writing space for the students

- *with measurements according to the anthropological appendix 2*

5/5 Possible to manufacture parts using Zanrec's intended machinery

5/5 Contain at least 45% recycled plastic material

- *with optimised material usage*

4/5 Provide backrest for the students

- *with measurements according to the anthropological appendix 2*

5/5 Possible to disassemble for shipping and reparations

- *using local tools, minimise shipping volume*

4/5 Provide work opportunities in the local community during production, manufacturing, assembly and disassembly

4/5 Facilitate reuse/recycling at the end of the product life

3/5 Enable students to stand when answering a question

5/5 Possible to assemble using local tools and machinery

3/5 Use standard measurements for non-manufactured parts, if needed

- *fasteners, rails or equivalent*

5/5 Allow arrangement according to East African educational standard

- *all students facing the teacher*

2/5 Be sold at an equal, or lower, cost than todays market price for existing school furniture

- *wooden benches cost approximately 70 000 TSH/unit*

5/5 Enable adjustment to varying classrooms and class size

5/5 Indicate correct assemblage

- *a brief or no instruction manual should be needed*

4/5 Express stability

- *7/10 should find it stable*

5/5 Permit a high students/classroom ratio

- *~ 5 students /m2 furniture area*

3/5 Enable a place to store personal belongings for the duration of a class

3/5 Obstruct redecoration of furniture by the students

4/5 Increase the perceived value of the plastic material

- *6/10 should find it more valuable than material in common plastic products*

3/5 Communicate environmental action taken by Zanrec

Also, the furniture should preferably:

- Facilitate cleaning of the furniture
- Correspond to the East African aesthetic
- Express school furniture
- Minimise risk of injury for the user

- *pinching, falling off, sharp edges*