

# Optimizing the Polyester Cargo Box of the Mobile Solar Kiosk for serial production at Kamworks

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KAM

WORKS

# **Optimizing the polyester cargo box of the Mobile Solar Kiosk for serial production at Kamworks**

## **Bachelor graduation report**

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## Preface

This report documents the findings and results of the bachelor assignment; the graduation project to obtain a bachelors degree at the faculty of Industrial Design Engineering at Twente University. The project was carried out at the company of Kamworks, situated in the small rural town of Sre Ampil, Cambodia.

In Cambodia things don't often go according to the plan. It takes a while to understand how and why things work the way they work. Especially on social and cultural level Cambodia differs a lot from western countries. These cultural aspects are reflected in Cambodia's workspace and economy. Next to this, the country is still recovering from the civil war which means the country's system and regulations don't work according to western standards.

Getting exposed to such a different culture resulted in learning about myself, my values and perseverance. It also gave a different perspective on my own country and it's culture. For example, I can now recognize peculiarities in the western culture as well and at the same time enjoy them because they are 'cultural'.

This, at the same time, being my first experience of studying abroad, makes it memorable and of great impact on personal level.

I am grateful to all who where there and gave me such a warm welcome. Looking back, I think of the Khmer people who always gave me the feeling of being special and I think myself lucky for having made such wonderful friends.

All in all, it was a wonderful experience and I would like to thank the following people for there collaboration and support:

First of all, I thank my company mentors, Arjen Luxwolda and Jeroen Verschelling; Jeroen for all the enthusiastic skype meetings and his never ending list of ideas and Arjen for his valuable help with all kinds of practical issues, like taking me to Phnom Penh to buy parts as well as solving technical problems during the prototyping.

Also my UT supervisor, Angele Reinders, deserves a thank you. She always gave me the feeling that I was doing things in the right way. It gave me self-confidence and I felt no restrictions.

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I cannot forget the rest of the Kamworks staff: Sarin, Serey, Sitha, Phalla and Sak. Sarin for his help with all kinds of composite problems, for sharing his thoughts about problems. Serey, Sitha and Phalla for their kindness and help in the workshop. They were always willing to share their tools, the plug sockets and space. Sak for being so playful and annoying, it pepped things up.

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I would like to thank all the students at Kamworks for being there when I needed them. Also my friends in the Netherlands for letting me know they were thinking about me with short messages and kind mails.

Finally, I would like to thank my parents, brother, sister, my boyfriend and in-laws for being supportive and full of confidence in everything I do.



## Executive summary

This report documents the results of the bachelor graduation project, which is part of the study Industrial Design Engineering at Twente University in the Netherlands. The assignment is carried out on behalf of a small Cambodian company, named Kamworks, founded by the Dutch charity foundation Pico Sol. Kamworks is specialized in solar energy and is situated in the rural areas of Cambodia, 30 km south of Phnom Penh.

The Cambodian economy is still recovering from the civil war in the 1970's. In rural areas 40 to 45 % of the people live below the poverty line. Many people are poorly educated or not educated at all, which leads to high unemployment rates especially in the rural areas. Furthermore, less than 9% of the rural Cambodian have access to a proper and reliable electricity grid. In rural areas small diesel generators serve as charging stations for car batteries which makes electricity rather expensive. Also petrol products, like gasoline and kerosene are used for lighting. All in all, the rural people's means for living are polluting and unhealthy.

Kamworks tries to improve this situation by developing small solar products for rural people, e.g. solar lights, and by offering employment. The previous years, these goals led to the development of a distribution concept for solar products under the name of Kamunasal in the rural area of Kandal province, which won a World bank Prize.

The concept in short: Young people from the province are trained in a four week course to become a Micro-Entrepreneur at Kamworks and sell the Kamunasal products. For this purpose stationary stalls and a market bike were developed. This market bike is subject for this bachelor graduation project.

The market bike was the result of the graduation project of Miriam Reitenbach. She used an old bike for the frame and glass fiber reinforced plastics for the cargo box. This box was not reproducible and thus it required redesigning to make it suitable for a small serial production at Kamworks.

Therefore, the goal of the assignment is to redesign the market bike for Cambodian Micro-Entrepreneurs to distribute solar products in the rural areas of Cambodia, and make this bike suitable for serial production.

This project asked for knowledge about glass fiber reinforced plastics, the Cambodian economy and trends and of course the cultural aspects which influences the way of working at Kamworks, economy, every day life, et cetera. Because Cambodia does have slim to non expertise in composites, this project was started with a small internship at NPSP Composites in Haarlem, to gain experience with and knowledge about composites. This knowledge proved valuable during the time in Cambodia. Furthermore, literature and the reports of previous students were examined thoroughly, to get insight in Cambodia's economy, the products of Kamworks and the distribution model. The experience of being on Cambodian grounds helped to understand the decisions made by preceding students and Kamworks.

The Khmer participants of the Micro-Entrepreneurial course served as subjects in user tests with the original Mobile Solar Kiosk. These tests were performed in order to see whether design adjustments were recommended. The subjects were also asked about the appearance of the bike. These tests resulted in valuable information for the rest of the project.

To get insight in the production situation and possibilities, tests with composites were performed at the workshop of Kamworks. Soon it became clear that the composite work situation at Kamworks is still very primitive, which asked for a flexible, easy-to-adjust, design approach.

The results of the research done on aforementioned levels was translated in a new concept of the cargo box. The box was placed on a bike frame which was redesigned by Jeroen Jansen. The combination of frame and bike is colored corresponding with the Kamunasal brand.

The new concept makes better use of the characteristics of the glass fiber reinforced material, such as form freedom and a high quality surface finish. In order to achieve a satisfying prototype, the production process was adjusted. It was necessary to produce the positive form or so-called plug in a different way to achieve a high surface quality. A major difference with the old production process is that the positive form remained intact and can be used over and over again. Furthermore, the positive mold does have mold division lines, but they are not visible in the final product. Also the shape is much more complex. By means of the user tests and interviews with Micro-Entrepreneurs the shape was defined.

During prototyping a flexible approach was applied. The design was adjusted a few times to cope with some unforeseen problems. Especially problems with the paint layer of the plug and the mold releasing asked for radical changes in the mold design. The final mold combination now contains four mold parts instead of the three mold parts in the initial concept.

The final prototype is an electric market bike, with a polyester cargo box and a sun-blocking roof. Compared to the existing mobile stores, this market bike is much lighter due to the composite material which makes the bike easy to steer. The redesigned frame with its damping system enables the driver to drive along bumpy roads. The electric system makes it possible to cover large distances on rough terrain. The batteries can be recharged by solar energy which makes the bike less polluting than conventional mobile stores, using moto's on gasoline.

The cargo box is fit with a product display in the lid, onto which products can be attached. This way the public can see the products. In the cargo box all sorts of products can be placed, from large to small products. Also, the equipment of the Micro-Entrepreneur can be stored. At the moment the prototype is used to further develop the final product.

Therefore, to help Kamworks employees and possible future students achieve better results during the production of the cargo box or new composite products for the Kamunasal brand, all the actions and recommendations for producing the plug, the molds and the final products are described in a manual.



## Terms and abbreviations

Don Bosco	Technical school in Phnom Penh with workshop for welding and woodworks
Female mold	Negative mold
GFRP	Glass Fiber Reinforced Plastic
Khmer	1) inhabitant of Cambodia 2) the language spoken in Cambodia
MDF	Medium Density Fiberboard
ME	Micro-Entrepreneur
MSK	Mobile Solar Kiosk
Moto	Moped
Plug	Positive form
SHS	Solar Home System

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# 1 Domain of the project





## 1.1 Introduction

This report reflects the results of the bachelor assignment carried out at a small Cambodian company, named Kamworks, which specializes itself in solar energy. The company is situated in Kandal Province, a rural area south of the capital Phnom Penh. Being one of the world's least developed countries, Cambodia scores low on the electrification rate. According to Cambodia Renewable Energy and Rural Electrification<sup>1</sup>, only 15% of Cambodia's people have continuous access to electricity via a reliable grid and most of these people live in Phnom Penh. In rural areas less than 9% has access to so-called 'grid-quality' power. The rest of the rural population uses rechargeable batteries and petroleum products, like gasoline and kerosene. Concerning cooking, still 90% of the population uses firewood and charcoal.

The fuels used in rural areas are not harmless for environment and health. For instance, kerosene and diesel are causing pollution and the constant exposure to petroleum products, firewood, charcoal and defect batteries are causing serious risk for people's health.

According to Arjen Luxwolda the government subsidizes the power from the grid which results in lower costs in the city for electricity than in the rural areas. However, 40 to 45 % of the people in Cambodian rural areas are living below the poverty line.<sup>2</sup> Due to the absence of a subsidized grid the electricity for the poorest people in the rural areas is much more expensive.

All together, the Cambodian rural areas are demanding a cleaner, cheaper and more reliable energy supply. Solar energy is a promising way of electrification in the rural areas of Cambodia, as the country is one of the sunniest in the world. With this goal in mind Kamworks developed a market bike and some stationary shops to provide the rural population with solar products.

The goal of this assignment is to redesign the market bike for Cambodian Micro-Entrepreneurs. The ME's use the bike to distribute the products. Hereby, it is important to pay attention to the Micro-Entrepreneurs, the possibilities of Kamworks, the availability of materials, wishes and trends among the public and the cultural aspects influencing the Cambodian market and economy.

## 1.2 Involved parties

### **Twente University – Industrial Design Engineering**

Twente University is operative in research and education varying from social studies to science. One of the science studies at Twente University is Industrial Design. This educational program trains students to design consumer products. The first three years consist of compulsory courses to gain general essential knowledge. This so-called bachelor program is completed with an individual assignment.

### **Pico Sol**

The foundation Pico Sol is an independent voluntary organization founded in 1999. Pico Sol aims to contribute to the improvement and development of life in rural areas of developing countries. Its field of expertise is solar energy for community facilities, such as schools and hospitals. By supporting this kind of projects Pico Sol contributes to the development of rural areas in developing countries.

### **Kamworks**

The bachelor assignment is performed at Kamworks. Kamworks is a spin-off of Pico Sol, therefore its field of expertise is solar energy. However, unlike Pico Sol, Kamworks is a commercial company. Therefore it is a long-term project independent of donations. Kamworks is located in the rural area of Cambodia in a village named Sre Ampil, next to an orphanage. Its goal is to provide 'affordable energy for sustainable development'. Based on this mission, Kamworks developed a list of five credo's for its products: Affordable, sustainable, locally producible, durable and desirable. Additionally, Kamworks provides employment in rural Cambodia.

#### *Products*

The main business of Kamworks is the installation of solar systems in community facilities and households. This main business will be extended with cheaper products for the consumer market. These products will be produced at Kamworks and are designed to comply with the demands of the rural population. The products are distributed under the brand Kamunasal. The production of the first locally produced product, the Angkor Light, starts at the end of 2008. In order to explore the consumer market import solar products are already being sold today.

#### *Trainings*

Kamworks also provides courses for orphans and other young people without perspective. A successfully completed course enables the student to become a micro-entrepreneur at Kamworks. They can work as installers of solar systems or as vendors of other solar products in small shops.

## **1.3 Problem description**

Currently, Kamworks is developing a distribution network in Kandal Province for the sale of solar consumer products. This network exists of fixed shops and mobile vendors. Kamworks plans to produce functional and appealing mobile stalls for the mobile vendors.

At this moment, a prototype of the mobile kiosk is available in the form of a delivery tricycle. This prototype is the result of a graduation project of a student at Delft University, Miriam Reitenbach. However, this prototype cannot be produced with local production techniques at Kamworks. To enable this, several adjustments have to be made. Besides local producibility there are other important issues such as outer appearance, volume, adaptability of interior and materials. The kiosk needs to represent the micro-entrepreneur and its products on the Cambodian market effectively. The interior has to be adaptive to a wide product range.

## **1.4 Objective**

The objective of this assignment is to:

*'Optimize the polyester parts of the delivery tricycle for serial production at Kamworks. Important issues are the local producibility, appearance, volume, adaptive interior, materials, affordability and demands of the rural population in Cambodia. These issues will be analyzed and taken into account in the design.'*

The result of the project will be a production plan for serial production at Kamworks of the polyester parts of the delivery tricycle. A prototype will be built. The duration of this project is 14 weeks.



## 1.5 Design approach

The book *Productontwerpen* by Arthur Eger et al.<sup>3</sup> is the basis for the applied design approach. The project follows mainly the procedure described in chapter 3 of the book. Phases and topics of the book can be found in figure 1.1, a schematic representation of the applied design approach.

Four succeeding phases are executed, beginning with the research phase. This phase consists of general and practical analyses. The general analyses are about getting to know the context in which to design the product and its market. Social and cultural standards and the economic situation are examined, as well as their effects on each other. Furthermore, Kamworks and its product brand Kamunasal are examined. These general analyses are performed by reading the previous reports of fellow students at Kamworks and additional literature.

The practical analyses consist of a product analysis and user tests. By means of the five credo's of Kamworks, the Mobile Solar Kiosk is analyzed step by step. Additionally, user tests and questioning of local people is used to obtain conclusions for the redesign. The second part of the practical analyses consists of gathering information about GFRP production processes and the facilities at Kamworks. By visiting the company of NPSP Composites in the Netherlands, useful information about processing GFRP's is acquired. The production facilities at Kamworks are analyzed at the moment of arriving and these are decisive for the final production process.

On basis of the findings of the research phase, the exact functions as well as suggestions for approving the design are developed. By means of this, the requirements are set up. Thereafter, the actual designing starts by finding solutions for every product function and combining these solutions to find the final concept. Mainly, sketching is used in this phase.

During the detailing phase the final design is developed as well as a prototype. Also the final cost price is estimated. Prototyping is done at the workshop of Kamworks. With the aid of 3D-modeling program Solid Works the concept is further developed and work drawings for the prototype and molds are made. After finishing the prototype, the production plan and important facts are described to provide Kamworks' employees and future students with important GFRP knowledge and guidelines.

In the last phase the project is evaluated. Conclusions and recommendations are set up to help future students in their attempt to improve the design, its production process or facilities at Kamworks.

## 1.6 Structure of the report

The schematic representation of the design approach in figure 1.1 also represent the structure of the report. Left, the phases are described while at the right the corresponding chapters are presented.

To increase the legibility, some phases and topics are divided over more chapters, whereas other topics are combined.

The design phase in the orange beam is presented much more detailed in figure 5.1 in chapter 5. There, all steps are presented in a schematic representation of the design process.

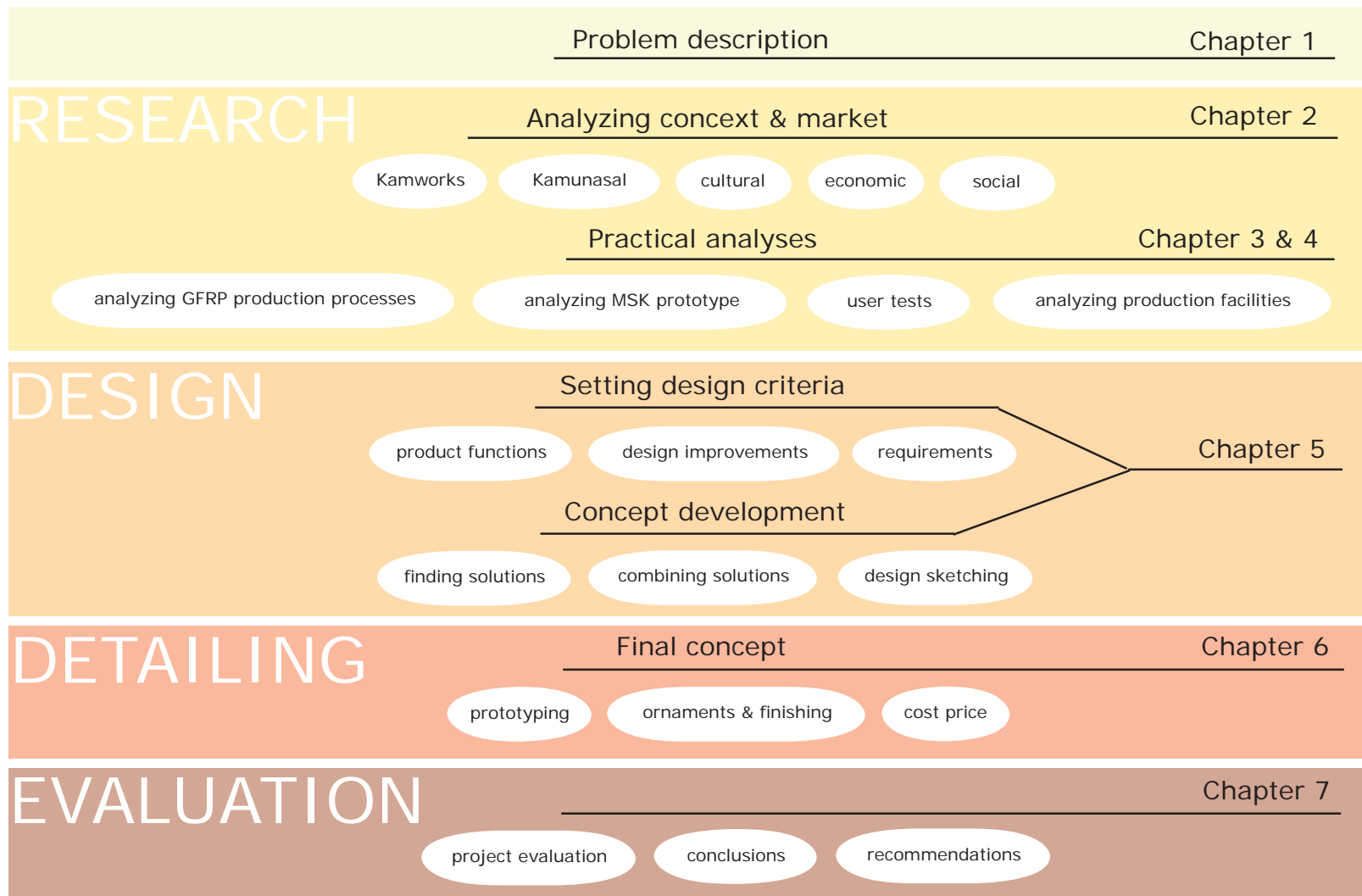


Figure 1.1: Design approach





## 1.7 Naming conventions

To avoid ambiguity, the following naming agreements are set up:

- The word *consumer market* can be interpreted as a market for consumer products in rural Cambodia.
- A *Micro-Entrepreneur* or *ME* is someone who works for Kamworks as a vendor or installer.
- *MSK* or *Mobile Solar Kiosk* refers to the original prototype of Miriam Reitenbach. When the word *Kamunasal bike* is used it refers to the redesign. The words *market bike* and *delivery tricycle* refer to either the MSK or the Kamunasal bike.



## 2 General analysis



## 2.1 Context analysis

Because Cambodia differs in so many ways from The Netherlands an analysis of the country's characteristics is performed. The aim is to get insight into the Cambodian situation concerning employment, people, selling methods and economy.

### **Cambodia**

Cambodia is a country in South East Asia, located in the tropics. It is surrounded by Thailand, Laos and Vietnam. Cambodia has a shoreline at the Gulf of Thailand. The country covers an area of 181.035 square kilometers and counts 13.6 million inhabitants. According to the Cambodia Development and Research Institute <sup>4</sup> only 20% of the people live in cities and more than 50% of Cambodia's population is younger than 20 years old.

### **Economic situation**

Cambodia is one of the least developed countries of the world. After many years of war the economic situation was very poor. Today Cambodia's economy is stabilizing step by step and despite of the challenging international economic environment, Cambodia's economy is even showing resilience. According to The World Bank it's economic growth is mainly driven by an expanding tourism sector and robust garment exports. Besides the above mentioned sectors, the agricultural sector is also an important and large source of income for Cambodia.

According to the Cambodia Development Resource Institute (CDRI) the number of unemployed people is 20 percent and most unemployed people live in rural areas. Note that 80% of Cambodia's population is living in the rural areas. <sup>2</sup>

Micro-entrepreneurship is the base of the traditional Cambodian way of life. Most people earn money in small family firms that are based on agriculture (85%), trade and skills. Only a few percent of the Cambodians earn income from large-scale industry. Kamworks' development strategy is to connect to this situation by supporting small-scale business of micro-entrepreneurs. <sup>5</sup> In the meantime Kamworks also contributes to the employment in the rural area of Kandal Province.

### **Sales and distribution**

In the rural area people buy their food and other needs at little market shops in villages or alongside the road.

Many different kinds of products are being sold in the market shops, varying from electronic devices to foods and clothing.

Mobile kiosks can be found in both urban and rural areas but the kiosks in rural areas are often powered by a motorbike because of the unpaved roads and long distances. In the cities the mobile kiosks vary from a hand pulled cart to a motor powered vehicle. <sup>6</sup>

The goods sold by mobile kiosks are mainly foods and other cheap products. More expensive products are sold in fixed shops. In general, the quality of the product is uncertain because of the many fake brands imported from China. Therefore, it is a challenge for Kamworks to convince people of the quality of their products. <sup>7</sup>

### **People and culture**

Due to the violent history of the country people tend to be suspicious towards outsiders. This affects the entire society, including the way of purchasing products. People tend to buy from whom they know.

Khmer people always try to be polite and this affects the way of interviewing people.

Cambodians always try to avoid insulting people. Therefore, if asked a question, it is possible they will give an answer which they think you want to hear.

Also, Cambodians do not say 'no' easily; they will say 'yes' and then act like 'no'.



Figure 2.1: Schematic representation Kamworks's activities

A typical poor family in rural Cambodia earns between \$300 - \$500 per year and spends about \$20 - \$24 per year on lighting.

very poor (\$1 per day)

A typical very poor family owns only few technical products, as some lamps and a radio. They live from day to day and are not able to make larger expenditure. Their main source of income is some cultivation, catching rats or frogs. In general, only one or two bikes serve for family transport.

poor (\$1.5 - \$3 per day)

These families seem to form the largest group in the rural area. They own some lamps and several other technical products, such as black and white television and a radio. They are often farmers and besides they run a very small shop. Sometimes these families own one family shared motorbike.

Rural affluent (>\$3 per day)

In the rural area also some richer families can be found. In the Cambodian culture it is not very common to move to another place, when they climb up in social status. These families are often farmers that are able to purchase machines to cultivate their land. They often have black and white or color television, a DVD-player and/or music players. Often these families own several motorbikes for the family.

Source: Design of a Mobile Solar Kiosk for Cambodian Micro-entrepreneurs, Miriam Reitenbach, 2007

## 2.2 Kamworks's activities

Until today Kamworks main activity is the installation of solar systems at Cambodian companies, institutions and organizations. However, Kamworks aims to enter the consumer market in rural areas as well. Two products for the consumer market have already been developed; the Solar Home System and the Angkor Light. Figure 2.1 is a schematic representation of Kamworks and its business. Each line represents a different activity of Kamworks; the upper one shows the high-end business of installing solar panels at e.g. companies, the other two show the sales of solar-goods at the consumer market using stationary stalls and mobile shops.

Kamworks already sold a few Solar Home Systems to some affluent families living in Kandal Province. In the future a growth of the sales of consumer products like Solar Homes Systems and the Angkor light is expected.

Kamworks's products for the consumer market are distributed under the brand Kamunasal. Kamworks developed five company credo's for their products: affordable, desirable, produced locally, sustainable and high quality.

## 2.3 Kamunasal products & identity

According to Kirsten Rijke <sup>8</sup>, the identity of the new brand Kamunasal is based mainly on two things. First of all, Kamworks contributes to the brand identity, for Kamunasal is produced and developed by Kamworks. Secondly, the first Kamunasal product for the consumer market, named the Angkor Light, influences the attitude of consumers towards the Kamunasal brand and thus its identity.

The five credo's of Kamworks are important pillars for the Kamunasal products. Kamunasal presents itself as a high quality brand which produces affordable products which fulfill the needs and wishes of rural people. The products are sustainable and produced locally.

Also the western origin of Kamworks glimmers through in the Kamunasal identity. This results in a western and therefore modern brand identity.

Already two products have been developed: the Angkor Light and the Solar Home system. They are designed to fulfill the needs of the affluent people living in rural areas.

Recently, a third product prototype has been developed, named the Ampul light.

This light has to be further developed to make it suitable for serial production.

### The Angkor Light

This is the first product developed under the brand Kamunasal. See figure 2.4. It consists of a light, powered by a battery which is recharged by a small solar panel. It can be used indoors and outdoors and the light can be adjusted to a beam or diffuse light. The product can be hung onto the ceiling or placed upon a table. Additionally, the Angkor Light can be used to recharge a cell phone or other small



electronic devices. This product is designed for the affluent rural people: See the blue cadre. The Angkor Light is locally producible as well as sustainable, high quality and affordable for its target group.

#### The Solar Home System

This product has been designed for the most affluent people in rural areas. It contains some solar panels and a battery pack in a box. The box has sockets for some plugs. See figure 2.2. The affluent people in the rural areas often own a television, a DVD-player and some music players. See blue cadre. The solar home system can be used to provide these larger products with energy.

The system satisfies with the five credo's of Kamworks; it is affordable and desirable for its target group and at the same time it is a sustainable, high quality product which is produced locally.

#### The Ampul light

Ampul means light in Khmer. This light has been developed to substitute the kerosene light. The target group are the very poor and poor people in rural areas. See cadre. The battery of the Ampul light can be recharged by a small solar panel that comes with the lamp. People can hang the light around their necks if they don't have free hands and the lamp can also be attached to a beam or nail in the wall. The light intensity can be adjusted.

The light will cost no more than ten US dollars which makes it a suitable product for selling at a mobile store. Figure 2.3 shows a prototype of the Ampul Light.

#### Future products

Mando Rotman<sup>9</sup> developed possible product market combinations for Kamworks. See appendix A. Some of these products are suitable for the Kamunasal tricycle, like a battery recharging service for medium and large capacity batteries.

The market bike can ride its route through villages and pick up empty batteries and deliver recharged batteries. This is especially useful for people who live very remote in the rural area. People in rural areas can not rely on brand names, for there are many fake brands and they hardly ever get warranty. Through regular visits of the mobile kiosk and the possibility for warranties, trust between people and Kamunasal can be built. This trust is essential for the high quality label that Kamunasal wishes to have.

Because mobile stores are generally used to sell cheap products also some small and cheap products are suitable for the Kamunasal Tricycle, like small solar battery chargers and small solar lights. Today Kamworks is developing a very basic small solar light, which will probably cost less than 10 dollars.



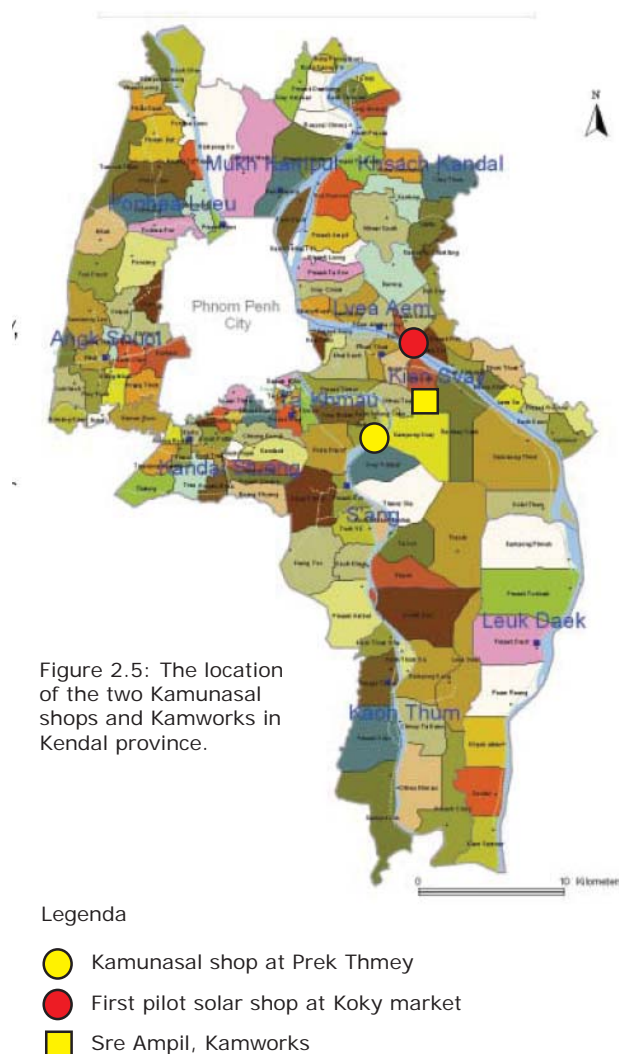
Figure 2.2: The Solar Home System



Figure 2.3: The Ampul Light



Figure 2.4: The Angkor Light



## 2.4 Distribution concept

At the moment Kirsten Rijke is developing a network of fixed shops in Kandal Province. Already two shops are operative. They are situated in the surroundings of Kamworks, in Kandal Province. The first shop is situated 12 kilometers from Kamworks at Koky market and the second one just opened at Prek Thmey, also 12 kilometers away from Kamworks. See figure 2.5. The first shop sells only import solar products whereas the concept of the second shop is based on the Kamunasal brand identity. The initial idea is to set up eight Kamunasal selling points, through funding of the World Bank.

The products which will be sold in the fixed shops are the Kamunasal products like the Solar Home System and the Angkor Light. These products are relatively expensive. Because mobile kiosks are usually not used for selling expensive goods, the Kamunasal tricycle should be used for smaller, cheaper products like the Ampul Light or repair/recharge services.

An important point that needs to be considered is that micro-entrepreneurs are apparently willing to share their business with their family. [7] This forms an opportunity for the mobile kiosk; it can be launched as an extension of the fixed shop. Two members of the same family can form an alliance; one family member stays at the shop and sells products whereas the other one drives around through the nearby villages with the mobile kiosk. Then the kiosk can be used for additional services, like charging batteries, conducting repairs e.g. of products bought in the fixed shops. At the same time it will promote the new Kamunasal shop in the area.

### Financing and salary

Miriam Reitenbach examined three different scenarios for the financing of the MSK. These scenarios are described in Appendix B. The best scenario is the renting of the MSK by Kamworks to the Micro-entrepreneur. This way, Kamworks will retain supervision and the MSK requires low investment of the Micro-entrepreneur.

Also three scenarios for paying the ME's were examined. For more information see Appendix B. Commission based salary turned out to be the best option. ME's are stimulated to sell more and they do not have to invest in the stock. This way, Kamworks retains some control over what the ME does.



Figure 2.6: students attending the course to become a micro-entrepreneur at Kamworks

## 2.5 Micro entrepreneurs

The future users of the mobile kiosk will be adolescents who live nearby Sre Ampil in Kandal province. These young people will receive a training of four weeks at the solar school at Kamworks. See figure 2.6. After finishing the course successfully, they are ready to hit the road with the solar kiosk. [5]

### Selection procedure

During the course the students gain marketing and technical knowledge. According to their abilities and affinity towards the subjects the best students are selected. Kamworks aims to select both male and female.

According to Kirsten Rijke the family and social network of the micro-entrepreneur need to be considered during selection. Because people tend to buy from family and friends it is best for the sales to have a micro-entrepreneur from the vicinity of the shop. For the mobile shop this means that the micro-entrepreneur should live near the matching fixed shop.

### Present situation

Today only fixed shops are situated nearby Kamworks, so the students will be selected for the fixed shops. In the future, also students for mobile kiosks will be selected at the end of the course.

The students attending the course have all at least basic education. Some of them speak English. Yet, the educational level should not be too high, as driving around with a mobile kiosk is considered as lower status. [5]





Figure 2.7: Cap with a solar powered fan

## 2.6 Promotional activities

As mentioned before, today only two Kamunasal products are being produced at Kamworks today: the Angkor Light and the Solar Home System. Both products have not been sold on large scale yet. Only few Solar Home Systems have been sold to families living in the area of Kamworks and two systems were donated to families who served as test families during development of the Solar Home System. The reputation of the SHS is still very poor.

Also the Angkor Light is not widely known yet. It is being produced at Kamworks right now, but because there is only one Kamunasal solar shop so far and this one is not known to the large public yet, sales are still low.

To achieve a well-known reputation for the Kamunasal brand, some promotion of its products and shops is required. The launch of a new shop can be promoted through driving the Kamunasal bike around the shop area and inform people about the new shop and its products. The Angkor Light, Solar Home System and Ampul Light can be used to demonstrate the principle of Solar energy to the people in the nearby villages.

Because there are only three Kamunasal products, using the market bike for promotional purposes means that it has to be possible to carry along the SHS and the Angkor Light as well. Then people can see the Kamunasal products and get to know them. Additionally some smaller non-Kamunasal products can be stored in the Kamunasal bike, like the funny solar powered cap-fan. See figure 2.7.

It is most likely that the redesigned market bike will be used at first to promote the launching of new Kamunasal shops. When Kamunasal is better known and there are more Kamunasal products, the Kamunasal market bike can be used as the initial distribution concept prescribes.

## 2.7 Conclusions

During the redesign of the market bike the following issues have to be taken into account:

- Mobile kiosks are generally used to sell relatively cheap products and food. More expensive goods are being sold in fixed market stalls.
- The Kamunasal brand is still developing and rather unknown to the public. To get a well-known reputation, Kamunasal should be promoted in the areas round the Kamunasal shops. The Kamunasal market bike should be designed to draw attention and to store all three of the Kamunasal products: the SHS, the Angkor Light and the Ampul Light. Also place for some promotional flyers should be designed.
- The Kamunasal bike should also satisfy the original distribution concept described in paragraph 2.4, where the tricycle is used as an extension of the fixed shop. Therefore it should be adjustable to all kinds of small solar products and recharge and delivery services of the Kamunasal shop.
- Kamworks contributes a lot to the identity of Kamunasal. During the redesign the five credo's of Kamworks should be considered very carefully. Also the modern identity of Kamunasal is very important to achieve.







### 3 The Mobile Solar Kiosk





In this chapter the prototype of the Mobile Solar Kiosk is analyzed to get an understanding of the decisions made during the development of the MSK by Miriam Reitenbach. This may help to get the redesign to a higher level.

First the technical aspects of the MSK will be analyzed, like the size of the box, the interior and the materials. Also the frame which was redesigned by Jeroen Jansen is analyzed. Thereafter the ergonomic situation is tested and the opinion of the future Micro-entrepreneurs is examined. Finally the decisions concerning the costs are reconsidered.

### 3.1 Choice of material

The carrier of the MSK is made from glass fiber reinforced polyester using the hand lay-up method. The kiosk is painted yellow, as the Kamunasal color is yellow. Compared to other mobile kiosks in Cambodia, the MSK appears very modern. Figures 3.1, 3.2 and 3.3 show what kind of materials are regularly applied in mobile kiosks and at the left page the Kamunasal kiosk is displayed.

The choice for GFRP was made by Miriam Reitenbach because of the following reasons: GFRP's enable to design complex shapes and the production of GFRP's can be performed at Kamworks, so costs for outsourcing will be saved. Another reason is that Kamworks can gain expertise in the processing of GFRP's and expand its business, for GFRP's are barely used in Cambodia. If expertise is sufficient it may even be possible to use natural fibers, which makes recycling possible. <sup>6</sup>

An additional study on materials is performed to see if the choice of material was indeed the right choice. See appendix D and E for more information. The study revealed that fiber reinforced plastics are the best materials for the carrier when compared to other materials. Some great advantages of GFRP's are the good weather resistance, the very low weight and the low maintenance costs. Other plastics produced by e.g. vacuum molding are no option because the carrier is too big to produce in the vacuum molding machine at Kamworks and outsourcing the production would be very expensive. Wood and sheet metal are discarded because of the limited form freedom.

The Kamunasal identity is partly presented by the choice of material. For example, the shiny plastic is very striking and the rounded corners are rather exceptionally. However, composite materials offer much more form freedom than the forms of the present carrier. During the redesign even more complex forms can be applied. This will be in line with the modern identity Kamunasal wishes to have.

#### Conclusions

- The carrier will be made of fiber reinforced plastics, because the material has great advantages on different levels
- The material offers more form freedom than applied in the prototype. During redesign more complex forms can be designed.
- Possibilities concerning fiber and resin types should be investigated, e.g. availability.



Figure 3.1: delivery tricycle in Phnom Penh



Figure 3.2: moto with side-car in Phnom Penh



Figure 3.3: moto with box at the back, Sre Ampil

## 3.2 Exterior

### Surface finish

The MSK was produced in a mold which was divided into four pieces, because the form is not drafting. Figure 3.4 shows some details of the prototype of the MSK. The walls are slightly curved (A) and the upper brims are bending inwards (H). Prints on all sides of the MSK carrier are the result of this mold division (K). The gelcoat used to color the MSK was applied too irregularly which resulted in an uneven coloring (N). Therefore the entire carrier was spray painted yellow. This resulted in a finer surface finish. However, the spray paint peels off very quickly (L) and if the sun shines into the carrier the walls will see through (N). Also air pockets can be recognized in the walls (N). Additionally, there are some odds in the finishing of the brims (H) and the insert of the solar panel (I). Finally, a gap between the two lids will result in a very wet interior when it rains (C)

### Branding

The Kamunasal brand is hand painted on both sides of the carrier using a beamer for projection (B). The letters are a bit untidy.

### Solar panel

On top of the front lid of the carrier a solar panel is embedded (M). This panel is placed with the intention to use it for educational and promotional purposes, like explaining how solar energy works. However, it contributes a lot to the total costs of the mobile kiosk. Because the mobile kiosk will probably be used for selling cheaper products and services like battery charging and repair, the solar panel is rather superfluous. Any promotional and educational activities can be performed using a small solar product.

### Lights

In the front, the carrier has two reflector lights embedded (E). This enables the driver to be seen in the darkness. However, the lights are not powerful enough to lighten up the road for the driver.

## 3.3 Interior

### Fixing the goods

During the design of the MSK, no attention for the inside of the kiosk was paid. On the inside, the surfaces of the walls are very odd, and fibers are extending from the polyester (J).

A wooden tray was made to present an idea about how products can be placed and fixed inside the carrier. However, the tray was made very quickly, because it was meant as a prototype, and therefore it does not have a quality look (G). The tray is placed upon Perspex profiles which are laminated onto the walls (D). To make this idea work, some adjustments have to be made.

### Hinges and lid

The brims of the box are bended inwards which made it necessary to design and produce hinges (F) for the cargo box. The hinges are able to keep the lid in a vertical position. It is better to design the opening mechanism in such a way that no custom made hinges are required.

### Battery pack, wires and lights

The MSK contains two batteries to power the driving mechanism and the lights. The batteries should be recharged at regular intervals by an external source and they can be placed somewhere inside the carrier. The batteries should be fixed properly and protected against other products, rain, moisture and vibrations from driving over bumpy roads. Also the wires connecting the lights and the driving mechanism to the batteries should also be fixed properly, protected against products and moisture. To connect the driving mechanism to the battery some outlets have to be designed in the carrier. A solution for fixing the wires of the driving mechanism to the frame should also be found.

At the inside, the lights are not properly protected against the goods (E). A solution should be found for protecting the lights from products.

### Conclusions

- During the redesign special attention has to be paid for the finishing of the product. better solutions for e.g. the hinges, the tray, the spray paint layer and the application of the brand should be found. Also the box should be made watertight and the reflector lights should be replaced by real head lights, so the driver can see the road.
- Because the mold division leaves its marks clearly, mold divisions should only be applied in areas out of sight or where two surfaces hit each other.
- The solar panel should be reconsidered, because it adds a lot of costs to the MSK
- Space for battery, lights, wires, e.g. should be reserved in the box.





### 3.4 Size

The size of the carrier depends on the products that will be stored. Sections 2.3 to 2.6 deal with the Kamunasal product range and how to use the Mobile Solar Kiosk. Because the products sold from mobile stores should not be too expensive, the carrier has to be designed for cheap and small products. The recently developed Ampul Light [Team Lumen, 2008] fulfills these requirements. However, because the Kamunasal brand needs promotion during the launching of a new shop [section 2.6] it has to be possible to carry along one of each present Kamunasal product. This means that also space for the larger products like the SHS and the Angkor Light should be reserved.

Because in the future more Kamunasal products will be developed, the market bike must also have space for other future Kamunasal products. In addition, recharging services for e.g. penlite batteries can be offered by the tricycle, to make it more profitable for the Micro-Entrepreneur.

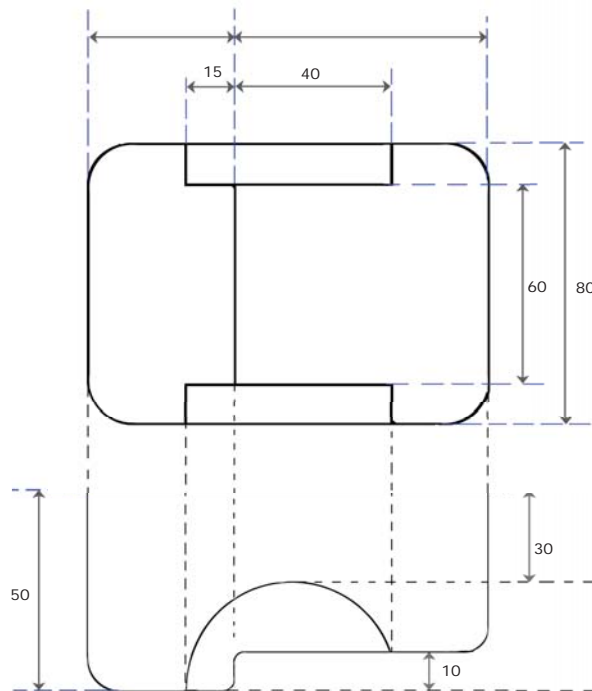


Figure 3.5: basic dimensions of the MSK cargo box

Miriam Reitenbach assumed, based on the product range at the present stationary stalls, that between 10-15 products should be sold, with about 1-3 products per group of products. The volume of these small products range from 150 cm<sup>3</sup> to 25000 cm<sup>3</sup>. She stated that the volume should be around 200-300 liters to store the products and the additional equipment of the ME (cash box, repair kit).

The actual volume of the MSK prototype is around 300 liters. The drawings in figure 3.5 present the dimensions of the carrier.

The carrier actually looks rather lumbering. It seems as if steering the bike is very difficult. The space inside is very large. Despite the fact that the 300 liters fits the demand of Miriam, the volume needs to be reconsidered.

Measuring the carrier made clear the dimensions are not conform the dimensions of the carrier in the MSK report. The report states for example that the width of the carrier should be 62 cm, while in fact the width is 80 cm. Appendix C describes all difference between prototype and the original design in the report.

#### Conclusions

- The volume of the carrier is around 300 liters. This seems rather large, so this needs to be reconsidered.
- The product range is very important for the design of the interior and the required space inside the carrier. The interior must be adjustable to a lot of different products.

### 3.5 Frame

The frame of the MSK was redesigned by Jeroen Jansen.<sup>10</sup> The redesign differs in some ways from the original design. For instance, a roof support construction has been designed, because a roof is required to protect the micro-entrepreneur against the sun.

#### The roof

Two ideas were already presented by Jeroen Jansen:

##### *The roof is made from cloth*

This is easy to construct, light weight and cheap. The cloth does not block the sun completely, so the micro-entrepreneur is not fully protected against the sun. The color of the fabrics will probably also fade really fast. The weather resistance is also low, because cloth will wear out rather quick.

##### *The roof is made from a lid of the MSK*

The lid from the MSK can also be used as a roof to block the sun. See figure 3.6 B. The mold is already present, so it is very easy to produce a roof. The composite material is weather resistant, so rain and sun do not affect the material much. Maintenance costs are low. The appearance of the roof matches the appearance of the carrier. However, the roof is quite heavy.

The dimensions of the roof support construction are a limiting factor for the design of the actual roof. The construction of the roof is shown in figure 3.6 A.

#### Connecting the carrier

The carrier needs to be connected to the front part of the frame. See the gray parts in the figure 3.6 C. The size of the front frame is a limiting factor for the size of the carrier. The dimensions of the redesigned frame are different from the original design.

Appendix C gives more information about the important frame dimensions.

#### Conclusions

- During redesign of the carrier, the redesigned frame should be thoroughly analyzed
- Ideas for the roof should be examined and additional ideas should be thought of.

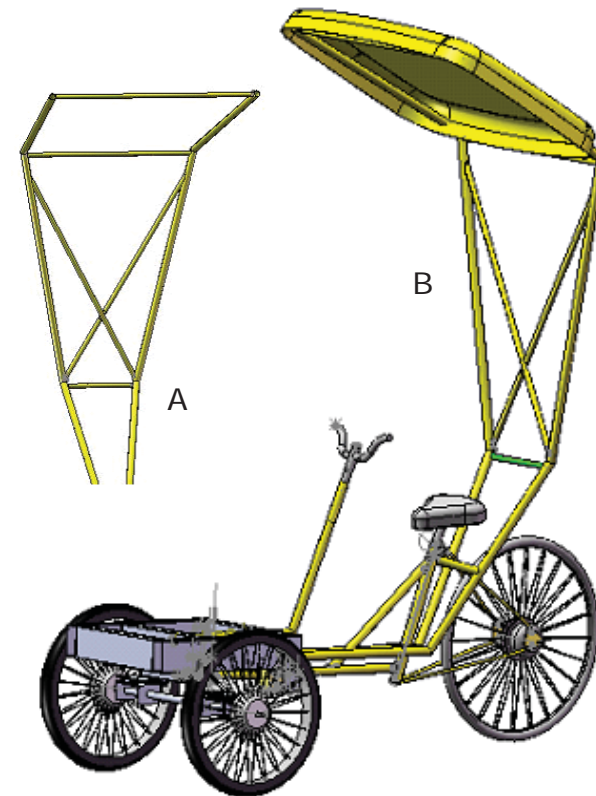


Figure 3.6: Models of the redesigned frame.

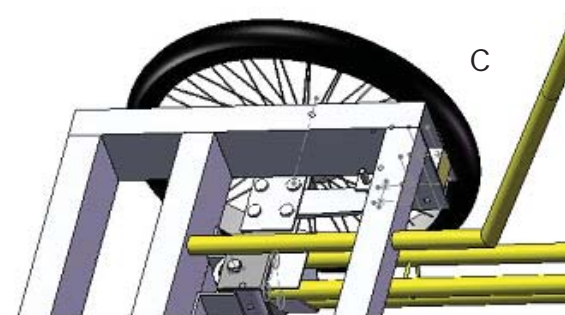






Figure 3.7: Tests with the Micro-Entrepreneurs

### 3.6 Ergonomics

Miriam Reitenbach determined the optimum height of the carrier by measuring the body dimensions of several Cambodian people and by making use of literature about ergonomics. Appendix M gives an overview of the data.

As cited in the graduation report of M. Reitenbach, Molenbroek (2007) states that the best working height for a standing person is 63% of the body height. According to Jurgens (1989), also cited in Reitenbach's report, the ideal working height for South East Asian people is between 900 and 1070 mm. Because the data are rather old and could well be outdated, it does not necessarily mean that the data are representative for Cambodian people. Therefore, also measurements among Cambodian people were made. This measuring resulted in a optimum height between 97 cm and 110 cm.

Finally, the height of the carrier to the ground was established at 92 cm, to enable every user to look into the carrier.

#### Tests

As mentioned before, no user tests were performed with micro-entrepreneurs and the interior was not thought of well. To get more information about how to design the interior some tests with the people attending the Micro-Entrepreneurial training at Kamworks were performed. Because the carrier is not firm enough to conduct a real user test, a different approach was applied.

The Micro-Entrepreneurs were asked to pretend the MSK was well functioning and they were the vendors. Their opinion about the way of handling the carrier was asked.

The general opinion of the group was that the height of the carrier was good. They all could reach the bottom of the carrier if they bent a bit forward. The tray made it easier to reach the products because they did not have to bend that far.

Opening the lids was no problem for the ME's. The lids open to two sides: the front and the back. However, the opened lids are blocking the view of the costumers and the ME. The two lids force people to stand at the side of the vehicle to see what's inside.

The back lid opens towards the frame of the bicycle. No costumers can stand in that area because of the frame. But if the ME wants to stay on his saddle, he can't look into the carrier because the lid is too high. He has to stand on the pedals and stretch his neck to see what's inside. See figure 3.7. These issues need to be considered during the redesign.

#### Suggestions

The group suggested a movable tray to make it easier to pick something from underneath the tray. They thought the tray should cover half of the box and should be able to slide from one side to the other.

#### Conclusions

- The height of the carrier seems good. All the subjects can reach the bottom easily.
- The lids block the sight of the ME when opened. The lids force the ME to step off the bike and stand next to it.
- The costumers can only look into the carrier if standing on one of two sides.
- A tray would make it easier to display the products and reach for them to show to costumers.
- A movable tray makes it easier to reach for products from the stock underneath the tray.

### 3.7 General opinion of costumers

Previous interviews among costumers and local people performed by Miriam Reitenbach resulted in the below mentioned knowledge.

#### Appearance

The subjects reacted all positive on the MSK. They liked the round shapes and appearance. Except for one, they all liked the yellow color. However, except for one subject, non could guess what kinds of products were being sold. Five of the subjects assumed that rather expensive products were being sold , two thought about cheaper products while the other two did not know what to expect.

The subjects thought it is important to show the products on the outside. Besides displaying the products, in addition a microphone can be used. Two subjects stated that only using the microphone would be sufficient to communicate the product range.

#### Material

When asked their opinion about the material of the MSK, the majority of the subjects thought that steel was better than plastic, as steel is stronger and has a longer life span. Only three thought that plastic was a good choice as it is lighter and therefore easier to maneuver over bumpy roads.

#### Conclusions

- It is important to make clear what products are being sold. Cambodian people are used to display the entire stock of products. For the redesign a solution to display some products should be found.
- The MSK appears new and modern and this draws attention from the costumers. The majority liked the yellow color and the round shapes.

### 3.8 General opinion of Micro-Entrepreneurs

It is also important what the ME thinks of the MSK, for the ME is the one that has to work all day with the vehicle. Because Miriam did not have access to Micro-Entrepreneurs she did not interview them. Today, a group of ME's are being trained at Kamworks, so these people are interviewed about the appearance, size, form and other features.

#### Outside appearance

##### *first impression*

The first thing the ME's said about the carrier was that the gap between the lids would let the rain trough and all the products would get wet. Also some remarks about the rigidity and solidity of the bike were made. They thought the bike was not rigid enough to drive.

##### *color*

All subjects liked the yellow color. They thought yellow is a good choice because it is the Kamunasal color and it is striking.

##### *size*

The subjects discussed the size of the carrier. They thought it should not be bigger because the steering would become difficult. They agreed that making the carrier smaller would make steering easier. But the volume has to be big enough to carry along products and additional equipment.

##### *shape*

All subjects were positive about the shape. Half of them liked the rounded corners and the other half liked the clean-cut edges. When asked if they could



imagine the carrier having more fluid lines, like race cars, they answered that it would be nice to design the carrier more like the hull of a boat. Because a boat is more streamlined and they like the streamlines.

#### *branding*

The subjects discussed the branding and they thought it would be better for recognizing the brand to put the logo also on top and on the front of the carrier. This means they want to have the logo visible from all sides of the carrier.

#### *mud-guards*

All subjects agreed that the mud-guards were not satisfying. The mud-guard should be longer as to protect the ME against mud when driving over wet dirt roads. They also thought that the carrier needs to be protected against the mud by the mud-guards, so no dirt will get on the carrier.

#### *panel*

When asked about the use of the panel, the subjects thought the panel should be present to communicate the products and the principle of solar energy. The panel should be visible for the costumers, so costumers can see that something with solar energy is inside the carrier. To make the panel better visible, the panel should not be at the same level as the surface of the carrier. Instead, the panel should extend from the surface for a couple of inches, so the costumers can see there is a panel on top of the carrier.

#### *lights*

Some subjects thought it would be nice and funny to have flashing direction lights, in front and at the back of the carrier. Also a brake light was suggested.



## Interior

### *tray*

The subjects suggested to install a movable tray to display the products. The tray should cover half of the box. If the ME wants to pick something from underneath the tray, he can slide the tray to the other side of the box and reach for the things he wants.

### *products and other equipment*

The tray should be used to store and display the products. Underneath the tray more products can be stored as well as personal belongings of the ME and the electronic components for e.g. propulsion of the bike, lights, flashing light device, horn, etcetera. The ME suggested that divisions for every product should be made onto the tray. The products should not be loose in the carrier. A solution for protecting and fixing the products should be made.

## Remaining

### *roof*

The ME's suggested to attach a parasol to the vehicle, like the one on ice-cream carts.

### *lock*

It should be possible to lock the cargo box.

### *music*

The ME's thought it would be nice to have some music because the distances are long and music would make it less boring to cover the distances from one village to the other. They also thought that it would be useful to attract costumers.

## Conclusions

- It is important for the trust of ME's and costumers to present a firm, high quality shop. The state of the MSK does not make people believe that high-quality products are being sold.
- Everybody likes the yellow color as it is the brand's color. The redesign should also be yellow.
- Although the ME's like the appearance of the carrier because of its rounded corners or clean-cut edges some of them suggest to design the form more like a hull of a boat. More streamlined.
- The mud-guards should be considered well, because the ME's don't want to get dirty when driving over a wet dirt road.
- Suggestions are made concerning the possibilities to apply more logo's on the carrier and to add flashing direction lights and stop lights. This should be considered during redesign.
- The panel is thought of in a positive way, despite the high costs. The ME's think it is important to show the people that something with solar energy is inside. It will make people curious.
- The ME's think the carrier is a bit to big. They think a smaller carrier would make steering easier.
- Some suggestions about a movable tray are made, to make it easier for the ME to get something from underneath the tray. This feature should be considered during the redesign.
- Space for personal belongings should be reserved.
- The ME's think there should be a roof like a parasol. During redesign this should be taken into account.
- Possibilities to play music should also be taken into account.

### 3.9 Total costs

The costs of the original tricycle were calculated by Miriam Reitenbach. Prominent cost influencing factors are the addition of promotional materials, such as a solar panel and posters and the size of the series. Miriam made three estimations. The estimations are based on the assumption that the production process will be performed at Kamworks as much as possible. The first two were based on a series of 10 pieces and the third on a series of three:

- The bike will cost \$627.36 if promotional material is included.
- Without the promotional materials the bike will only cost \$482.36.
- A series of three will cost \$526 per piece without promotional materials

#### Promotional material

The addition of the promotional material results in a 30 percent increase of the total cost price. The promotional materials exist of posters, a led display and a solar panel to explain the principle of solar energy. The solar panel contributes the most to the increasing costs with its \$125. The posters and the led display are both estimated at \$10 a piece. Leaving the panel and led display out will result in a much cheaper and more affordable vehicle. The principle of solar energy can also be explained by simply making use of the Angkor light and some posters.

#### Test series

The third estimation was made based on a series of three to test the acceptance and functioning of the Mobile Solar Kiosk. The price will go up to \$526 per piece without promotional materials.

#### Frame redesign and roof

The frame which is redesigned by Jeroen Jansen is a bit more expensive than estimated by Miriam Reitenbach. The labor costs and the new damping system are cost increasing, because some steel parts have to be built at DonBosco's. The roof however, turned out to be cheaper than estimated. Because the lid of the cargo box can also be used as a roof, no costs for an extra mold have to be made. The roof will be about \$20, instead of the \$50 according to Miriam Reitenbach.

The total costs of the redesigned frame, including the costs for the roof and electric components are \$304,80. Assuming that the costs for composite material will not differ much from the estimations Miriam made, the total costs will become \$570 for a delivery tricycle without promotional materials.

The building of the first frame is entirely boarded out to Don Bosco because it is not possible at the time to build it at Kamworks. This will make the costs for the first tricycle somewhat higher.

#### Conclusions

- Addition of promotional material should be considered once more, because it makes the whole much more expensive.
- The costs for the cargo box can differ from the estimated costs for the box, due to difference in material and/or production process. The price will be a heavy factor during decision making, because it is important to keep the costs as low as possible to keep the bike affordable.

### 3.10 Conclusions for the redesign

After analyzing the MSK it can be concluded that special attention for the unfinished parts, like the roof and the interior is required.

#### **Shape and material**

The carrier will be made of fiber reinforced plastics, because the material has great advantages such as high form freedom, good strength, low maintenance costs, light weight and no corrosion.

The Micro-entrepreneurs like the color and material and also the rounded corners and clear-cut edges. They are positive about the idea to design a stream-lined box with more complex forms. To utilize the possibilities of the material and to fulfill the wishes of the ME's, the shape of the box will be changed. This will result in an even more modern looking tricycle. During redesign of the exterior, the wishes and remarks of the micro-entrepreneurs are important to keep in mind.

#### **Interior, product storage and roof**

The inside of the present-day carrier does not have a quality look. Fibers are extending from the surface and no solutions for fixing and protecting the goods are present. A tray is present to store some products but the Micro-entrepreneurs think that it would be difficult to pick something from underneath the tray. Therefore, solutions for fixation, storage and protection of the goods should be developed. At the same time, the interior should be designed to have a nice, high quality appearance.

The roof of the new bike has to fit the redesign of the carrier. The roof can be made of a lid of the prototype, but additional ideas should be developed to make the best choice.

Finally, ergonomics and wishes of Micro-entrepreneurs are important for the redesign.

#### **Lighting**

The reflector lights should be replaced by real head lights so the driver can see in the dark. At the side some reflectors can be added to make the driver visible from the side. Also some flashing direction lights can be added.

#### **Size**

The dimensions of the redesigned frame are a limiting, yet important factor for the size of the carrier and these dimensions should be taken into account during redesign of the carrier.

According to the ME's, the size of the carrier appears big and it seems difficult to steer. Possibilities to reduce the size in such a way that it fits the redesigned frame and can store the products and personal belongings, should be investigated.

#### **Promotional material**

The solar panel is very expensive and contributes to high costs. Leaving out the solar panel will reduce the costs. However, ME's think that the solar panel helps draw attention if placed a couple of inches above the surface of the cargo box. The pros and cons should be weighed carefully. Other promotional materials can be used to substitute for the solar panel.

#### **Sound**

To attract people's attention a horn and/or music installation can be added.





# 4 Production methods





This fourth chapter gives insight in the production possibilities at Kamworks. First, the production of the Solar Home System is analyzed and compared to the production of the MSK. Problems are listed. Additionally, the facilities at Kamworks are analyzed. Secondly, three different ways of processing composite materials are described and analyzed. Finally, some testing is done to gain experience with composite materials and solve the problems.

## 4.1 Analyzing the present production process

### Analysis of the production of the Solar Home System

Today Kamworks is producing the Solar Home System. The box with battery and plug-sockets exists of glass fiber reinforced polyester. The first series of 5 of the box have been produced using the hand lay-up method. Many different problems occurred during the production of the first boxes. Below the problems are listed:

- The inner surface of the box remained very sticky in the first attempts. Later on, the stickiness decreased a bit, but it is still a problem. The stickiness is probably the result of absorbing moisture from the air in the resin.
- Putty which was used to fill up the holes in the mold attached to the final product. Filling up holes in the mold can also be done with gelcoat.
- The polyester resin dried too fast. The accelerator cobalt was already in the resin, so it was not possible to change the amount of accelerator. Inhibitor was used to overcome this problem. However, until now a supplier of inhibitor has not been found in Cambodia and resin without cobalt is also unknown in Cambodia.
- It turned out that it is best to mix the resin in small quantities, so no resin will be spoiled.
- Transparency of the gelcoat. There is no solution to this problem yet.
- The weather influences the reaction time of the resin. In the morning, the resin dries slower than in the afternoon.
- White gelcoat dries slower than transparent gelcoat because there is less cobalt in the white gelcoat.

### Analysis of the production of the Mobile Solar Kiosk

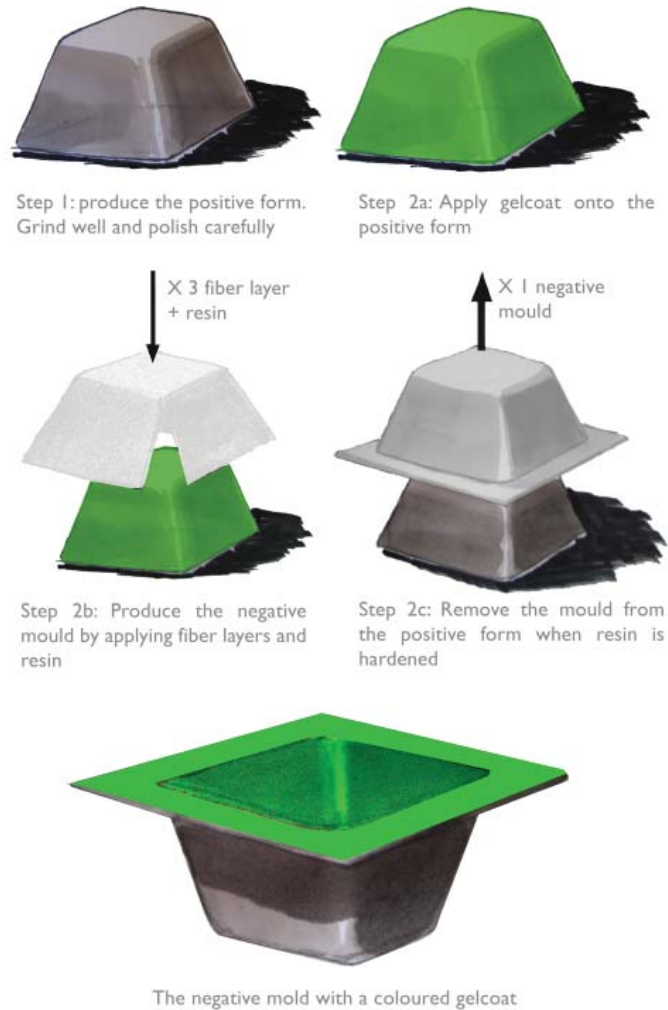
During the production of the MSK the following problems occurred. Combined with the above mentioned problems, it gives a complete list of all the points that need to be considered during the redesign. The following difficulties appeared:

- All above mentioned problems also occurred during the production of the MSK.
- Finishing the surface of the positive form: The positive form was made from polystyrene. This is a rather coarse foam which is really hard to handle. Grinding it will crumble the foam. Therefore, an epoxy layer was applied onto the foam and this layer was polished.
- Removing the mold from the positive form: Probably because the positive form has slightly curved walls it was not possible to release the mold from the positive form. The mold was divided in four to overcome this problem. The mold division remained visible in the end product.
- Very long after-treatment of the final product: This was due to all the imperfections in the mold.
- Resin did not reach all the fibers, this resulted in dry fibers extending from the inner surface.

### Conclusion

- To produce a high quality surface, solutions for the stickiness, producing the positive form, mold divisions, making putty and transparency of the gelcoat must be found.
- Tests with the composite materials have to be performed to see how to solve these problems.

Figure 4.1: Producing the negative mold



## 4.2 Processing composites

To get insight in the possibilities of glass fiber reinforced plastics, three production processes were analyzed. The first one is the hand lay-up process which was used to make the MSK and the SHS. The other two processes are more sophisticated processes which are used in composite processing factories, such as NPSP Composites Haarlem in the Netherlands.

### Hand lay-up

The Mobile Solar Kiosk was produced by hand lay-up of glass fiber mats. This process is quite time consuming and consists of a lot of successive steps. In short, the steps are as follows:

- Step 1: producing the plug,
- Step 2: use this form to make a female mold
- Step 3: use the female mold to produce the final product.

Step 1 and 2 only have to be performed once so these are one time expenditures.

The hand lay-up process is generally applied in the boat production industry. Large sail boats and catamarans are being produced with glass fiber reinforced plastics. The boat is produced layer by layer. All imperfections are grinded out before the next layer will be applied. This results in a very high quality boat hull. However, to produce such a high quality all steps have to be performed perfectly. At first, the positive form has to be perfectly smoothened. No imperfections are allowed, because these imperfections will also show on the negative mold and all imperfections in the negative mold will return in the final product. Through after-treatment these imperfections can be removed, but this takes a lot of time and should therefore be avoided. An accurate way of working is required to produce a high quality product.

### The female mold

Figure 4.1 shows the first two steps of the hand lay-up process: producing the female mold. During step 2 the female mold is produced including a colored gelcoat. The coloring of the mold helps to notice any imperfections in the mold, like scratches. Secondly, during the application of the different colored gelcoat of the final product a contrasting mold helps to see where more gelcoat is required.

#### *The final product*

Figure 4.2 shows the required steps to produce the final product. First, the desired gelcoat is applied onto the mold. The color of the gelcoat should differ from the color of the mold because then imperfections in the gelcoat can be noticed very easily.

By applying the fibers and resin into the mold, the final product is obtained. The layers of the fiber mats are rolled on layer per layer. It is important that all imperfections are eliminated before adding a new layer.

#### *Shrinkage and draft angles*

The positive form should be designed with draft angles to enable the mold to release from the form. These angles should be at least 1.5 degrees.

The shrinkage of the materials should also be considered during the designing of the positive form.

Through shrinkage, it is possible that the final product can get stuck in the mold.

#### *Resin and fiber types*

The hand lay-up process can be performed with two types of glass fiber: Chopped strand mats and woven roving. In the boat building industry these two types are both used in the hull and deck of the boat. The woven roving is stronger but also harder to shape into the right form. They are applied as inner layer to strengthen the material. Appendix F1 describes the necessities for the hand lay-up process.

The resins which can be used for hand lay-up are epoxy, polyurethane and polyester. Polyester is the cheapest (\$2.60/liter).

Epoxy and polyurethane have better mechanical properties than polyester. Polyurethane also emits less gases during the chemical reaction than polyester, and it is not as sensitive to absorption as polyester.

<sup>11</sup> According to Bill O'Leary from boat building company Steppaboard <sup>12</sup>, all three resins are used on large scale in the boat building industry.

#### **Conclusions**

- The plug requires a thorough treatment to smoothen the surface and eliminate all odds.
- The color of the gelcoat of the female mold should contrast with the color of the final product, so small faults can be recognized.
- Draft angles and shrinkage should be considered during the design of the product.
- The choice for a certain resin should be carefully considered.
- The advantages and possibilities of the different fiber types should be considered.

Figure 4.2: Producing the final product

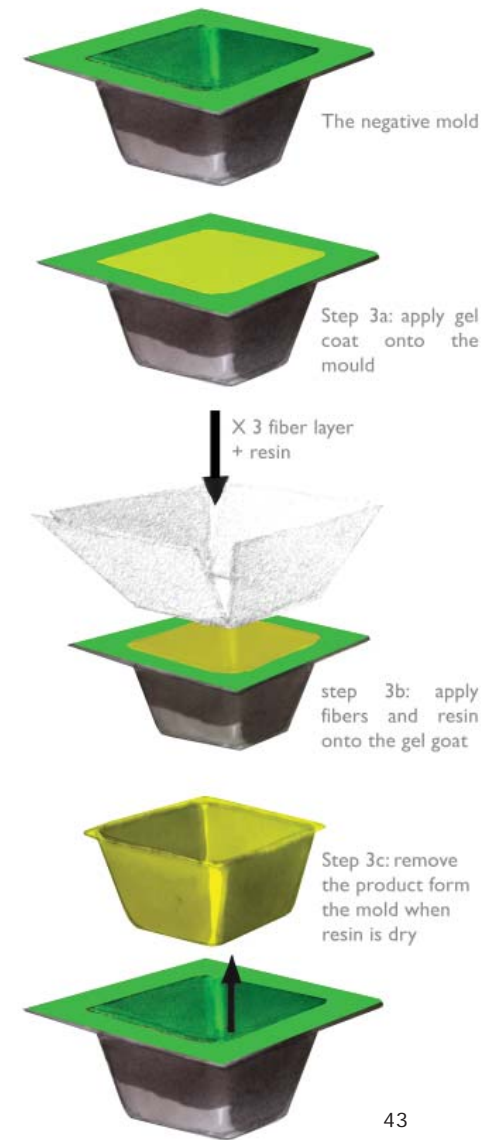
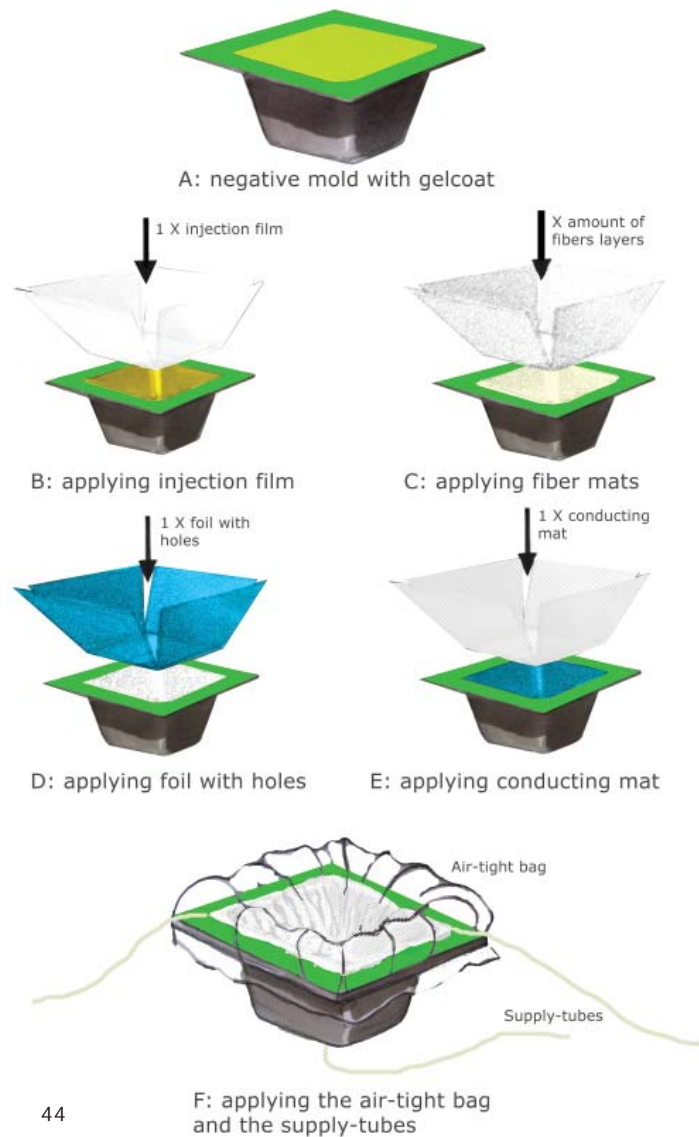




Figure 4.3: producing the final product with the vacuum bag process



### Resin injection molding

Because the hand lay-up process is very basic and time consuming, two other processes are investigated through an internship at NPSP Composites in the Netherlands. NPSP Composites is a company that produces composite products using the RTM process (Resin Transfer Molding). This is a more sophisticated production process of composites which is used for serial production.

### Vacuum bag molding

Several types of RTM can be performed, and the simplest one is RTM with a vacuum bag. Vacuum bag laminating is usually applied as a step towards laminating with double molds. The vacuum bag enables to observe the route and behavior of the resin. If the resin reaches all the fibers, the bag can be replaced by a positive mold.

#### Processing steps:

Step 1: produce the plug

Step 2: use the plug to make a female mold

Step 3: use the female mold to produce the final product

The first two steps of the vacuum bag process are the same as the hand lay-up method. However, the third step differs in several ways and additional materials are required. Figure 4.3 shows the successive actions of step three. The materials in B and C remain in the final product whereas the materials of D, E and F are thrown away after finishing the process. Appendix F2 shows all the required materials. Although more steps have to be carried out during the process this method is less time consuming and less hazardous than hand lay-up.

#### Fiber and resin types

Vacuum bag laminating can be applied on many different fiber types. Double layer fiber mats and all kinds of natural fibers can be used in this process. The normal hand lay-up glass fiber mats are not usual for this process. However, tests proved that at least for small products the normal chopped strand mats can be used. These tests are described in appendix G.

Also different types of resin can be used during vacuum bag laminating. The resins must have a lower viscosity than the hand lay-up resin because it is transported through small tubes.

### VA-RTM

The regular RTM process uses two molds: a negative and a positive mold. At NPSP Composites, the molds are held together by a vacuum pump. Therefore, gutters are present in the brims of the mold. In appendix F3 all the necessities are listed.

*Processing steps:*

- Step 1: produce the positive plug and a negative plug  
Step 2: use these plugs to make a female/negative and male/positive mold  
Step 3: use the molds to produce the final product

The RTM process is generally applied when large series have to be produced. The process is less time consuming than the hand lay-up and the vacuum bag process. During the third step gelcoat, injection film and fibers are placed onto the molds. See figure 4.4 for the successive actions. After applying the fibers et cetera, the molds are placed upon each other and the resin is injected.

*Fiber and resin types*

All kinds of fiber and resin can be used in this process, depending on the desired material strength. However, the hand lay-up fibers are not suitable for this process. Also different types of resin can be used with RTM. Like the vacuum bag process, the resins must have a rather low viscosity because the resin is injected through tubes.

**Comparison**

The processes are compared to each other and the pros and cons are listed. In appendix I an extensive comparison is given.  
The most important findings are:

hand lay-up process: cheapest, requires few materials, no waste products, no natural fibers are possible, not healthy, longest production time, good product appearance.

Vacuum bag process: step towards RTM-like process, requires many materials, many waste products, good product appearance.

VA-RTM: superior product appearance, few waste products, requires a resin injection machine which is not yet present at Kamworks.

**Conclusion**

- Vacuum bag processing requires many materials and has many waste products and is therefore not suitable as a permanent way of serial production in a developing country.
- Because the vacuum bag is a step towards RTM and RTM is applied if large series are required both processes seem not very useful, as the series of the carrier are 10 per year.
- For these processes machinery such as an injection machine and vacuum pump are required.

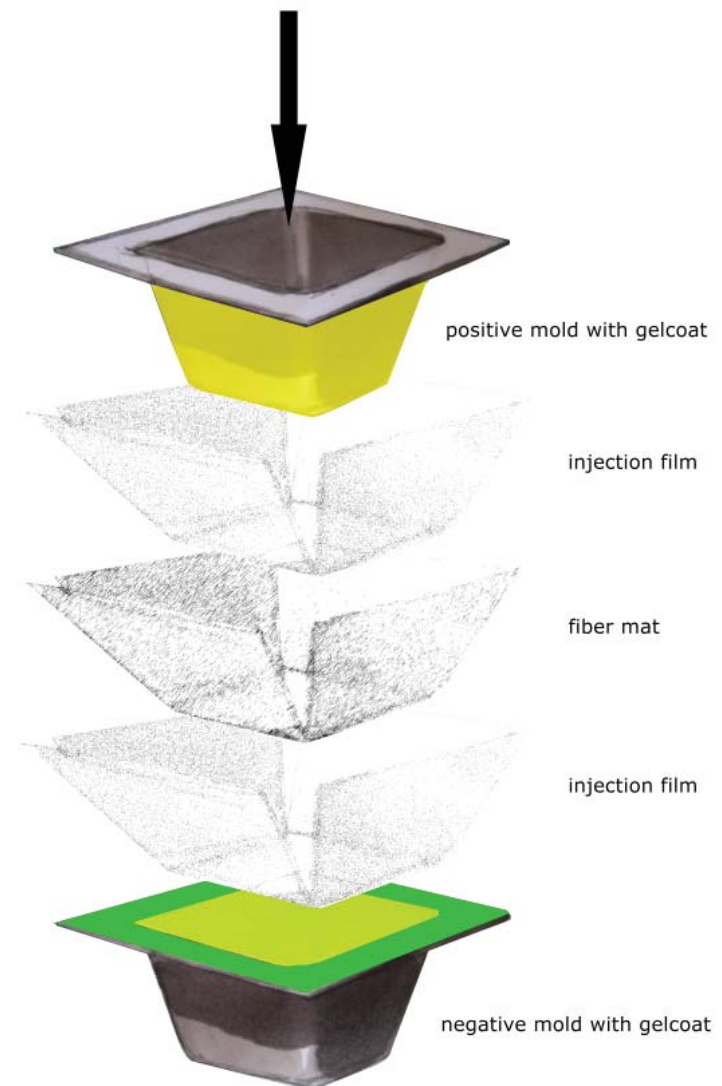


Figure 4.4: Producing the final product using the RTM-process

### 4.3 Testing

To gain experience with composite materials and find solutions for the production problems some tests with composites are performed. This paragraph describes in short the tests and the results. Detailed information can be found in appendix G. The following questions were asked:

- How to solve the stickiness of the inner surface of the box? Is the stickiness the result of moisture from the air?
- How to make putty to repair the mold? What works best?
- Is it possible to apply the vacuum bag process at Kamworks?

#### Results

##### *Stickiness*

The stickiness can be solved in two ways. The first solution is applying the vacuum bag process. If the product is in a vacuum during application of resin and during the hardening of resin, the polyester does not take up moisture from the air. The moisture in the air is probably the result of the stickiness. The vacuum bag process results in a non sticky product. The second solution can be applied during the hand lay-up process. Adding paraffin oil to the last resin layer will result in a non sticky surface. However, the oil affects the strength and stiffness of the final product. The sample with paraffin oil remained very flexible and was less strong than the sticky samples without paraffin oil.

##### *Putty*

Four different types of putty for mold repair were tested: two putties with auto body filler and two putties from gelcoat. Gelcoat putty is made by adding powder like chalk or aerosil. Auto body filler putty is made by adding a putty hardener. It turned out that the gelcoat with aerosil powder was the best solution. No clods were present in the mixture and it became very hard.

##### *Vacuum bag process*

The vacuum bag processes was tested two times. The first time a simple shaped mold was used and all the materials described in appendix F2. A small foot pump, foil and tubes bought at the market in Phnom Penh were used to achieve the vacuum. The test was performed to see how the process works and whether it is possible to perform such a process at Kamworks. In short, the following problems occurred: the pump was not powerful enough, the vacuum pot and foil were leaking and the resin started to harden too fast. Despite the problems, a very smooth surface finish was acquired and the resin was equally spread over the fibers.

The second test was done with a more powerful pump and air-tight vacuum pots. This time a more complex shaped mold was used and general chopped strand fiber mats for hand lay-up were used instead of the double stitched mats. The resin reached again all the fibers but the shape made it somewhat harder to remove the product from the mold.

It has to be mentioned that both processes were very intensive to perform. Pumping for such a long time in the Cambodian heat is not something you want to do! Using hand pumps is not recommended for bigger products than the small bowl used in the previous tests.

#### Conclusions

- The stickiness can be solved by adding paraffin oil or applying the vacuum bag process.
- Car repair putty can be used to repair the mold but also putty made from gelcoat works well. Gelcoat with aerosil powder gives the best result.
- The vacuum bag process can also be performed with general chopped strand mats, available in Cambodia.
- Complex shapes can be achieved with the vacuum bag process and the general CS-mats.
- The cargo box is too big to produce with the vacuum bag process using a hand pump.







Figure 4.5: Composite area

#### 4.4 Production facilities

The MSK was produced in the workshop of Kamworks. To get insight in the working situation the workshop was observed. The pictures show the available tools and machinery in the workshop.

##### The composite production site

The composite production site of Kamworks is situated in a 30 square meter workshop in the same building as the Kamworks office, the Kamworks electronics workshop. The house of Arjen Luxwolda is located on the second floor of the building, above the office and the two workshops.

Only a small corner of the 30 square meter workshop serves as the composite area. The rest of the workshop is used for other purposes, like welding, sawing and sanding. Picture 4.5 shows the composite area a midst of all the machinery in the workshop.

The composite necessities, like brushes and rollers, are stored on wooden shelves. Some of the chemicals are stored in plastic water bottles without a label. See figure 4.6.

Today the composite corner is used to produce the box of the Solar Home System. Only one man is set to this task. Several problems have occurred during the production which are directly imputed to the poor facilities. A list is given below:

- Very poor ventilated area results in inhalation of poisonous gases emitted by the chemical reaction of the polyester
- Due to the other activities in the workshop like sanding, sawing and welding, the composite area is not dust free. This results in impurities in the composite products, e.g. saw-dust in the gelcoat.
- The mixing of chemicals is done with small bottles, shells and syringes. The floor at the right of the yellow workbench is used for this purpose. Due to the awkward mixing-'tools', chemicals are often spilled. This results in puddles of chemicals on the floor into which the bottles get stuck. See figure 4.7.
- There is a lack of proper cleaning agents like acetone, so the tools are hard to clean.
- The space for cutting the fiber mats is very small. Every time the roll has to be put down flat before cutting and lifted up straight to store it again. This is physically very heavy.

In short, one can say that the working space is still very primitive.

##### Availability of tools and materials

All the tools required for the production process are available in Cambodia, except for the air-eliminating rollers. These are still imported from the Netherlands, which makes them expensive and hard to replace.

The resin and fibers are bought in Phnom Penh. The merchant only sells one type of polyester resin and two types of fibers: chopped strand mats and woven roving. The merchant cannot provide any information about his products nor where they come from.

Research on internet resulted in nothing. All the possible composite factories appeared to sell products but not the raw materials. They did not know or they did not want to give any addresses of sellers of raw composite materials.



Figure 4.6: bottles with chemicals



Figure 4.7: workspace for mixing the chemicals

#### 4.5 Future perspective

Analyzing the SHS-production, different types of GFRP-processes and the facilities at Kamworks together with the tests from paragraph 4.4, results in the following conclusion: Kamworks is still in its infancy concerning the composite production and expertise.

This is decisive for the type of production process. At this moment the workshop is not even fit for the hand lay-up process and there are still unsolved problems with the production of the SHS (See paragraph 4.1). Before introducing a more sophisticated production process, like described in paragraph 4.3 and tested in paragraph 4.4, Kamworks should master of the hand lay-up process and realize a proper composite area.

A second factor for deciding which production process to choose, is the size of the series. For a small series of 10 pieces per year the hand lay-up process is sufficient.

However, if Kamworks decides to produce more composite products next to the SHS and the Kamunasal tricycle and the series of the other product are big enough for double mold production, it might become a healthy idea to introduce a double mold production technique at Kamworks. Producing with double molds makes it easier to produce large series and thus a market leading position can be obtained. For the series-size of cargo box it is still not necessary to produce with double molds, but if Kamworks has the machinery and other necessities it is a small and easy step to produce the cargo box with double molds too.

For now the goal is to gain expertise in the hand lay-up process of glass fibers. Because in Cambodia no other composite factories are known, even with the hand lay-up process a market leading position can be obtained. To achieve this goal, it is wise to arrange a proper composite workshop where tests can be performed and products can be produced in a ventilated and dust free environment.







# 5 Concept generation



This chapter deals with the actual redesign of the Mobile Solar Kiosk. Three concepts are developed and one of these concepts will be further developed in the next chapter. To get to this result an action plan was set up, which is described in the next paragraph.

## 5.1 Action plan

Figure 5.1 is a schematic representation of all the required actions to generate concepts. The yellow area is dealt with in this chapter. In figure 5.1 all steps are linked to separate paragraphs of this chapter or the corresponding appendices. The blue area is the input of information, acquired through the research phase, and described in the previous chapters. The proposals for improving the design, together with the product function analysis and the stakeholders, form the input to set up the requirements. By means of the requirements, solutions for each basic function (see product function analysis, paragraph 5.4) are generated. The solutions are criticized by means of the requirements and combinations are made to generate concepts.

A survey is held to choose the best combination. The chosen combination will be further developed in the chapter 6.

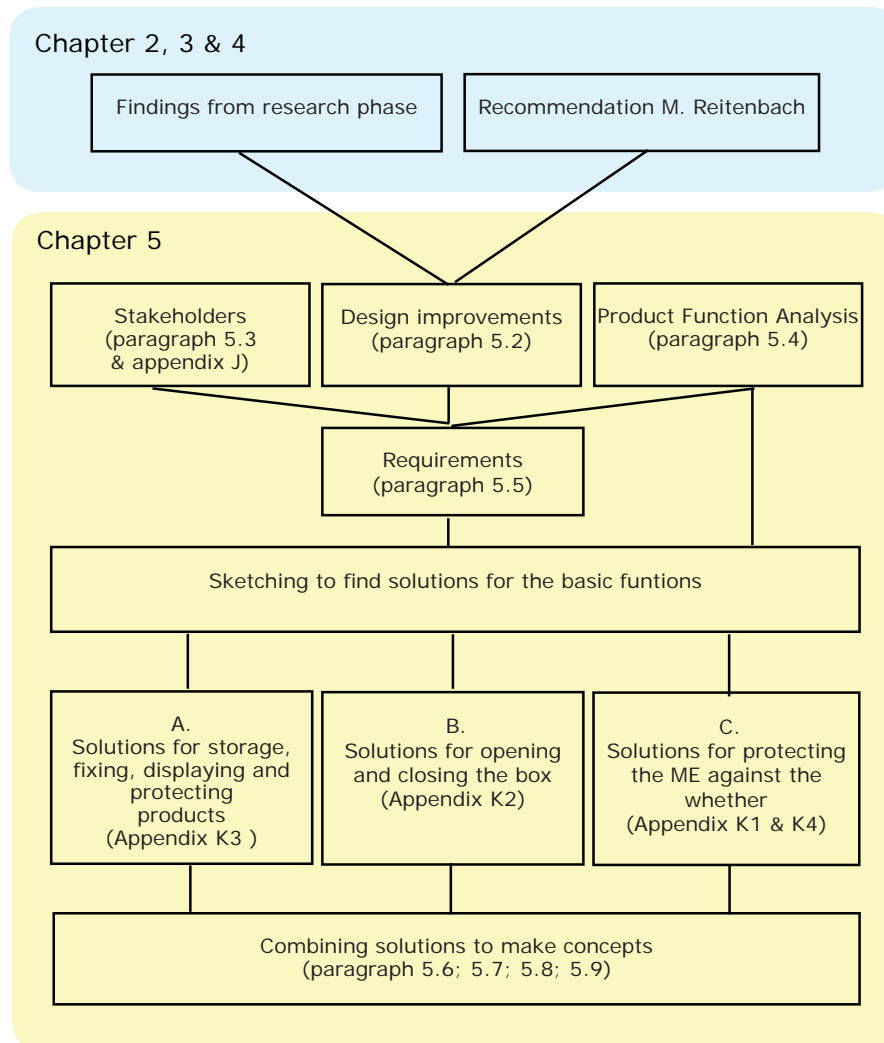


Figure 5.1: action plan for developing concepts

## 5.2 Design improvements

The most important findings from the research phase have been processed and with the recommendations of M. Reitenbach in mind a list of ways to improve the design was made.

### Cargo box

- The interior of the cargo box must be redesigned. Special attention has to be paid to ergonomics, appearance and protection of products.
- The products should be protected from breaking down or damaging due to heavy shaking of the box while driving on bumpy roads. Fixing the products should be possible. [from Miriam Reitenbach]
- There should be a possibility to place promotion posters for the products sold. [from Miriam Reitenbach]
- The panel should only be placed in a box that is used for promoting purposes. Boxes that will be used as selling carts do not need a panel to explain the working of their products. A small solar product is sufficient. The panel should be left out in the redesign.
- A music installation should be added to the bike. Both, M. Reitenbach and the Micro-Entrepreneurs at Kamworks recommended to install a music player. This can be used to draw attention [from Miriam Reitenbach] and to ease the day of the Micro-Entrepreneur [paragraph 3.8 of this report]
- The mud guards should be redesigned according to ME's, because they do not look like they protect the driver from getting dirty. It is also important for the ME that the box remains as clean as possible.
- The roof construction designed by Jeroen Jansen and the matching roof concepts need to be reconsidered for it is very important that the roof matches the look of the carrier. The look of the carrier will probably be different from what Jeroen Jansen had in mind.

### Production process

- In order to start the first series of the MSK, several design adjustments have to be made. [from Miriam Reitenbach]  
Draft angles and shrinkage are important factors to keep in mind.
- Divided molds should fit perfectly to ensure no print will remain in the final product, or divisions should be made on areas of the product that are either not visible or in sharp corners.
- The production of the molds should be done with great care. It is important to produce a positive form with a perfectly smooth surface to acquire a satisfying end result.
- The positive form may not break during the production of the negative molds. Therefore a stronger material than polyurethane should be used. At established composite companies, MDF is used to generate the positive form. See appendix H for more expert information.
- The color of the gelcoat of the female mold should contrast with the color of the final product, so small faults can be recognized.

### 5.3 Stakeholders

M. Reitenbach developed a list of stakeholders for the design of the mobile solar kiosk. Eight categories were accounted for. As a consequence of decisions made by M. Reitenbach later on in her project and insight in the importance of some stakeholders for the redesign the list is slightly adapted. The most important stakeholders for the redesign are Kamworks and the Micro-Entrepreneurs, for Kamworks must be able to produce the bike and the ME's must be able to use it. For an extensive list see the adapted version of Miriam Reitenbach's list in appendix J.

### 5.4 Product functions

The functions of the Kamunasal bike are divided over four different categories. These categories are the different phases of the life of the market bike. Table 5.1 lists all the categories and corresponding functions. Some of the functions are marked with letters corresponding to the letters in figure 5.1.

Phase	Function	Sub function
product development	creating a possibility to sell Kamunasal products	promoting the Kamunasal brand
	making profit	<ul style="list-style-type: none"> <li>- Durable</li> <li>- Affordable</li> <li>- Locally producible</li> </ul>
Installation	Installing the box and roof onto the frame	<ul style="list-style-type: none"> <li>- Fixing the box an roof</li> <li>- detaching the box and roof</li> </ul>
Use	Open box (A)	<ul style="list-style-type: none"> <li>- open box</li> <li>- leaving box open</li> </ul>
	Close box (A)	<ul style="list-style-type: none"> <li>- close box</li> <li>- leaving box closed</li> </ul>
	Lock box (A)	preventing products from being stolen
	Store products (B)	<ul style="list-style-type: none"> <li>- protecting products</li> <li>- fix products</li> <li>- keep dirt and moisture outside</li> </ul>
	Display products (B)	- making product range visible
	Store personal belongings and other equipment (B)	protecting personal belongings and equipment
	Transport box	shockproof
	Communicating products	<ul style="list-style-type: none"> <li>- being striking and recognizable</li> <li>- represent brand identity</li> </ul>
	Protecting ME against the weather (C)	<ul style="list-style-type: none"> <li>- roof that blocks the sun</li> <li>- waterproof roof</li> <li>- Mud guards that protect the driver</li> </ul>
Maintenance	Repairing box	<ul style="list-style-type: none"> <li>- locally repairable</li> <li>- repairable by ME</li> </ul>
Disposal	Preparing the bike for sale	-Painting bike in different color

Table 5.1: Product Function Analysis of the Kamunasal tricycle



## 5.5 Requirements

This list of requirements in table 5.2 was set up according to the different phases of the life of the product and corresponding functions, described in table 5.1 on the previous page. The demands and specifications were determined by means of the list of requirements for the original MSK <sup>6</sup>, recommendations and findings acquired by additional research, interviews and testing:

- Interview with Cambodian Micro-Entrepreneurs at Kamworks (section 3.6 to 3.8)
- Interviews with composite experts (appendix H) and internship at NPSP composites in the Netherlands (appendix F2, F3 and H)
- Composite testing at Kamworks (appendix G)

Phase	Demands	Specifications
Product development	The box and roof have to be locally producible.	<ul style="list-style-type: none"> <li>- The box and roof have to be producible at the workshop of Kamworks or one of its partners [Reitenbach, 2007]</li> <li>- Hand lay-up of glass fibers should be used as production process [Appendix K]</li> </ul>
	The materials have to be locally available or deliverable.	The materials have to be available in Cambodia and/or orders have to be delivered within a month [Reitenbach, 2007]
	It must be possible for Kamworks to take on the production of the box and roof in their activities	The maximum production time is two weeks [Reitenbach, 2007]
	The box and roof must be durable	<ul style="list-style-type: none"> <li>- The lifetime of the box should be at least three 3 years. [Reitenbach, 2007]</li> <li>- The lifetime of the roof should be 2 year</li> <li>- The materials need to have good resistance against corrosion, sun and rain [Reitenbach, 2007]</li> <li>- The colors of the materials may not degrade within a time period of three months [Reitenbach, 2007]</li> </ul>
	The entire MSK must be affordable for rural people	<ul style="list-style-type: none"> <li>- The production costs of the entire MSK may not exceed \$800</li> <li>- The box itself may not cost more than \$350</li> <li>- The roof may not cost more than \$100</li> </ul>
Installation	The box and roof has to be producible in small series	10 pieces in the next three years [Reitenbach, 2007]
	The box and roof have to reflect the Kamunasal identity	Brand name and brand color must be used.
	It must be possible to fix the box and roof to the redesigned frame [Jeroen Jansen]	<ul style="list-style-type: none"> <li>- The box should fit onto the 50 cm wide and 54 cm long front frame.</li> <li>- The box should fit between the front wheels. (Length axis is 86 cm)</li> <li>- The roof should have a front width of 1 m a back width of 708 mm and a length of 710 mm</li> </ul>
	The box and roof should be detachable from the frame	Fixing the box and roof should be done with materials that enable disassembling

Table 5.2: List with requirements for the redesign of the MSK

Use	The MSK must be ergonomically correct for both ME and costumer	<ul style="list-style-type: none"> <li>- The height of the cargo box should be between 92 and 107 cm. [Reitenbach, 2007]</li> <li>- The costumer must be able to see the products if standing at a distance of 1,5 m</li> <li>- The show-models must be accessible without bending of the ME or costumer.</li> <li>- Opening the box should not cost more than 40 N</li> <li>- The box may not have sharp edges that might hurt the ME or costumer</li> <li>- The box should only close if intended</li> <li>- The roof has to be waterproof and block the sun</li> <li>- The entire vehicle should be light weight</li> </ul>
	The MSK must be recognizable for costumers and draw attention in its environment	<ul style="list-style-type: none"> <li>- The logo and brand name have to be recognizable at a distance of 10 m [Reitenbach, 2007]</li> <li>- The logo and brand name can be on the roof as well</li> </ul>
	The box must be adjustable to a changing Kamunasal product range	Capacity must be about 200 to 300 liters. [interview Micro-Entrepreneurs]
	The box must have space for personal belongings of ME and additional equipment.	Capacity must be about 15 liters.
	The products in the trailer may not break or damage	<ul style="list-style-type: none"> <li>- The products should be fixed [Reitenbach]</li> <li>- The products should be protected against rain and dust [Reitenbach]</li> </ul>
	The ME has to be able to open the box if standing at the side of the bike	Opening the box may take half a minute
	The ME must be able to survey the situation	ME has to be able to overlook the vehicle when standing at a side
	It must be easy for the ME to catch the products in a short time	Products have to be accessible within 1 minute [Reitenbach]
	The ME must be able to display all the products he is carrying	One sample of every product should be in sight if the MSK is open [Interview Micro-Entrepreneurs]
	The MSK must be easy to clean	<ul style="list-style-type: none"> <li>- All spots on inside and outside must be reachable for the ME</li> <li>- The mud guards and roof must be able to be cleaned using a hose</li> </ul>
	The MSK must be recognizable for other road users	Front and back lights should be present[Reitenbach]
	The roof has to match to the rest of the MSK	The color should be yellow and the forms should match the forms of the box
Maintenance	It must be possible to repair the box locally	<ul style="list-style-type: none"> <li>- Small repairs should be done by the ME [Reitenbach, 2007]</li> <li>- All other repairs should be done by Kamworks [Reitenbach, 2007]</li> </ul>
Disposal	It must be possible to sell the bike if the bike is written off	<ul style="list-style-type: none"> <li>- Sanding and polishing the surface of the box should result in a nice looking box again.</li> <li>-It should be possible to give the box a different color</li> </ul>

Continuation of table 5.2: List with requirements for the redesign of the MSK

## 5.6 Morphology

As stated in figure 5.1, solutions for four different product features were developed: storage & fixation, opening & closing, mudguards and the roof. The solutions were criticized by means of the requirements. In the corresponding appendices K1, K2, K3 and K4, the solutions and comments are presented. The best solutions were selected and combined to develop three different concepts. Figure 5.2 shows which solutions were selected and used to develop the concepts.

The roof is excluded from the combining stage because it is a distinct feature and it is not affecting the form as much as the other features. However, whilst combining the solutions the possibilities to adjust the roof were kept in mind.

The three numbered combinations in figure 5.2 are further described in the next three paragraphs. The combinations were criticized by a group of six students working at Kamworks. See paragraph 5.10. Their comments were processed in the analysis of each combination.

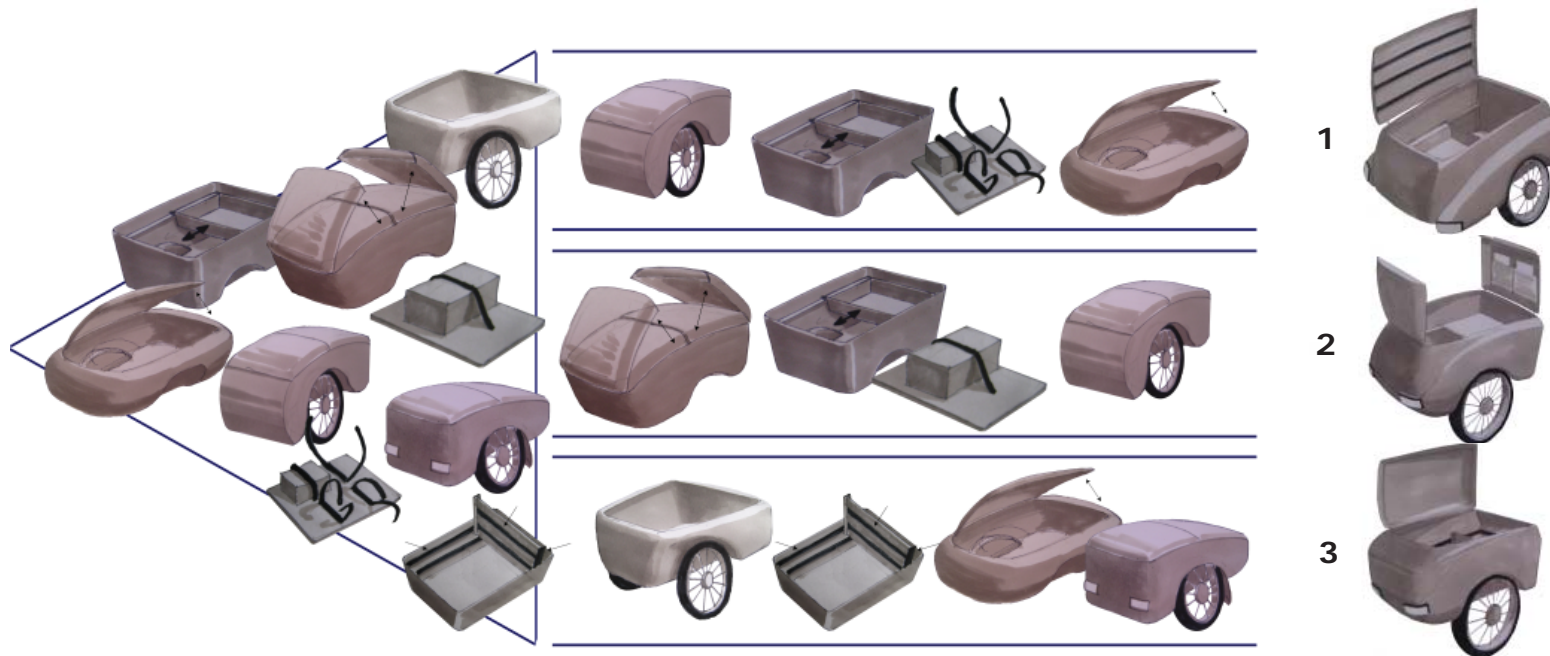


Figure 5.2: Selected solutions for developing the concepts

## 5.7 Combination 1: old-fashioned

### Features

Figure 5.3 shows the 'old-fashioned' combination. The shape and way of opening the box makes it possible to use the lid as a display. Velcro straps are placed inside the lid to attach the products to the lid (B). The products can be easily removed from the lid to show to the costumers. Because there is only one lid and this lid is higher than the box it is easy for people to see at a distance what products are being sold at the Kamunasal Kiosk. This is important because Cambodians are used to display the entire stock. If some products can be seen at a distance, this will make them curious.

Inside the box is a sliding tray onto which the product stock can be placed (A). The space underneath the tray is reserved for the battery (for e.g. propulsion, lightening, music), a small music player, the ME's personal belongings and some additional equipment like tools. The tray can be moved to the other side, which makes it easy for the ME to pick something from underneath the tray. At the same time, the tray keeps things out of sight for costumers.

### Shape

The box exists of different parts under which the lid, the mudguards, the tray, the rails to guide the tray and the box itself.

It is not possible to produce the box with a single mold. Together with the lid and the mudguards, this will lead to a production of the carrier with at least five molds (A).

### Appearance

The mudguards are not integrated in the box which makes it look old-fashioned. Because Kamunasal wishes to have a modern identity, this form is not appropriate. This was also a major concern of the interviewed students. (See also section 5.10)



Figure 5.3: Combination 1, Old-fashioned, A: exploded view of interior and exterior, B: Use of the display, C: Top-view, D: front-view, E: Side-view.



## 5.8 Combination 2: aerodynamic

### Features

The box has two lids that open to the front and the back. The lids can be used to store some promotional material, like flyers. See figure 5.4A. They cannot be used as a display as the view is blocked by the other lid. The double lids make it impossible for the customer to see the products at a distance.

Inside the box a sliding layer is placed onto which products can be attached by rubber straps. As in combination 1, the space underneath the layer can be used to store the battery, personal belongings and other equipment of the micro-entrepreneur.

The box has unextended integrated mudguards. These guards are too short to protect the driver against splattering mud. See figure 5.4C

### Shape

The carrier exists of two lids, a layer, the rails for the layer and the box itself. The shape of the box requires at least two molds and the lids also require two molds. The layer and rails can be produced from plastic sheet.

There is a curved line visible at the side view. This line separates two surfaces from each other. The box and line are shaped in such a way that it is possible to use the already existing line as the mold division line.

### Appearance

The shape of the mold division line and the surfaces make the box look aerodynamic. Together with integrated mudguards and slightly curved lids, this results in a rather modern look.

However, the two lids make the box look closed. It is less easy for costumers to get in contact with the ME and his products.

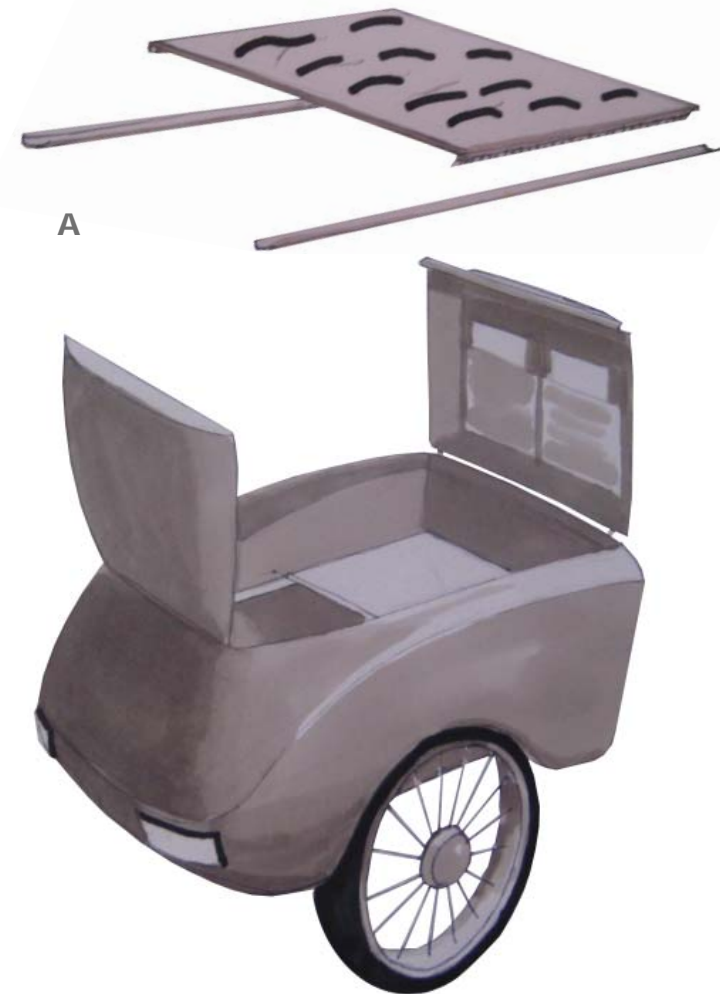


Figure 5.4: Combination 2, aerodynamic. A: exploded view, B: front-view, C: side-view



A



B



C

Figure 5.5: Combination 3, friendly. A: exploded view, B: side-view, C: front-view

## 5.9 Combination 3: friendly

### Features

This single lidded box uses the lid as the display. A plastic sheet with elastic bands attached to it can be placed in the lid. See figure 5.5A. The detachable plastic sheet makes it possible for the ME to arrange the elastics as he desires. The elastic bands can be re-arranged any time.

The interior is divided into compartments by detachable partitions. There are Velcro straps on all sides of the box and on the partitions (A). The inside can be re-arranged depending on the product stock and size. Also partitions for the battery and the personal belongings and tools of the ME can be built. The contents of the box are visible for the costumers, because nothing can be covered.

The mudguards are extended at the back to protect the driver against mud (B).

### Form

In the front the box is round. There are two surface splitting lines, deriving from the back of the box. These lines split the front in three surfaces. The upper line is at the same time the mold division. The box can be produced with two molds and the lid with one mold. The display can be made from a plastic sheet.

### Appearance

There are only a few differences in shape with combination 2, which results in a different appearance. The rounded front of the box gives it a friendly look. The back of the box is also less tensed.

## 5.10 Survey

The combinations were analyzed and judged by a group of six student working at Kamworks. They were asked to give there opinion about appearance, representation of Kamunasal, the way of storage and displaying the products and the way of storing the personal belongings and tools of the ME. Below, the comments at each combination are described.

### **Combination 1 : old-fashioned**

Only one subject liked the old fashioned appearance of the carrier. The rest thought that it would not be representative for the Kamunasal brand as it stands for modernity and quality. The display in the lid was considered positive. The products can be seen at a distance, which attracts attention from the crowd. Also the sliding tray was considered as a good solution. The products can be stored in the tray, and all other material can be stored underneath the tray.

### **Combination 2: aerodynamic**

Three group members thought this is the nicest shape. It looks modern and fast. However, the two lids make the box more closed to the audience. The layer was considered positive and handy. Two subjects thought it is not necessary to fix all the products. They preferred the tray of combination 1, because products can be picked up without detaching them first.

### **Combination 3: friendly**

This shape was elected by two subjects. They liked the friendly shapes. However, all subjects rejected the divided interior. The general opinion of the students at Kamworks is that as long as the Kamunasal product range is not clear no divisions should be designed. The ME has to change the partitions immediately if he wants to carry something else. The extended mudguards were considered as handy and desirable for the ME.

### **Additional notes:**

One subject thought a lid that opens to the side of the frame would bet better. Three sides would be open for the public and the ME can stand at one of the sides to show his products. If the lid opens to one of the long sides, the long side and the frame side of the box are unable to be used by the public.

### **Conclusion**

The survey proved that friendly and aerodynamic carriers are the best combinations. Because it is very important to satisfy the wishes of the user, the comments of the students have to be kept in mind during the development of the final concept. Combination 2 and 3 both have its pros and cons. Therefore, the two combinations have to be combined once more to achieve a satisfying concept.

### 5.11 Display

The survey of section 5.10 pointed out that a display in the lid is the best option to show the people what kind of products are being sold. To find out how to attach the product to the display, it was subjected to a try-out. Three different solutions were tested: ropes, Velcro and elastic bands. See appendix L for more information.

The try-out proved that the Velcro was the best way of attaching products. With Velcro, the product can be hung decently and it can withstand heavy shocks of the display due to bumpy roads. The other two solutions look rather careless and products fell off during the shock test. Furthermore, the try-out with heavy products, like the Proseed lamp, showed that elastics are not appropriate.

Additionally the Micro-Entrepreneurs were asked to do the try-out. They all thought that the Velcro was the best option because this looks tidy and is very easy to use.

However, the Velcro straps were attached to the display with glue. After some time the straps came off the display because the glue was not working properly. It also affected the Velcro straps. Another solution for fastening the Velcro to the display and the products should be found.

### 5.12 Conclusion

To develop a satisfying concept several aspects of the second and third combination have to be combined again. The most important aspects are listed below:

- A lid should be used as a display
- Velcro straps should be used to attach the products onto the display, as this has a decent look and can hold heavy products.
- A lid opening to the frame/back is better than a lid opening to the side, because the first lid will only block the side of the frame whereas the side opening lid will block an entire side as well. This means only the front and one side are left for the public.
- A sliding tray or layer should be used to store the products
- As long as the Kamunasal product range is not clear and fixed, no divisions should be made in the box. The interior can always be adjusted.
- Aerodynamic and modern shapes are better liked than old-fashioned shapes.
- Extended mudguards are desirable.

All above mentioned will be processed in development of the final concept.



# 6 Final design



## 6.1 Approach

This chapter documents the process of achieving the final concept and prototype. Keeping in mind the conclusions of the previous chapter the following decisions are made:

- A lid will be used as a display
- The lid will open to the frame side of the box, so three sides will be open to the public.
- Velcro straps will be used to attach the products onto the display
- A sliding tray will be used to store the products
- No divisions will be made in the box
- The box will have extended mudguards

To achieve the final design, three design tools are used: drawing by hand, modeling with the program Solid Works and prototyping. It has to be mentioned that these three design tools were not used conventionally, because according to Mintzberg (2001), as cited in Reitenbach's report, a 'doing first' approach is mostly recommended when designing in developing countries. This approach was also used and recommended by Miriam Reitenbach.

A second reason to choose this approach was the fact that the frame of the bike was not present at Kamworks at the time of developing the concepts. The frame was being built at DonBosco simultaneously with the concept development at Kamworks. Because the work drawings of the frame were incorrect Don Bosco had difficulties assembling the frame and they had to make some adjustments. Therefore, relying a 100 percent on the Solid Work files of the frame would be unwise.

Eventually, a plug that fits the frame was built. Some design adjustment were made due to the dimensions of the frame and to new insights achieved during building.

Figure 6.1 describes the actual approach schematically. The scheme shows in what order design adjustments were introduced. The advantage of this approach is that the design can be adjusted and improved immediately.

For the interior and the finishing of the box, the same approach is used. The fiber reinforced parts are equipped with hinges and head- and taillights et cetera. Because this phase relies heavily on the availability of these parts, there is not much design freedom; thus the modeling in Solid Works is skipped.

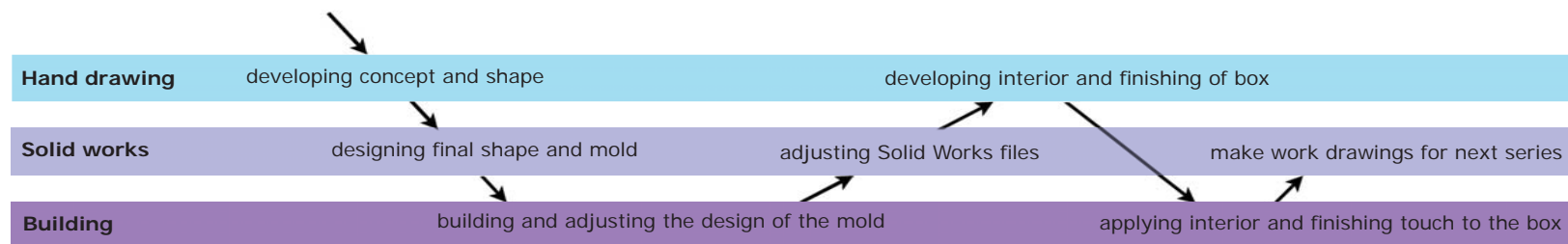


Figure 6.1: Approach

## 6.2 Final concept

Keeping in mind the conclusions made in chapter five, the final concept is made and presented in figure 6.2. As the aerodynamic shape is liked the best by all the surveyed students this shape is further developed. The concept is adjusted on several aspects:

- The two lids are replaced by a single lid opening to the frame side of the carrier.
- The lid can now be used as a display
- The mudguards are extended
- The wooden tray is replaced by a sliding tray

The advantages of the adjustments are that the carrier is very open to the public. The costumers can stand at three sides of the carrier and the ME can choose were to stand. The opened lid is high and will draw attention. Another advantage of the lid opening to the back is that the bike can be stalled in more ways than a box with the side opening. The side lid forces to place the bike with the open side to the public. This is not always convenient because at some places the bike will only fit the other way around. With the frame-side-opening lid this problem cannot occur. The sliding tray makes it easier for the ME to reach products which are stored underneath the tray in de box. Finally, the longer mudguards will protect the driver better than the unextended mudguards.

### Finishing

To finish the carrier some ornaments are added. First of all, the brand name is placed at the front, top and both sides of the box. The advantage of these stickers over the hand painted branding is that it can be applied very easy and it looks also very tidy and decent. Secondly, a metallic colored strip is placed onto the mold division line. The metallic strip ensures that possible roughness on the mold division line is hidden. It also gives the carrier a modern and aerodynamic look. Finally, LED's can be placed in the display to lighten the display and it's products. The decisions for the finishing were made with help of the micro-entrepreneurs. Appendix O shows the discarded options for the finishing of the bike.

The remaining finishing, like hinges, lights, reflectors, lock etc. were not designed in advance. The reason for this is that it is no use designing and making lights or hinges if you can not find these on markets in Phnom Penh. By wandering around on the markets these objects were purchased. Appendix P shows all the objects for finishing the carrier

### Roof

The design of the roof is influenced a lot by the design of the roof's frame by Jeroen Jansen. As can be seen in appendix K1 only few options were left open. Although it does not match with the appearance of the cargo box, the cloth-option is chosen because this is the cheapest and easiest way to make the roof. By wandering around Phnom Penh it became clear that the fabric that is used in tuktuks is available all over Phnom Penh. Designing a different roof is too time-consuming for the duration of this project, moreover because the roof's frame requires redesigning too, to make it fit the modern and high quality looks of the carrier. Therefore, a yellow colored piece of tuktuk fabric was bought. To make it match the carrier a bit more, the fabric will be attached to the frame with ropes and shiny rings.

### Frame

The bike frame is painted in a metallic-blue color to fit in with the Kamunasal colors: blue and yellow.



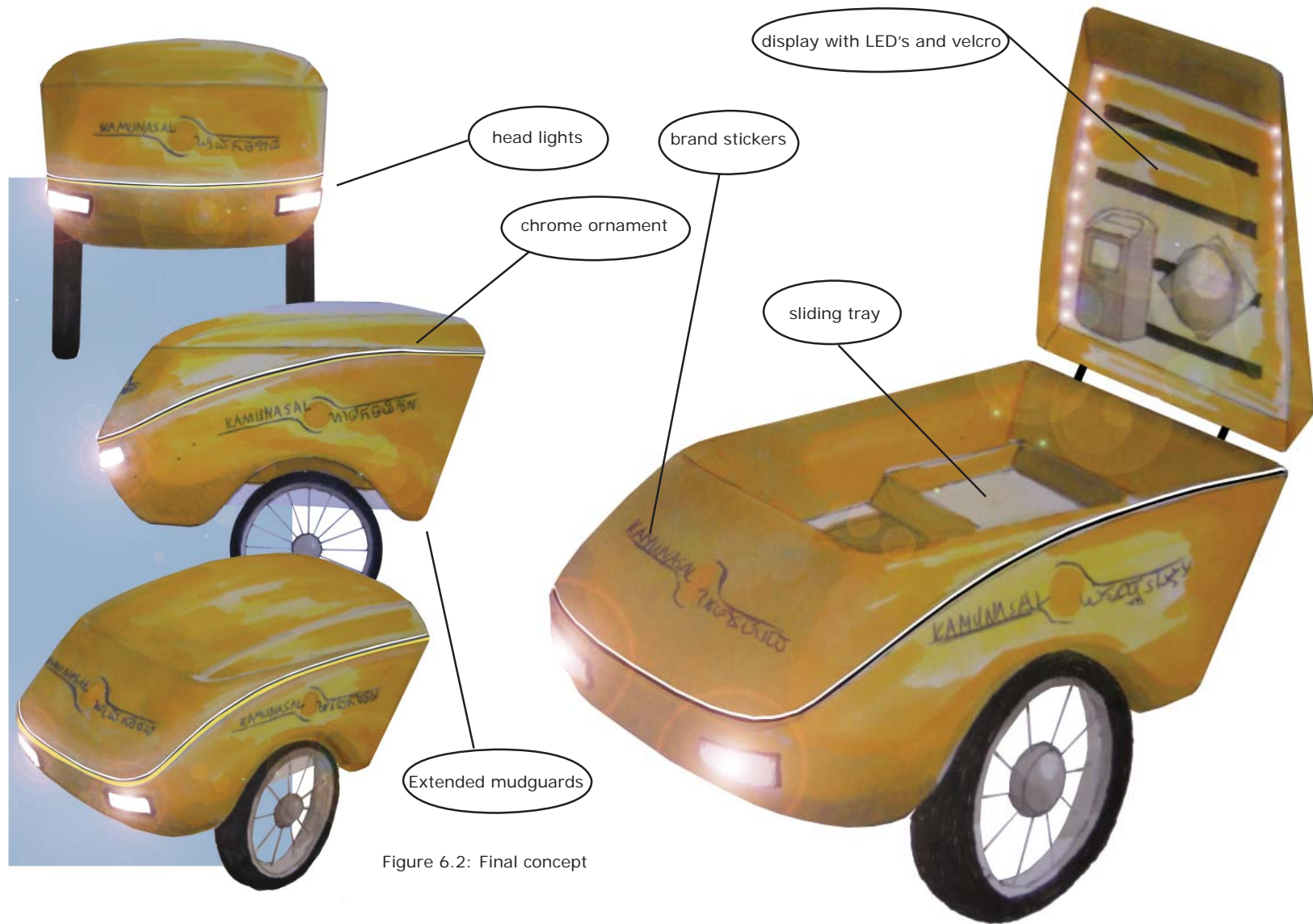


Figure 6.2: Final concept





**A:** Processing MDF



**B:** The varnished positive form of MDF



**C:** The spray painted positive form



**D:** Copying the surface finish



**E:** Making the brims for fastening the other mold parts



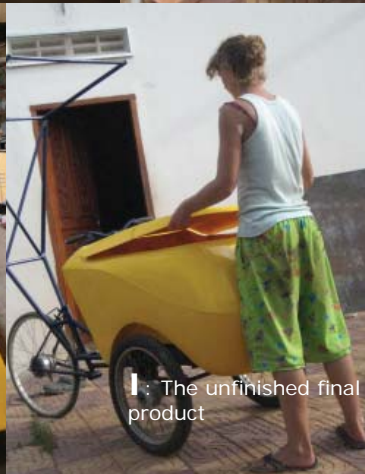
**F:** Fine surface quality of the lid



**G:** All molds together



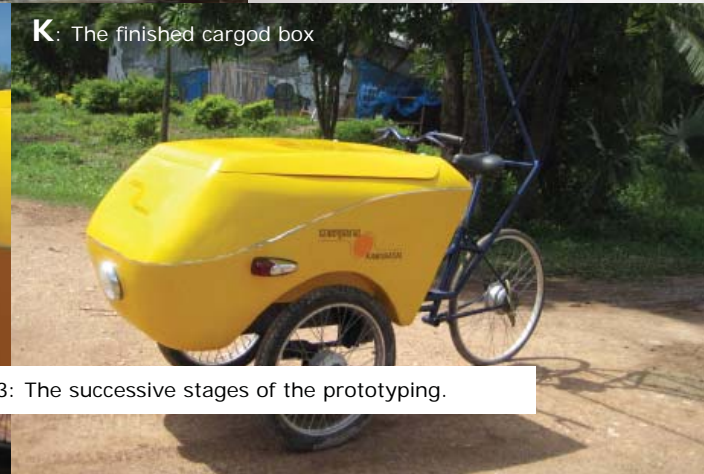
**H:** Producing the final product



**I:** The unfinished final product



**J:** Applying the brand



**K:** The finished cargo box

Figure 6.3: The successive stages of the prototyping.

## 6.3 Prototyping

Figure 6.3 shows the successive stages of the applied production process. As described in chapter 4 several problems occurred during prototyping of the MSK. To avoid these problems some important changes have been made in the production of the positive form, namely:

- Instead of using polystyrene foam for the positive form, now MDF is used (step A and B).
- The surface finish quality of the positive form has to match the desired surface finish quality of the final product (step D, F and K).
- Mold division lines are situated on surface splitting lines in the final product, as to prevent visible marks of the divisions in the final product (step E and G).

The new methods also had some difficulties which can be easily avoided the next time someone wants to build a positive form. Therefore, they are described below:

### **MDF (Medium-Density Fiberboard)**

MDF is the material which is also used by Composite factories as NPSP in Haarlem (Netherlands). This material is easy to work with and high surface quality is possible. Unlike polystyrene foam, MDF does not crumble when sanded and no epoxy layer is necessary. The material is also much stronger than polystyrene foam, so the positive form will not brake in pieces when removing the mold.

The only disadvantage of MDF is that it must not get in contact with water. There is also waterproof MDF but this was not available at the moment at Kamworks.

### **Surface finish**

To achieve the desired surface finish the positive form was sanded and painted by a car-painter in Phnom Penh. Because there, water is used when sanding, the form was varnished first to prevent it from soaking up water (B and C)

It has to be mentioned that, despite the fact that the form was varnished, the MDF soaked up water eventually because it was placed in a pool of water for a couple of days. This happened due to some communication problems between Kamworks and the non-English speaking staff of the car-painter. It is better to use water proof MDF to avoid such problems.

Secondly, the paint appeared to dissolve in thinner, which was used to clean the positive form before applying the wax. Also bubbles appeared on the paint surface a week after the car-painters finished the job. It is obvious that the paint quality was very bad. To avoid these complications, bring your own paint to the car-painter or make sure they use a high quality brand.

### **Mold division lines**

The final mold exists of three pieces and one for the lid, instead of two pieces and one for the lid. This extra mold division was necessary because the bad surface quality of the positive form (bubbles) resulted in the same surface quality in the molds. This caused the molds to stick to the positive form much more than the two mold pieces with high quality surface. Therefore, the piece was divided in two over the edges.

However, the surface finish of the two mold pieces appeared to be of such a bad quality that the wax could not prevent the mold from sticking to the final product. There were too much tiny holes and wrinkles in the surface of the mold, that came from the positive form. The wrinkles and holes prevented the wax from covering the surface entirely. To prevent these problems, it is really important to pick a high quality paint for the positive form.

Pictures of the aforementioned problems are documented in appendix Q.

Despite the above mentioned problems the surface quality of the final product is satisfying. It was not necessary to spray paint this box, like the old box. The color is very bright and the surface is smooth and shiny. There is no roughness like on the old box. The places where the mold stuck to the product are less shiny, but this can be solved by sanding and polishing these places.

## 6.4 Details and finishing touch

### Lighting

The original MSK has two lights in the front. These lights are not powerful enough to light up the road in the dark. Therefore, one genuine headlight is placed in the front (figure 6.4D). At each side, aerodynamically shaped direction indicators are placed (figure 6.4F).

### Hinges

The hinges of the prototype are shapes by hand. They represent the idea to use droplet-shaped chromium hinges. These hinges could not be found in Cambodia, but if a series of the box is produced the hinges can be ordered abroad. Because this is only the prototype, normal hinges are used to represent the idea (figure 6.4A).

### Display

The display can be attached and detached from the lid with four wing nuts (figure 6.4B). By attaching Velcro straps on the board, the ME can hang his products onto the display (figure 6.5B). Detaching the display makes it easy for the Micro-Entrepreneur to determine the correct place for the Velcro straps on the products and/or the board. Also, the ME can reach and replace the (possible) LED's at the back of the display.

### Branding

The Kamunasal brand is a transparent sticker (figure 6.4C). It is very easy to place and it looks very decent. If a new sticker is required, it can be placed by the ME himself very easily.

### Reflectors

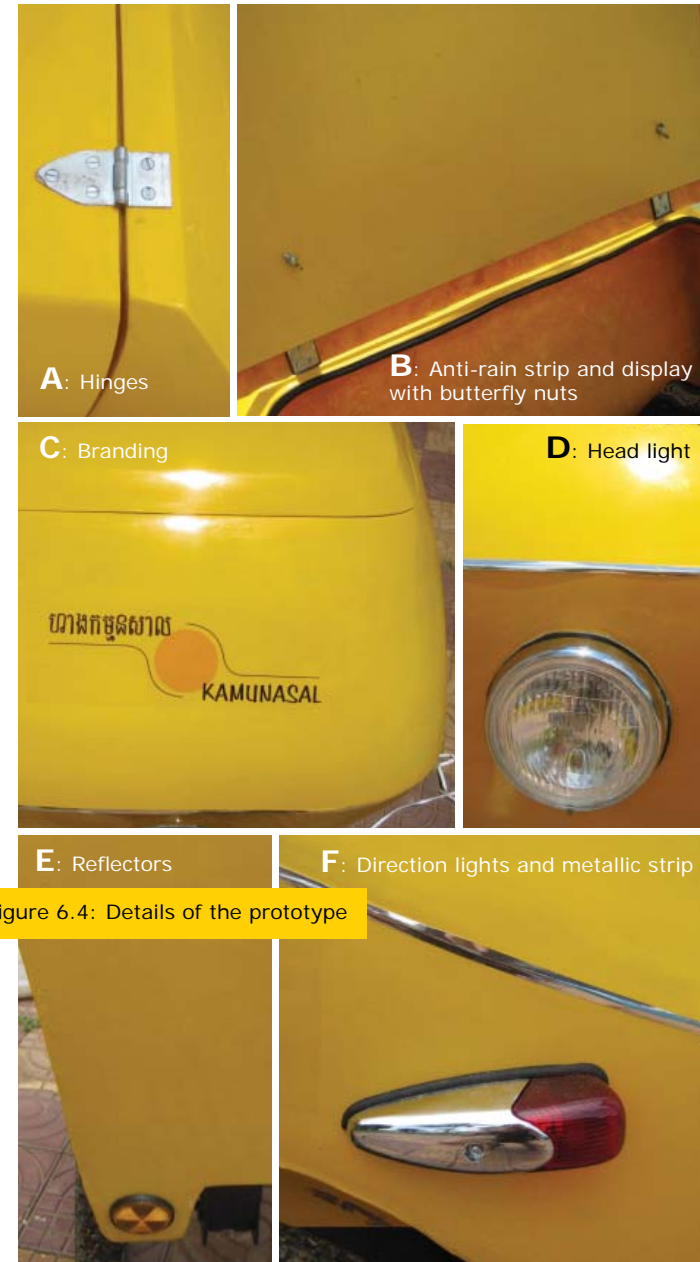
At the two lowest points of the back of the box, two reflectors are placed (figure 6.4E). The reflectors make sure vehicles behind the Kamunasal bike can see that the bike is wider than a normal bike or moto. At the back of the bike frame a real light will be placed.

### Anti-rain strip

The hinges are placed on top of the box. A narrow opening between the lid and the box is the result. To stop the rain from entering the box an anti-rain brim is placed which presses against the lid with a rubber strip. This way the opening is closed. The anti-rain brim goes all the way around the box (figure 6.4B).

### Metallic strip

To ensure possible roughness at the mold division lines is hidden, a metallic strip is placed onto the mold division line (figure 6.4F). The strip also emphasizes the curved line and the aerodynamic shape of the box.





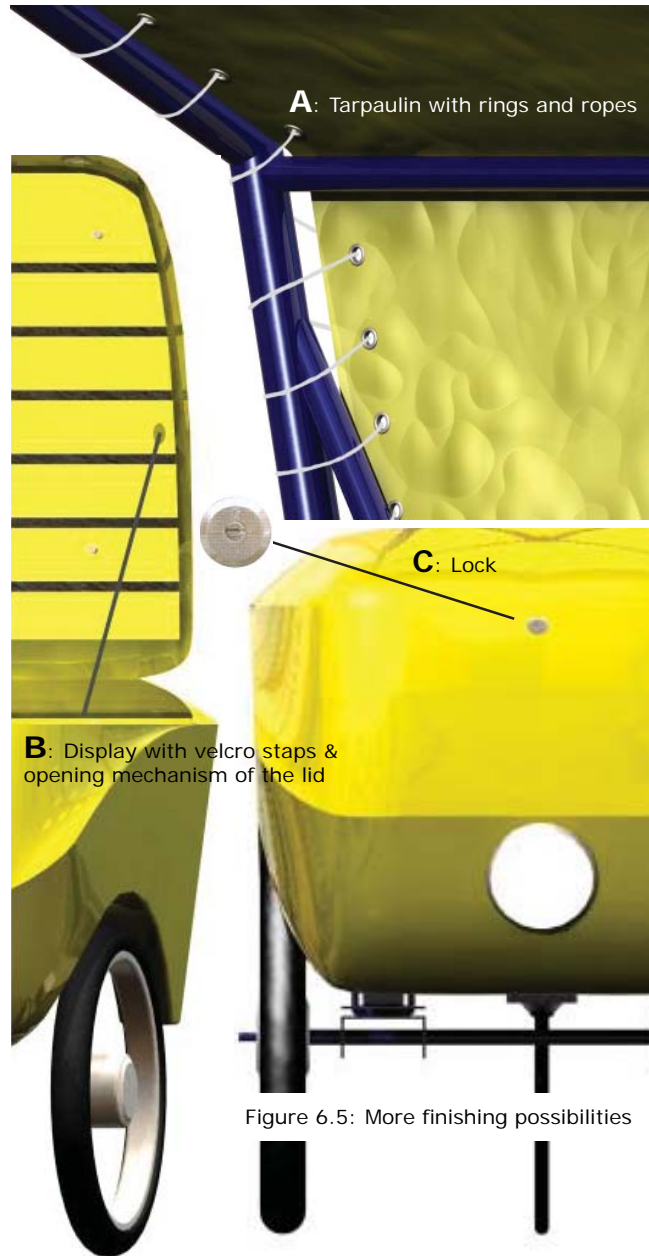


Figure 6.5: More finishing possibilities

#### Damping box

Between the bottom of the box and the frame, a rubber sheet is placed. This rubber sheet reduces the possibility that the box is damaged by shaking due to rough ground.

#### Roof

As previously decided the roof is made from tarpaulin. Metal rings are placed on the edges of the tarpaulin with which the tarpaulin is tightened to the roof's frame. The cord is wound round the frame and through the rings of the tarpaulin (figure 6.5A). This way it is easy to replace the tarpaulin. The tarpaulin can be made the right size and rings can be added at Kamworks.

#### Opening lid

The lid can be opened by hand. To keep the lid open a bar can be fixed between the lid and the box (figure 6.5B).

#### More options

*Several ideas of the concept in paragraph 6.2 are not fully developed in the prototype, e.g. the sliding tray and the LED's in the display. These ideas were meant to be developed on basis of the actual dimensions of the prototype. Due to lack of time, the ideas were not further developed. But it is still possible to install a sliding tray or LED's in the display.*

*Below, the ideas are described and also some other ideas are suggested.*

#### Sliding tray

The original tray can be replaced by a sliding tray. The tray can be used to stall products which need to be quickly accessible. By sliding the tray to the other side of the box, the ME can reach the products beneath it. Figure 6.2 shows the concept of the sliding tray.

The tray can be made of multiplex. The exact sliding mechanism depends on the available material in Cambodia.

#### LED's

The display and its products can be enlightened by putting LED's in the sides. The LED's draw attention to the display and its products (figure 6.2 of paragraph 6.2)

#### Opening lid

A second option for opening the lid is to install a gas spring which makes opening the lid much easier. The gas spring ensures the lid will not drop down. If heavy items are placed on the display, the gas spring helps the ME to open and close the lid carefully.

#### Lock

For safety and security it is good to place a lock on the box. The lock can be placed in the front of the box, like in figure 6.5C.



## 6.5 Dimensions and ergonomics

As stated in the report of M. Reitenbach the future users are mainly male, but female users may not be excluded. On basis of the Internationaler anthropometrischer Datenatlas from H.W. Jürgens and additional measurements with eight Cambodian people, the dimension of the MSK were determined. The Datenatlas contains data of body-dimensions of South East Asians, while the supplementary measurements were done with both male and female Khmer people. The dimensions of the Kamunasal bike are also based on these data, so many dimensions are the same as in the MSK. Appendix M shows the data.

### Cargo box

As can be seen in picture 6.6 the height of the box (working height) is 90 cm. The width is 82 cm. These dimensions are more or less the same as the MSK. The length of the box is 15 cm more than the original version, due to the backwards bended, aerodynamic shape of the box. However, if the box is measured horizontally from one side to the other, the box is 1 meter. The volume is about 300 liters.

### Roof

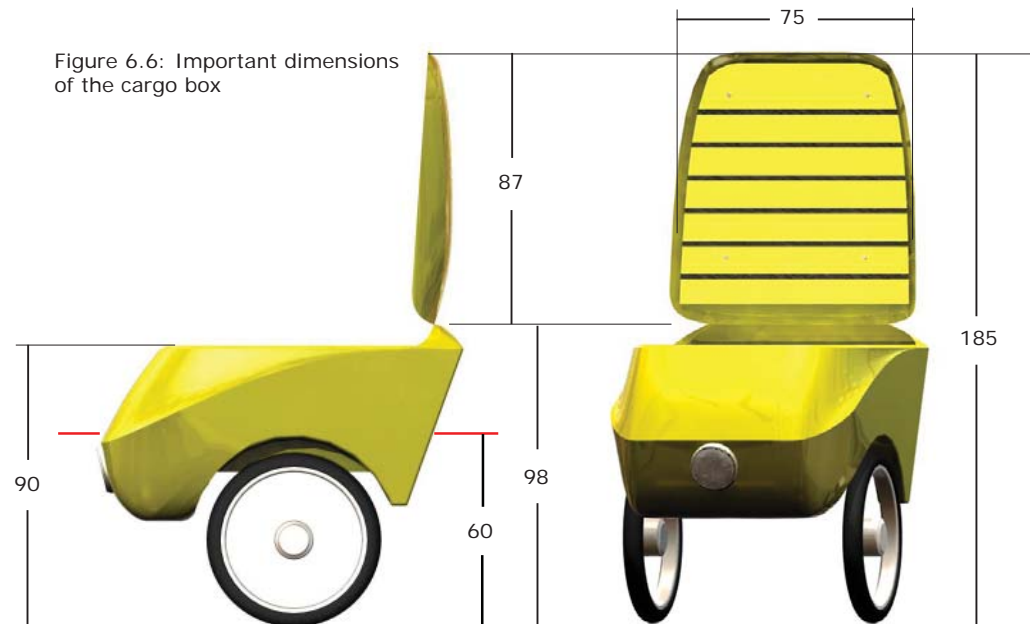
The roof of the market bike was set on a height of 235 cm. This height appeared to be too large for several reasons. First of all, the oversized truss frame of the roof is not very rigid, but very heavy. In combination with the three wheels and the low torsional rigidity of the bike frame, the Kamunasal bike becomes unstable, or 'wobbly'. Also, the large roof frame makes the tricycle too big for practical reasons, e.g. the bike is too high to enter the workshop. Furthermore, 95% of the Cambodian men are smaller than 172 cm, which makes the roof excessively large. Therefore, the height was reduced as much as possible to 215 cm by cutting the steel pipes of the frame. See figure 6.7. However, the frame remained unstable. It is also important to mention that the look of the roof does not match with the Kamunasal bike at all. All in all the frame construction is a suboptimal design.

### Display

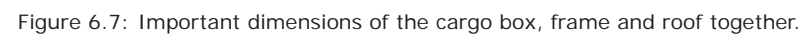
The height of the opened lid is 185 cm. The height of the upper brim of the display is 180 and the upper Velcro strip is 165 cm.

According to Jürgens (as cited in the report of M. Reitenbach), 95% of the South East Asian men are taller than 153 cm. Miriam Reitenbach did some additional body measurements under 8 employees of Kamworks. According to these data Cambodian people can reach their hand an average of 27 cm above their head. Because it is most likely that the person who uses the tricycle will be a man<sup>6</sup>, this height is ergonomically correct; the smallest ME is perfectly able to reach 180 cm, thus the top of the display.

An advantage of such a high lid is that the lid and it's products on the display can be seen from a distance and draw attention of the costumers.



As mentioned before, the sliding tray is not further developed into a physical product, due to lack of time. Because the sliding tray is one of the improvements suggested by the Micro Entrepreneurs themselves [paragraph 3.8], it is important to still pay attention to the tray. As can be seen in the figure 6.1 in paragraph 6.1, the next step in developing the interior is to build the actual tray inside the already finished box. There after, SolidWorks drawings and the work drawings for next series can be made. This working method is the reason why the sliding tray was not already developed in Solid Works. Therefore, no renders of the tray are available. For making the tray, the exact dimensions of the cargo box are important. The tray can be installed at a height of 70 cm, see the red line in figure 6.7. The tray will be 75 to 80 cm wide and 50 cm long, to enable the slide-principle.



## 6.6 Reproducing the box

To help the employees at Kamworks building the Kamunasal box, a production plan of is written. All steps required to build the positive form, the female molds and the final product are described. This production plan is at the same time a manual on producing fiber reinforced products. The manual contains tips and recommendations for several situations. The manual is meant to help Kamworks employees and future students building plugs, molds and composite products.

The manual is based on the first GFRP manual made by Miriam Reitenbach. The manual is adjusted on several aspects, e.g. the production of the plug. Therefore the manual is indicated as Version 2.



## 6.7 Cleaning & Maintenance

Maintenance of the Kamunasal bike is important to prevent irreparable defects. If due to any circumstance, defects occur, they should and can be repaired at the workshop of Kamworks. Because eventually, the Kamunasal tricycle will be produced at Kamworks by the Khmer staff, the GFRP-knowledge will be sufficient for conducting repairs.

Nowadays the Solar Home System, made from GRFP's, is in production at Kamworks. This means Kamworks already has some GRFP-knowledge. However, the GRFP-knowledge is still very small because only one man is set to the SHS-production. If the SHS turns out to be successful, more employees will be set to the task and Kamworks will gain expertise.

To prevent defects and lengthen the life of the Kamunasal bike some tips are presented below:

### **Parking accommodation**

If not used, the bike should be stalled in a dry place. Although the polyester box can stand rain and moisture very well, the steel frame is less water resistant. Rain can easily enter the steel pipes through the open ends of the pipes. The frame is not provided with a paint layer at the inside, so rust will occur very quickly. Also scratches on the paint will result in a rusty surface. To prevent this corrosion, the bike should be stalled in a dry place as much as possible. Also rubber stoppers should be put on the open ends of the steel pipes.

### **Cleaning**

To keep a professional and nice look, the box and frame should be kept clean. The box can be easily cleaned with a wet towel. Every part is easily accessible, except for the parts behind the wheels. At the same time, these parts are probably the dirtiest after a day of driving through the mud. However, because the mudguards catch all the mud, the frame remains relatively clean.



## 6.8 Cost price

Appendix N shows all the required materials and the (estimated) costs. The Appendix was composed of data from Miriam Reitenbach, Jeroen Jansen and new estimations and costs. Due to differences in production process the costs differ from the original costs. The following text describes the changes which resulted in different costs:

### Main differences

As previously decided in paragraph 3.9 the LED display and Solar panel are left out in the redesign. This results in a costs reduction. As also predicted in paragraph 3.9, the costs of the cargo box differ from the estimated costs of Miriam due to differences in the production process. The difference which contributes the most to the costs is that MDF is used to produce the positive form instead of polystyrene foam with an epoxy-layer.

Smaller differences can be seen in the finishing of the product: brand stickers are used instead of hand-painted brands, metallic ornaments are applied on the mold division lines, reflectors and direction lights are placed at the back and sides of the box and ornamental hinges are used instead of homemade hinges.

Even more changes can be introduced, such as the gas spring to open and close the lid or a horn to draw attention, but this can be done according to the ME's wishes. Nevertheless, these options are shown in the cost estimations in appendix N.

The following table shows the most important differences and their influences on the total costs.

	<b>MSK</b>		<b>Kamunasal bike</b>	
	<b>method</b>	<b>costs</b>	<b>method</b>	<b>costs</b>
<b>promotion</b>	LED-display, solar panel, posters	\$145	flyers (20)	\$13
<b>production process</b>	Polystyrene foam with epoxy layer	\$38,5	MDF and paint	\$200
<b>finishing touches</b>	<i>branding</i> : hand-painted	\$2	<i>branding</i> : stickers	\$10
	<i>lighting</i> : two head lights in front of box	\$6	<i>lighting</i> : one head light in front, two direction lights at the sides and two reflectors at the back	\$10.50
	<i>open/close lid</i> : home-made hinges	\$2	<i>open/close lid</i> : ornamental rust-free hinges and metal poke to support lid	\$30
	<i>showing products</i> : wooden layer	\$5	<i>showing products</i> : removable display in lid and sliding layer	\$20 (estimation)
			<i>ornaments</i> : metallic strip	\$3
			<i>roof</i> : frame with tarpaulin	\$28.19
<b>costs</b>		\$ 197.5		\$316.69

Table 6.1: Original MSK and Redesign compared: causes for differences in costs

Table 6.1 shows that the differences result in a small change in the costs. It is obvious that the promotional material in the MSK contribute a great deal to the total costs of the MSK. As stated in paragraph 3.9, the addition of the promotional materials results in a 30 percent increase of costs. In the redesign no solar panel, LED-display or posters are present, so a total of \$145 dollars can be deducted from the cost price.

However, as can be seen in table 6.1 some adjustments were made in the production process and the finishing of the carrier. The biggest cost increaser is the MDF material with its 150 dollar paint layer. Smaller cost increasers are the roof, stickers, extra lights and materials for opening and closing the lid.

The rest of the required material remained the same as required for the MSK.

#### Serial production: cost reducer

The total costs are higher than the prototype made by Miriam Reitenbach. However, an important difference is the fact the the biggest cost increaser (MDF plug with paint layer) is only a one time expenditure. When producing in series, the costs of the box will drop with every copy. Therefore, a cost estimation is made for a series of ten pieces. The following table shows how the estimation is calculated.

Table 6.2 is composed on basis of the cost estimations of Miriam Reitenbach, Jeroen Jansen and new data obtained during the production process of the redesign.

Appendix N shows all the involved data.

#### Conclusion

The estimation for the costs for a series of ten shows that the tricycle becomes almost \$ 100 more expensive compared to the MSK without promotional material, as described in paragraph 3.9. The difference is due to the new production method for the positive form, the new frame and the roof.

Through extensive examination of the cost analyses of Miriam Reitenbach and Jeroen Jansen, it became clear that some small costs were left out. But because many small costs can add up to one large costs, these costs were added as well, which helps increasing the total price too. Still, the Kamunasal bike is \$50 cheaper than the MSK with promotional material.

Cost price for a series of 10 pieces		
One-time expenditures		
positive mold	MDF	\$ 50
	labor Kamworks	\$ 80 (estimation)
	external labor car painter	\$ 150
	extra's (sanding papers/bands, varnish)	\$ 30
negative mold	composite materials	\$ 112.81
	labor Kamworks	\$ 30 (estimation)
<b>Subtotal</b>		<b>\$ 452.81</b>
<b>Per piece</b>		<b>\$ 45.28</b>
Materials		
Composites		\$ 128.56
Frame parts		\$ 114.71
Electric components		\$ 160
Finishing and ornaments		\$ 49
Flyers		\$ 13
<b>Subtotal</b>		<b>\$ 456.89</b>
Labor costs		
External (DonBosco)		\$ 10 (estimation)
Kamworks		\$ 60
<b>Subtotal</b>		<b>\$ 70</b>
Capital costs		
Machinery		\$ 5 (estimation)
Breakage		\$ 5 (estimation)
<b>Subtotal</b>		<b>\$ 10</b>
<b>Total</b>		<b>\$ 580.63</b>

Table 6.2: Cost price analysis for a series of ten

# 7 Evaluation





## 7.1 The criteria

The nearly finished prototype is submitted to an evaluation on the criteria. It is evaluated on the requirements which are dependent on the five company credo's: affordable, sustainable, locally producible, durable and desirable. The full list of requirements is presented in chapter 5, paragraph 5. The following text describes in what extend the prototype meets the requirements and the wishes of the company. The most important points are discussed, beginning with the five credo's.

### **Affordable**

The total costs of the tricycle depend on the materials, production process and the size of the series. During the redesign of the market bike, two options for reducing the costs were suggested: a different production process and different promotional material. The series of the cargo box appeared to be way to small to justify a more sophisticated production process. However, to improve surface quality and reduce the repairing costs, the production process of the positive form is adjusted. By skipping the solar panel, Led display et cetera, \$145 is saved.

The costs total up to \$570 per bike, cheaper than the MSK with promotional material but more expensive than the MSK without solar panel et cetera. This is due to the different way of producing the positive form. To reduce the costs, the series can be enlarged.

In conclusion, all requirements concerning the affordability are met.

### **Sustainable**

To reduce costs, the solar panel and LED display are eliminated in the redesign. However, the bike still has an electrical propulsion which is powered by two lead acid battery packs. Also the lights like e.g. the head lights, direction lights and possible LED-lights in the product display, are powered by the batteries. Because these batteries require recharging, the bike is not necessarily sustainable. It depends on how the batteries are recharged. If the batteries are connected to a solar panel every time the ME needs to recharge them, the Kamunasal bike is sustainable.

### **Locally producible**

All parts of the tricycle are available in Cambodia. Concerning the cargo box, the most important is the composite material. This material can be found in the capital city Phnom Penh. The available composite materials are very basic and only suitable for hand lay-up processes.

The remaining materials of the cargo box are lights, stickers, reflectors et cetera and can be found in Phnom Penh as well. Appendix P shows all the materials which can be added to the prototype and were found on the markets in Phnom Penh.

### **Durable**

Composites are materials with good weather resistance and low maintenance costs. Furthermore, composite materials are very strong. The materials are applied in great numbers in the boat building industry. This proves the endurance and quality of the material.

The batteries and electric components are parts which are used in everyday life by Cambodians. Kamworks buys shipments of batteries from Vietnam. These are usually good quality. The lights can be found on the markets and are spare parts for moto's, tuktuks et cetera. These parts are probably Cambodian quality, but they are very cheap and if broken, the cargo box can still be used.

### **Desirable**

The distribution concept of the Kamunasal products is not yet tested in a way which proves its use and effectiveness. Because this distribution concept is the reason for development of the tricycle, no decision can be made about whether the bike should be produced or not. However, the shape of the box is different from what people know and is therefore seen as new, modern and high quality. The box itself may be desirable for other purposes than to serve the distribution concept and its ME.

### **Adaptable to product range**

With its 300 liter volume, the box is spacious. Next to the products attached to the display, the stock can be stored in the cargo box. Because there are no divisions inside the box, all sorts of products of varying sizes and shape can be stored. If the sliding tray is installed as well, the ME can put the products there which have to be easily accessible.



### **Ergonomics**

With its 98 cm, the height of the box is as required: between 92 and 102 cm. A sliding tray can be added to the interior which makes it easier for the ME to reach the products. The ME does not have to bend. Because the products-to-show are attached to the 180 cm high display, costumers can see the products from a distance. However, there are no tests performed yet which prove that costumers can indeed see the products from one and a half meter distance, as required. The dimensions of the display are adjusted to the body dimensions of South East Asian people, so the ME can reach every spot.

The ME is protected against rain and sun by a small roof. This roof is lowered 20 cm because first, Asian people don't need such a high roof, secondly the roof is unpractical because the bike becomes too high to enter the workshop and thirdly, the higher the roof the more the shadow can shift away from the ME. Because no user tests are performed yet, the remaining requirements cannot be judged yet. However, there are already ideas to solve possible problems. For instance, a gas spring can be installed to prevent the lid from dropping too fast and to assist the ME opening the lid.

### **Appearance & Kamunasal identity**

A very important factor during the redesign was the product and brand identity. The box had to match with the image Kamunasal wishes to have: modern, western, high quality and innovative. The GFRP material is new to the Cambodian customer. The benefits of the composite materials are utilized in several ways. First, the material is light weight. It is much lighter than wood or sheet metal and thus the composite box is a light weight box for Cambodian means. Secondly, it is also a low maintenance material in contrast with the traditional materials wood and sheet metal. Thirdly, the GFRP's enable complex shapes, and these possibilities are used: the box is aerodynamic.

In conclusion, the use of GFRP material resulted in a modern and western looking box with innovative qualities as low weight, high strength and low maintenance.

Because no user tests have been performed yet, no decisive verdict can be made about whether the public and ME like the appearance of the box. However, the comments of the Kamworks employees and kids of the orphanage are promising.

### **Safety & recognizable**

The box is provided with lights, reflectors and brand stickers. All these things help to make the box more visible and recognizable. The lights are for safety as well as attracting attention. The brand name is to let the costumers know and recognize that it is a Kamunasal selling vehicle. The shape and appearance of the box are probably very unique which makes it easier for people to remember and recognize the vehicle as well.

### **Product lifetime, cleaning & maintenance**

The box is easy to clean. Water and a towel will be sufficient. The composite material is low maintenance and very strong. Water cannot enter the box. The composites do not require paint layers every year, like metal or wood to keep the water out. The color is 'in' the material and thus the 'paint' cannot peel off. The supposed lifetime of composites is at least 3 years. The metal parts require more maintenance because of the wet climate and chance of corrosion. The tarpaulin roof is subject to heavy winds, sun and rain. The tarpaulin is applied in tuktuks too, but only tests can prove whether the roof lasts the required one and a half year.

### **Disposal**

If Kamworks decides that the bike is written off, it can still be sold on the second hand market. Of course, this should be considered carefully, because there is a chance that the brand identity and unique appearance of the bike are lost as soon as other people start using the bike to sell their own products.

If Kamworks decides to do so, it is possible to sand and polish the box until it shines again and the bike frame can be painted over in a different color. In principle, the material of the box remains yellow. However, the brand stickers can be removed easily and the box can be painted over as well, but the benefit of the color 'inside' the material will be lost.

## 7.2 Process evaluation

The redesign is the result of a three month design process which was based on a simplified procedure from the book 'Productontwerpen'.<sup>3</sup>

The book describes all the phases and actions within these phases, but it does not restrict the designer to one sequence.

This project has been influenced by external factors such as differences in context and culture, time restriction and the absence of experts in the country. As a reminder, figure 1.1 shows a representations of the entire process and figure 5.1 and 6.1 give a closer look on small parts of the design approach described in figure 1.1.

The following text discusses important external factors and how these factors were accounted for in the different phases of the design process.

### **Gaining knowledge about material, company and target group**

On advice of several people who experienced live in Cambodia and/or worked with composites, the project was started with an internship at NPSP Composites in Haarlem to gain extra knowledge about GFR-plastics. Because Cambodia does not have composite factories, let alone experts on composites, it was necessary to study the material in the Netherlands. In Cambodia, the gained knowledge turned out to be of great use. Also the contacts acquired through this internship proved to be of great value during the time in Cambodia.

Despite the contacts with composite experts in the Netherlands and Germany, the lack of composite knowledge and experts in Cambodia still remained an obstacle to take. This will be explained with the following example: The seller of the composite material himself did not know anything about the resin and fibers he was selling. In the Netherlands we are used to shop keepers who provide information and advice about there merchandise. In Cambodia, the merchant could not tell anything about his products and only one type of resin was available. Inquiries about other resin types were futile. The composite experts in Europe were not able to help with this kind of 'practical' problems.

Internet research and phoning the supposed composite factories in Cambodia or Thailand was not effective at all, due to the underdeveloped internet and mobile phone network. Here follows an example: Internet research resulted in a list of possible composite factories. The criteria was that internet pages of the factories said anything about composites, fibers or plastics. Most of the pages were not finished and many of them were not even working properly. To discover whether the factories were selling composite materials, mails were sent and the phone numbers from the internet pages were dialed. The constant failing of internet and mobile phone network hampered the undertaking and many phone numbers turned out te be not working as well as the email addresses. Eventually, only two of the factories responded and they turned out to not know, nor sell anything 'composite'. A striking difference with Western companies is that most Cambodian companies only respond when the costumer explicitly says he is going to buy something. The contact with the companies was also handicapped due to the language barrier.

Simultaneously with the search for composite factories, Kamworks and the target group were examined and experienced. Because the work spot was situated next to Kamworks it was easy to get to know the company. Next to my own experience with the composite factories, the Khmer staff helped to get to understand the culture and the way of working at Kamworks.

Kamworks turned out to be mal-equipped concerning composite production. Like many small workshops in Cambodia, the staff is sitting on the floor outside in the sun while sawing, welding or sanding, generating poisonous dust and fumes. The composite area of Kamworks is a four square meter corner of the workshop where the chemicals are stored in overflowing plastic water bottles. When dosing and mixing, the chemicals were spilled creating puddles of resin, hardener, inhibitor, gelcoat and pigment on the floor in which the bottles were stuck.

Furthermore, the workshop was not ventilated which resulted in hazardous gases. Because there were no gas-maskers present at Kamworks this resulted in headaches after a day of work. In conclusion: the absence of a good worksite influenced the design process much.

By interviewing the Khmer students following the solar/entrepreneur course more knowledge about the future users was obtained. The course was about learning the principle of solar energy and how to run a Kamunasal shop. Because the mobile stall can be launched within this product distribution construction, the students approached the future user very well. Because the students knew a lot about solar energy and the Kamunasal brand, they were valuable high-involved Khmer people. Trough them, insight in the target group was obtained and they provided me with ideas and suggestions about how to improve the design.

### **The design approach**

The presence of the Khmer students was of great importance during the development of the concepts. To make the most of their presence, they were asked to judge drawings, ideas, concepts et cetera. Also the fellow western students and Khmer staff were involved in the decision making during the process.

The design approach in figure 5.1 shows which steps were taken to obtain a final concept. The approach differs somewhat from the conventional design approach. Usually, solutions for product functions are thought of, the best solutions are selected and concepts are developed. The best concept is chosen and further developed to a prototype.

The approach of figure 5.1 uses the product solutions to develop three concepts, which differ from each other in combination of functions and shape. The concepts are in no means final concepts and can be further developed if desired. Because the shape and look of a concept influences the judgment it was necessary to explain each combination thoroughly before letting people judge it. Useful discussions arose during the judgments and gave new insights on the concepts. Design adjustment were made and the final concepts were developed. The final concepts were judged again.

The 'extra' judgment in the middle of the concept development helped to make the right decisions. For instance, at first the idea was to make a lid which opens to the side. However, a side opening lid is inconvenient because of two main reasons: the bike can only be stalled with one side to the road and the box only has two sides open to the public. This was seen as a major disadvantage for many subjects, so this was taken into account in the final concepts.

Furthermore, the final concept was not highly finished because it is of no use in a developing country. The finishing of the box, e.g. lights and reflectors depended on the availability on the Cambodian market. After searching the markets, decision about the finishing could be made.

Another major influence on the design approach was the absence of the tricycle frame. By examining the SolidWorks files and work drawings, the concepts were developed. However, the files and drawings appeared to contain errors and obscurities which hampered the design of a matching cargo box. Because simultaneously with the design phase, the frame was being built at Don Bosco and not at Kamworks, it was difficult to adjust the frame or the redesign. The redesign succeeded because of the flexibility of the entire design phase.

### **Prototyping**

Paragraph 6.1 describes the applied prototyping approach. The approach makes use of SolidWorks, drawings and the workshop of Kamworks. During the production of the prototype, some small adjustments were made in the design, because of new insights derived from the building process. Thereafter, the SolidWorks files were adjusted too.

This example proves that also the prototyping phase was of great flexibility. Due to this flexible approach, improvements on the design could be introduced immediately.

A major influence on the prototyping was the state of the workshop at Kamworks. As described earlier in this paragraph, the workshop leaves much to be desired. Due to the absence of a proper production site, the prototyping turned out to be all but easy. First of all it was physically tough. Secondly, it was dangerous and unhealthy, working in the small corner of the unventilated workshop. This all resulted in a very long prototyping duration, even longer than I had expected.

Also the white paint of the plug (positive form) turned out to be low quality. Wreathes arose in the paint, which resulted in bad quality surface of the plug. This was probably one of the reasons why the last piece of the negative mold would not come off.

Next to this, the lack of experience concerning composites caused some delay. Before the prototyping started, a test was done to see whether clean-cut edges and very steep slopes were possible to produce. A small mold with a complex shape was used to test the case; a good-looking product came out of the mold. It was assumed that the steep slopes would also be possible in a bigger product, like the cargo box.

However, whether it was because of the bad surface quality of the mold or the steep slopes, the mold would not come off. Tests on small scale are no guarantee for success on bigger scale. To develop a mold that will come of, tests on larger scale would probably be more reliable.

The tests were done on such a small scale because of the time-restriction. Tests on large scale would cost too much time. This example proves that the time-restriction was of great influence on the prototyping approach and the quality of the prototype itself. Sadly, there was not enough time to mend the molds nor develop a new one.





## 7.3 Recommendations

### Improve the workshop

- After doing some tests with the composites it became clear that Kamworks was not ready yet for any other process than hand lay-up of glass fibers. Even for hand lay-up the workshop was not equipped well. For better results, ventilation, mixing table and different storage of chemicals is recommended.
- Make sure proper cleaning materials are on stock in the workshop. Acetone is recommended.

### Conduct large scale tests with composites

- Tests on small scale are not representative for results on bigger scale. For a product like the cargo box it is therefore necessary to conduct tests on real size. The molds and plug of the redesign can be used to conduct these tests.

### Use better materials for the plug

- Use waterproof MDF. The plug does not have to be varnished before bringing it to the car painter and the car painter does not have to be careful with the plug.
- Use glue based on epoxy or another waterproof glue.
- Bring your own paint to the car painter or make sure a high quality brand is used.

### Finish the prototype

- Install a mechanism that keeps the lid open, e.g. a gas-spring
- Install the frog lock at the front of the box
- Install the batteries and connect the lights and driving mechanism to the batteries.
- Sew the roof and attach it to the frame
- Finish the product display with Velcro straps.
- Make a sliding tray.
- Add a mud guard to the frame. The back wheel of the frame is not covered by a mud guard. When driving over muddy roads, the dirt will probably end up on the back of the roof. This does not look good.
- Find solutions to fix all wires connecting the lights and such to the batteries.
- Find a solution to protect the headlight from the inside, but at the same time make sure the light remains accessible for replacement.

### Test the prototype

- Interview future users and possible costumers
- Test the box on the road and on the market
- Test the effect of the roof and adjust if necessary.
- Test the use of the product display in the lid. Use small, big, light weight and heavy products.
- Test the use of the sliding tray. Use small, big, light weight and heavy products.
- Test the effect of the display on the costumers. Can they see the products? Do they recognize them?

**Test the bike frame**

- The frame is not yet tested. The first impression is that the frame is not very rigid. Through tests the cause of this problem should be found.

**Improve the prototype**

- The test will result in a list of possible improvements. These should be incorporated in a new design.
- It is better to redesign the frame and the box simultaneously. Adjustments can be made on frame and box together which will result in a better matching combination. In this way, the frame is no more a limiting factor, neither practically nor aesthetically.

**Search for reliable composite suppliers in or near Cambodia**

- Try to find a supplier who can provide you with information about his products. This supplier should have more than only one resin type available.
- Try to find out what is possible with waste products, like chemicals and broken cargo boxes.

**Investigate the possibility to replace the tricycle frame by an electrically propelled moto**

- Kamworks owns two electrically propelled moto's
- In Cambodia a bike has lower status than a moto.
- Delivery moto's are widely used in Cambodia



## 7.4 Final conclusion

The result of this project is a cargo box and its corresponding negative mold and positive form. The box and molds are made of glass fiber reinforced polyester which is an innovative and modern material in the Cambodian context. The box is placed on a bike frame to form a delivery tricycle for selling solar products of the Kamunasal brand. The bike frame was designed by Jeroen Jansen earlier this year, but built at DonBosco during the redesign of the box. The box contains a lid with a product display, reflectors and lights for safety and an adjustable inside interior.

Through the research phase with which the project started, important knowledge about e.g. the Cambodian culture, the target group and their wishes, the rural area's and the composite material was acquired. This knowledge was processed into a new and improved design of the cargo box. Three major changes are made to suit the wishes of the Cambodian entrepreneurs, concerning the production of the molds, the shape of the box itself and the addition of a product display.

The new production method of the molds using MDF instead of polystyrene foam resulted in a heavy and firm plug. Unlike the plug for the original cargo box, this plug is still in one piece and can be used over and over again. The plug also resulted in a much better surface quality of the negative molds and the final product. The surface finish was, except for some spots caused by the wreathes in the white plug, of very high quality. It did not require after treatment. This is a huge improvement compared to the long and disputed after treatment of the original box. This surface was of such a low quality that it required a paint layer.

Two mold pieces were damaged during the production process. This was due to bad surface quality and very complex shapes. New molds have to be produced. To be sure the mold pieces don't damage again, tests have to be performed which prove the way of dividing the mold piece. The other mold pieces remained intact and the surface quality is very high.

The shape is adjusted to make better use of the possibilities of GFRP's and to better represent the Kamunasal identity. Compared to normal Cambodian delivery tricycles, the box has very complex shapes. Its aerodynamic appearance is very modern and new in the eyes of the Cambodian costumer. Also the light-weight material is new and high quality, and thus in line with the Kamunasal identity.

The two lids are replaced by one lid with a product display inside. This change leads to a better contact with the public and costumers. The carrier is more open to the public and the products are visible from a distance.

A sliding tray can be placed inside the box instead of the original wooden tray of the MSK. The sliding tray enables the ME to reach products faster and easier.

However, many of these supposed improvements have not been tested yet, so it is not sure the design adjustments work as meant and predicted. Therefore, tests should give answers and certainties.





## 7.5 Personal reflection

Living and working in Cambodia for three months was a memorable experience, therefore I would like to conclude this report with a retrospective view.

The assignment was to redesign and build a cargo box of composite materials. Beforehand, I already thought of composites as interesting material. The great form freedom is what I like about it. However, my experience with it and knowledge about it was very poor when I started the project. The internship provided me with the basics I just had to know. I assumed that the experience and more knowledge would come during the tests with composites and prototyping. The knowledge and experience came, but it could not prevent the problems with the wreathed surface of the molds. Despite the fact that the approach resulted in two broken mold pieces, I still think this was the right approach because it was the most suitable for the time given. The problems resulted in even more useful knowledge and experience. The materials were hard to handle, but I feel I learned a lot about them.

Furthermore, living and working in a developing country like Cambodia asks a lot of flexibility. Getting accustomed to the climate, the culture and the people took some time, but it resulted in a wonderful and unforgettable experience. Because the Cambodian economy and trade is very ineffective, also my patience was tested time and time again. Despite the fact that I really liked to be in Cambodia, I often felt lucky I was not the only western girl at Kamworks. With the other students I was able to discuss things I thought were remarkable. They were also of great help during the designing phase. The designs were discussed very seriously. I think this was very important because it is hard to discuss things with supervisors or other people in The Netherlands. Things like discussing and judging concepts just need to be done with a group round a table.

The Cambodian take-care-of-yourself-and-your-family-because-no-one-else-does culture reminded me to just go on and continue after each set-back in the process.

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## Appendix A: Product Market Combinations

[Mando Rotman]



## Appendix B: Financing and salary

Miriam Reitenbach examined three options for financing of the MSK and salary of the ME. These decisions are important for the redesign of the carrier as they influence the decision making concerning costs. Below the options are listed with their pros and cons.

### Financing

Kamworks sells MSK to ME	Kamworks sells MSK to ME, financed by a micro-loan	Kamworks rents MSK to ME
<ul style="list-style-type: none"> <li>+ ME has more (financial) responsibility</li> <li>+ mobile store can possibly be partly funded by donors</li> <li>+ low risk Kamworks</li> </ul>	<ul style="list-style-type: none"> <li>+ Low investment for both, ME and Kamworks</li> <li>+ Kamworks can help ME with the interest payments</li> </ul>	<ul style="list-style-type: none"> <li>+ Kamworks retains supervision and quality</li> <li>+ low investments ME</li> </ul>
<ul style="list-style-type: none"> <li>- Kamworks has less supervision</li> <li>- ME has to get money from family and relatives (high investment, but very common in Cambodia)</li> <li>- high investments make it less attractive for ME</li> </ul>	<ul style="list-style-type: none"> <li>- high interest rates</li> <li>- Not yet very common, though gets more and more established</li> </ul>	<ul style="list-style-type: none"> <li>- Kamworks needs more capital and labour power</li> <li>- Higher risks Kamworks</li> <li>- What happens if mobile store breaks down?</li> </ul>

For the first group of micro-entrepreneurs the third option is recommended in order to test the concept of this distribution model in the first instance. By doing this, Kamworks maintains supervision and control over what the ME does with the mobile store. High quality and consistency of the mobile stores can be maintained. Selling the mobile store might have as consequence that the ME starts his own business with other products, by making use of the good name of Kamunasal.

### Salary

Kamworks pays salary	ME buys stock of products	Commission based salary
<ul style="list-style-type: none"> <li>+ ME will prefer this option</li> <li>+ More attractive to work for Kamworks</li> </ul>	<ul style="list-style-type: none"> <li>+ ME responsible for asset (theft, maintenance)</li> <li>+ Low risk Kamworks</li> </ul>	<ul style="list-style-type: none"> <li>+ The more sold, the higher income</li> <li>+ Stimulates effort of ME</li> </ul>
<ul style="list-style-type: none"> <li>- Less control over what ME does</li> <li>- Less incentive to work hard</li> </ul>	<ul style="list-style-type: none"> <li>- High initial investments for ME</li> <li>- High threshold for ME to work for Kamworks, as products are unknown and sales is insecure</li> </ul>	<ul style="list-style-type: none"> <li>- Commission based incentives have a negative connotation in the Cambodian labour market [MIT, 2007]</li> <li>- If employed, Kamworks needs to ensure that the salary + bonus stays above competitive rate</li> </ul>

Paying a fixed salary to the ME will entail a higher risk for Kamworks as selling the products is not guaranteed. On the other hand, buying a stock will be too costly for the ME. Therefore the third option is most promising for the first year to test the distribution model.

For the redesign this means that the carrier can not be too expensive as it will be unaffordable for both, Kamworks and ME.



## Appendix C: Dimensions

The dimensions of the actual cargo box of the MSK are not similar to the dimensions of the cargo box in the figure C1 on this page. These figures present the original idea. [Miriam Reitenbach,2007] In table C1 the most important differences are listed.

Table C1: Important differences in size between the prototype and the original design.

part	dimensions prototype (cm)	dimensions original design (cm)
width of carrier	82	62
height of carrier (from the ground)	92	92
height of open lid (from the ground)	137	147

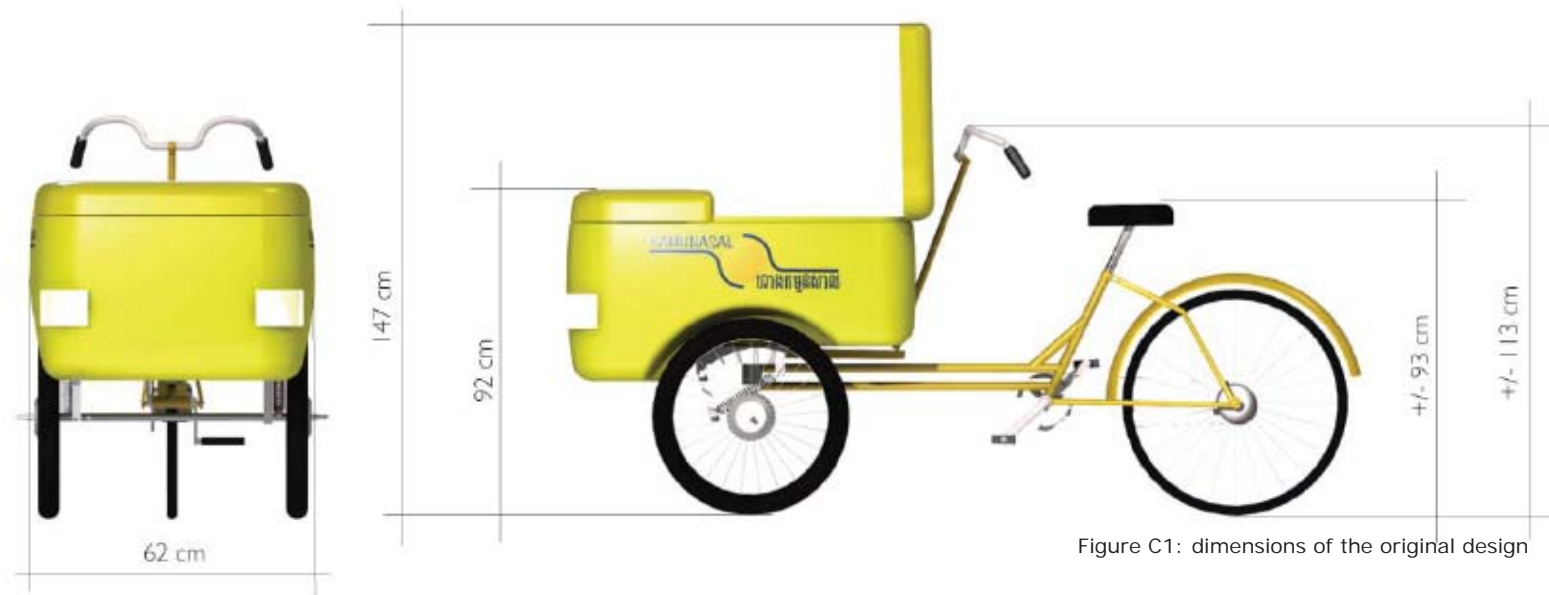


Figure C1: dimensions of the original design

The redesigned frame is based on the actual dimensions rather than on the dimensions in the report. Therefore, some important differences between the original frame and the redesign are listed in table C2. Figure C2 shows the corresponding parts. [Jeroen Jansen, 2008]

Table C2: important dimensions of the frame

part	dimensiosn redesign (cm)	dimensions prototype
width roof	100	-
height roof	235	-
width front frame	50	61
length front frame	54	31
length front axis	86	86

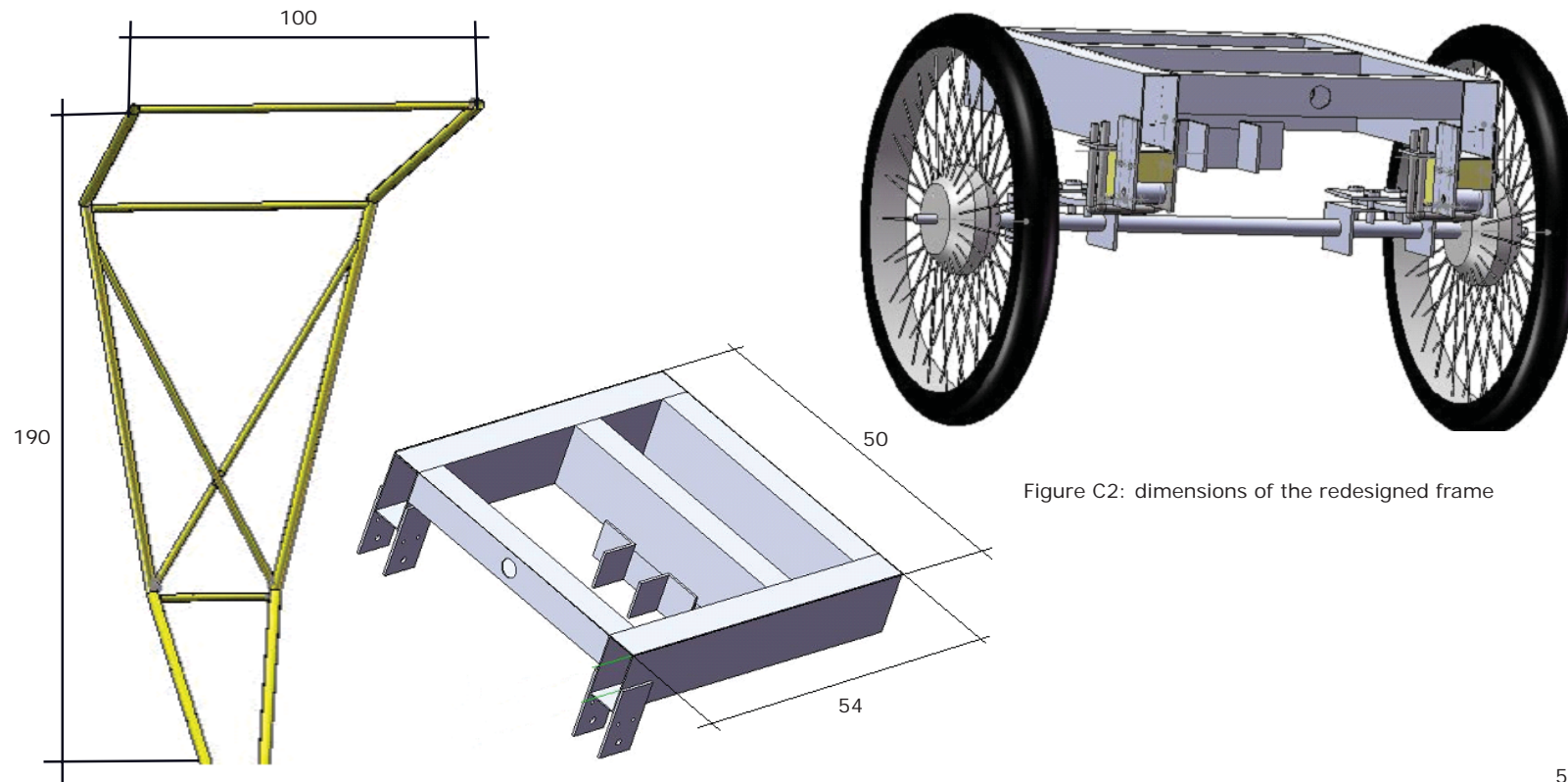


Figure C2: dimensions of the redesigned frame

## Appendix D: Choice of material

Fiber reinforced plastics

- much form freedom, possible to make complex forms
- tools are not limiting for the size of the product
- rather expensive
- time consuming process
- weatherproof, UV proof
- representative for Kamunasal and Kamworks identity
- light weight, strong, low maintenance costs
- Kamworks has experience with composite materials and uses it to produce the first series of the Solar Home System

Vacuum molding

- less form freedom than fiber reinforced plastics
- tools are limiting for the size of the product. At kamworks a vacuum molding machine is available but it can only be used for small products.
- suitable to produce large series
- representative for Kamunasal and Kamworks identity

Wood

- very little form freedom
- cheap
- easy to repair
- time consuming
- regular maintenance intervals, like applying new varnish
- not weatherproof without regular maintenance
- not representative for the Kamunasal and Kamworks identity
- heavy construction

Sheet metal

- little form freedom
- not weatherproof, corrosion
- time consuming
- not representative for the Kamunasal and Kamworks identity
- heavy construction

### Conclusion

Because the series of 10 is very small and the available vacuum molding machine is too small, vacuum molding is rejected. Despite the fact that fiber reinforced plastics are rather expensive, this is the best option for Kamworks. The material is light weight which is an advantage for an electric powered bike.

The composite material also represents the the modern identity of the brand Kamunasal.

Because the mobile kiosk will be used in the rain and sun the properties concerning weather resistance are important factors. Fiber reinforced plastics have good properties. Besides cleaning, no regular maintenance treatment is required.

The final reason to choose composite materials is the fact that Kamworks already uses it for het production of the Solar Home System. Perhaps, Kamworks can develop expertise in composite materials and use it for more products.

## Appendix E: Fiber reinforced plastics

The prototype of the kamunasal tricycle, made by Miriam, was produced by hand lay-up of glass fibers. The new carrier will also be made of composites. It is important to gain an understanding in the production process. Therefore, an internship at NPSP Composites in the Netherlands was performed. In this appendix the findings of this internship are described. Three processes were analyzed: the hand lay-up process, the vacuum bag process and the VA-RTM process. the pros and cons of each process are listed and finally compared to each other.

First the general properties of fiber reinforced plastics are described.

### Fiber reinforced plastics

With fiber reinforced plastics, or so-called composites, it is possible to make very lightweight and strong constructions. The material enables to produce very complex forms, like double curved surfaces. Composites also have good mechanical properties (rigidity and strength) and low maintenance costs. The properties which are important for the Kamunasal tricycle are listed in table 3.

**Table 3: most important properties of Composites**

properties	importance for Kamunasal Tricycle
long service life	high quality, affordability: the tricycle has to hold for a long time, because Kamunasal stands for quality and the bike is quite an investment for Cambodian people.
low maintenance costs (especially in the long run)	high quality and affordability: Less repairs means less expensive in the long run
high form freedom	Kamunasal brand identity: complex forms show that Kamunasal is a modern brand
high weather resistance (corrosion, UV and moisture)	high quality: the tricycle will be in a very sunny and sometimes very wet environment in the rural areas
good impact behavior	the tricycle will be used on unpaved, bumpy roads
possibility of serial production	the tricycle has to be locally producible at Kamworks
possibility to incorporate insert in the laminate	it increases the design possibilities and the qualitative look



## Appendix F1: Production methods, hand lay-up process

The prototype of the delivery tricycle was produced through hand lay-up of glass fibers. This process is rather time consuming. The production of the mould takes a lot of time but this is only once. The third step; the production of the real product, contributes the most to the production time.

### Necessities

Glass fiber (chopped or cloth)

Resin materials (polyester, epoxy or polyurethane)

Single negative mould

Tools that enable the process e.g. rollers, brushes and mould release wax

### Waste material

None

### Processing steps in short

*Producing the positive form:*

1. Produce desired positive product form in foam (at Kamworks polystyrene is used)
2. Use positive form to produce the negative mould. First, apply epoxy layer to ensure the polystyrene does not dissolve through the polyester resin.
3. Finish the positive form.

*Producing the negative mould:*

1. Apply the gelcoat onto the positive form.
2. Apply the polyester resin to the mould and lay-up fibers
3. Release the positive form out of the mould.

*Producing the product:*

1. Clean mould and apply mould release wax onto the mould
2. Apply gelcoat onto the mould
3. Apply polyester resin to the mould and lay-up fibers
3. Release product from mould

### Costs

This process requires less materials than the other two, but it is very time consuming. Therefore, the labor hours are high.

### Health

Another fact that needs to be considered is that hand lay-up of fibers is rather unhealthy. Through reactions of resin and hardeners poisonous gasses are present. Also the resin is dangerous for your health.

### Fiber, resin and availability

Epoxy and polyester can be used in the hand lay-up process. Both resins are available in Cambodia. The fiber mats which can be used are chopped strand mats (CS-mats) and woven cloth. Both types are available in Cambodia.

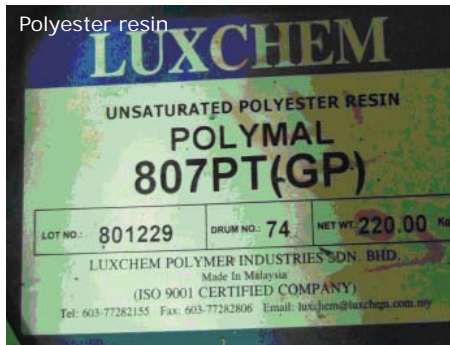
Polyester costs around \$2.60 per liter whereas epoxy is more expensive: \$4.00 per liter.

MEKPO-808  
METHYL ETHYL KETON PEROXIDE  
FINE QUALITY FOR EXPORT

Hardener



Putty



Polyester resin



Gelcoat



Glass fiber mats



Putty hardener

## Appendix F2: Production methods, vacuum bag process

A more sophisticated production process of composites is the RTM process. Several types of RTM can be performed, and the simplest one is the vacuum bag process. This process is generally carried out to get insight in the behavior of the resin during injection. If the knowledge is sufficient the bag can be replaced by a second mould; the positive mould. During an internship at NPSP composites, the process was carefully observed. See the pictures on the right page. Although more steps have to be carried out during the production of the product this method is less time consuming than hand lay-up. Step 1 to 9 is preparation before the real process starts. When the pump is switched on, you just have to wait until the resin is hard.

### Necessities

Vacuum pump, tubes and vacuum pots  
Double Stitched Glass Fibers or natural fibers like coco or hemp  
Resin  
Single negative mould  
Tools that enable the process e.g. brushes and mould release wax  
Injection film  
Separation foil  
Conducting mat  
Foil

### Waste material

Tubes  
Separation foil  
Conducting mat  
Foil

### Processing steps in short

#### *A. Producing the positive form*

1. Produce desired positive product form in foam (at Kamworks polystyrene is used)
2. Use positive form to produce the negative mould. First, apply epoxy layer to ensure the polystyrene does not dissolve through the polyester resin.
3. Finish the positive form.

#### *B. Producing the negative mould*

1. Apply the gelcoat onto the positive form.
2. Apply the polyester resin to the mould and lay-up fibers
3. Release the positive form out of the mould.

#### *C. Producing the product*

1. Clean mould and apply mould release wax onto the mould
2. Apply gelcoat onto the mould
3. Lay-up injection film
4. Lay-up fibers
5. Lay-up separation foil
6. Lay-up conducting mat
7. Prepare entrance for resin and air tubes for vacuum
8. Apply foil all around product and make sure everything is air-tight
9. Connect the tubes to the vacuum pump and the resin tank
10. Release product from mould

### Costs

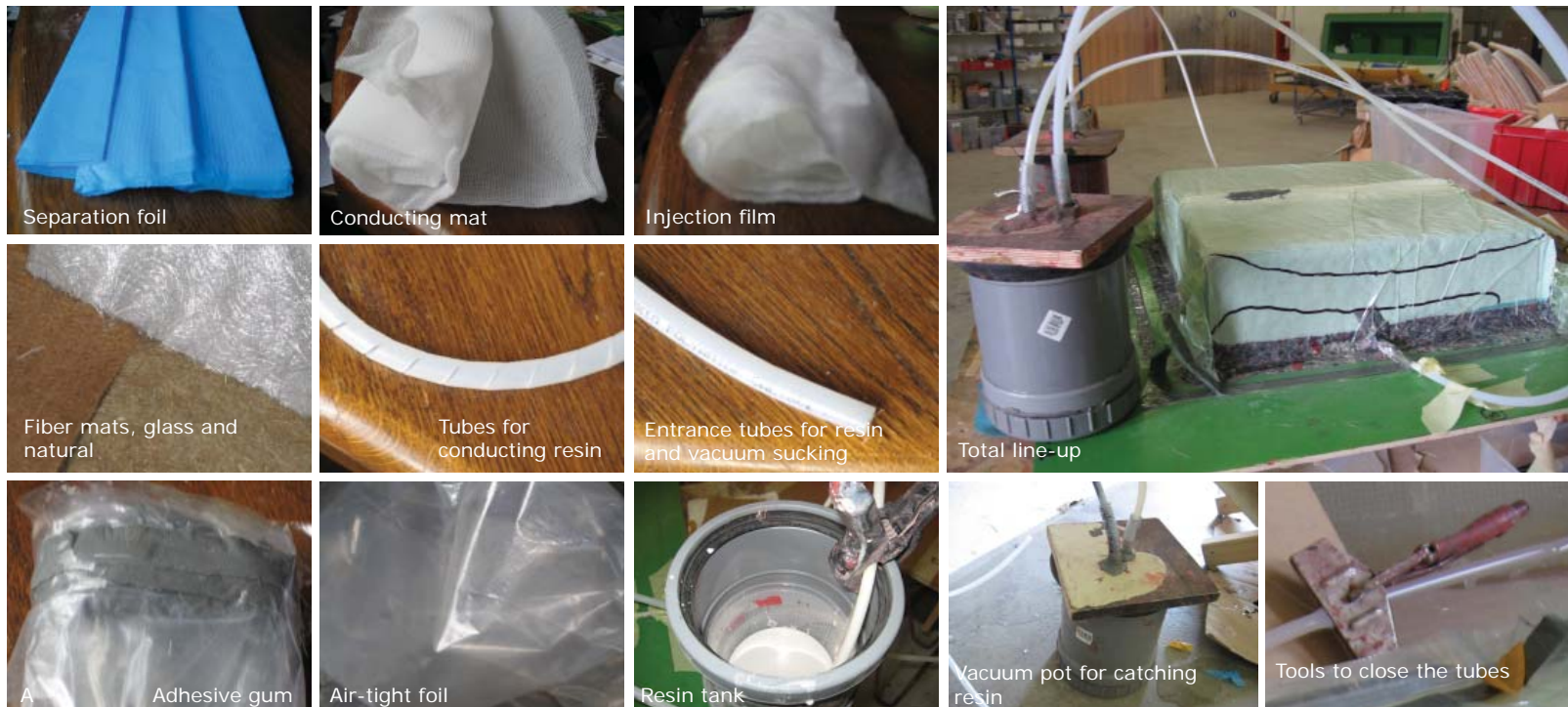
This process requires a lot of extra materials to produce a product. These expenditures are recurring costs. However, a small decrease in labor hours will occur by applying this process.

### Health

Because the resin is being sucked through the fibers by the vacuum pump, this process is much healthier than hand lay-up. The only contact with the resin is when you add the pigment and the hardener. The resin is applied onto the fibers by the sucking of the pump and because of the air-tight bag no gasses are free in the working space.

### Fibers, resins and availability

Mainly epoxy resins with low viscosity are used. They are produced in South East Asia in the countries Thailand, Japan or India. [Epotec Epoxy systems, [www.thaiepoxy.com](http://www.thaiepoxy.com)] Many fibers can be used with this process. like all kinds of natural fibers. However, the only fibers and resins available in Cambodia are those for hand lay-up.





### Appendix F3: production method, Resin Transfer Molding

This process is applied at NPSP Composites in the Netherlands and can be introduced after the vacuum bag process is successfully performed. The bag will be replaced by a second mould; the positive mould. This process enables a constant thickness of the walls and a fine surface finish at both sides of the product.

This method requires an extra step; producing the positive mould. Naturally, this extra step increases the production time. However, this step only has to be carried out once. Therefore, adding an extra step results in a shorter production time on the long run.

#### Necessities

Vacuum pump and tubes

Double Stitched Glass Fibers or natural fibers like coco or hemp

Resin

Positive and negative mould

Tools that enable the process e.g. rollers, brushes and mould release wax

Injection film

#### Waste materials

Tubes

#### Processing steps in short

##### *A. Producing the positive and negative form*

1. Produce desired positive and negative form in foam (at Kamworks polystyrene is used)
2. Use positive and negative forms to produce the negative mould. First, apply epoxy layer to ensure the polystyrene does not dissolve through the polyester resin.
3. Finish the positive and the negative forms.

##### *B. Producing the negative mould*

1. Apply the gelcoat onto the positive form.
2. Apply the polyester resin to the positive form and lay-up fibers
3. Release the positive form out of the mould.

##### *C. Producing the positive mould*

1. Apply the gelcoat onto the negative form.
2. Apply the polyester resin to the negative form and lay-up fibers
3. Release the negative form out of the mould.

##### *D. Producing the product*

1. Clean moulds and apply mould release wax on them
2. Apply gelcoat on both mould
3. Lay-up injection film on both moulds
4. Lay-up fibers onto one of the moulds
5. Place moulds onto each other and ensure they are fixed and air-tight
6. Connect tubes to the mould, resin tank and vacuum pump
7. Switch on pump and wait
8. Release product from moulds

**Costs**

This process requires materials for an extra mould. This is only a one time expenditure. The production time on the long run will decrease, so labor hours will decrease.

**Health**

Because the resin is being sucked through the fibers by the vacuum pump, this process is much healthier than hand lay-up. The only contact with the resin is when you add the pigment and the hardener. The resin is applied onto the fibers by the sucking of the pump and because of the air-tight fixed moulds no gasses are free in the working space.

**Fibers, resins and availability**

The same as with the vacuum bag process mainly epoxy resins with low viscosity are used. They are produced in South East Asia in the countries Thailand, Japan or India. [Epoteck Epoxy systems, [www.thaiepoxy.com](http://www.thaiepoxy.com)] Many fibers can be used with this process, like all kinds of natural fibers. However, the only fibers and resins available in Cambodia are those for hand lay-up.



Sample A



Sample B



Sample C



Sample D



Paraffin oil

## Appendix G: Composite testing

Tests were performed to find solutions for the present production problems with the SHS. In addition the possibilities to apply a vacuum bag process were examined. The results of the two processes were compared.

### Test series 1; may 13, 2008

*goal of the tests:*

1. To find the best putty for mold repair. Normal auto body filler for car repair and two types of hardeners are tested as well as gelcoat with two types of powder.
2. To find a solution against stickiness of the polyester paraffin oil and the vacuum bag are tested.
3. Find out difficulties with vacuum bag process

### Results putty tests

Four samples of putty were made, respectively auto body filler with  
 Sample A. ATM putty hardener (present at Kamworks)  
 Sample B. dibenzoyl peroxide 50 % (imported from the Netherlands)

and gelcoat with  
 Sample C. chalk powder (present at Kamworks)  
 Sample D. tixotropic powder (imported from the Netherlands)

Samples A and B are still soft after two hours. Nail prints can be made easily. The hardener used in B starts to react very fast (within 5 minutes) which forces the user to apply the putty very fast because otherwise grains will arise in the putty.

Sample C and D start to harden within 10 minutes. The chalk powder in sample C is very hard to mix with the gelcoat. The tixotropic powder almost dissolves by itself. No clods are present in sample D.

Gelcoat with tixotropic powder gives the best putty for mold repair.

### Results stickiness

Two solutions are tested: adding paraffin oil to the resin and applying the resin in vacuum to the fibers using the vacuum bag process.

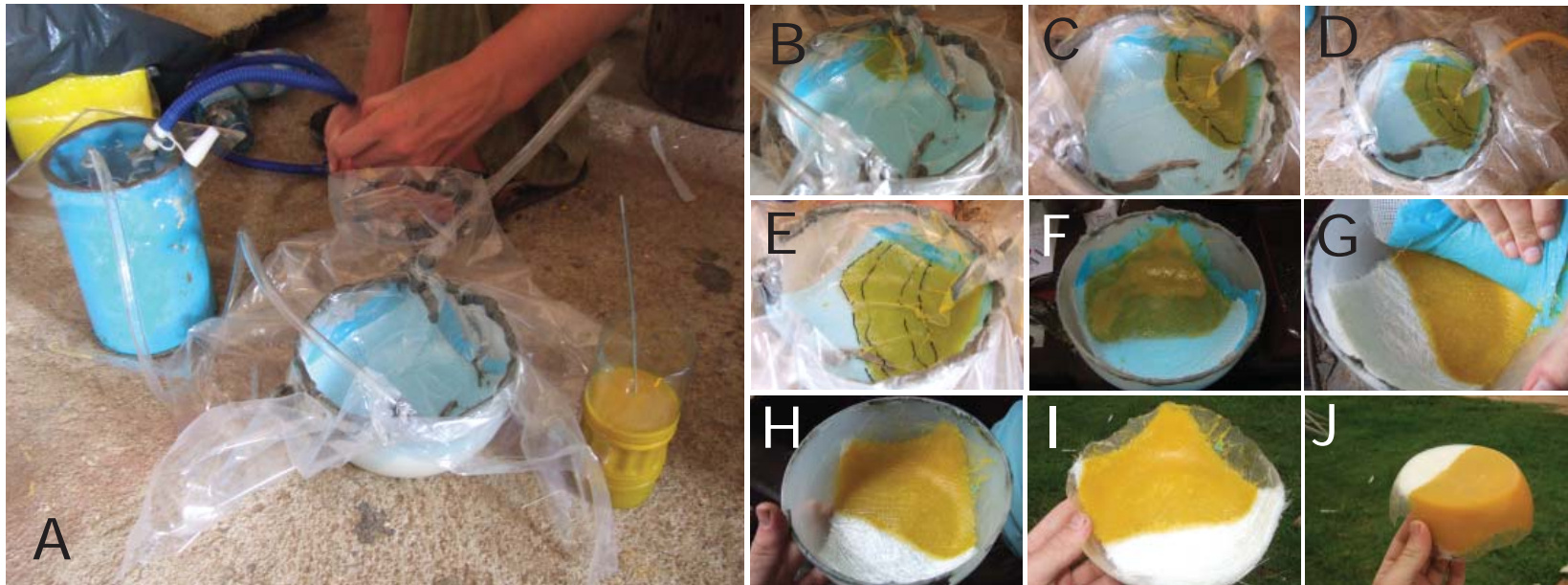
Adding paraffin oil results in a non sticky sample but the sample remains also very flexible. Strength is reduced by adding paraffin oil. Paraffin has to be added only in the top layer to keep original strength.

Applying the vacuum bag process results in a not sticky sample. The stickiness is the result of humid air. By processing the resin in vacuum, the polyester does not take up moisture from the air.

### **Results Vacuum bag process**

The vacuum bag process was tested with a small foot pump, foil and tubes bought at the market in Phnom Penh. A small bowl was used as a mold. Double stitched fibers, separation foil, conducting mats and injection film were also used.

The photos show different stages in the process



A. test line up | B. start, 15.03 | C. line 1, 15.05 | D. line 2, 15.12 | E. line 3, 15.16 adn line 4, 15.22 | F. almost hardened in the bowl, 15.45 | G, H, I and J. Taking out the actual product

### **Conclusions**

- ~ vacuum pot was leaking = bottom and top were to flexible
- ~ foil was leaking
- ~ pump was too small, not enough sucking power too pull resin through all fibers before it started hardening
- ~ too much resin was used
- ~ resin hardened too fast, not whole area was reached yet
- ~ resin became too hot in the reservoir. Tube started to melt.
- ~ final product is smooth and on the inner surface the prints of the conducting mat can be see. The product is not sticky.



### **Testseries 2; may 23, 2008**

These tests were performed with a bigger hand pump and a stronger vacuum pot than the previous tests.

#### *goal of the tests:*

1. To find out if the regular chopped strand mats for hand lay-up processes can be applied in vacuum bag process as well. These Chopped Strand Mats are available in Phnom Penh.
2. To see if complex shapes are possible to produce with a vacuum bag process.

#### **results chopped strand mat**

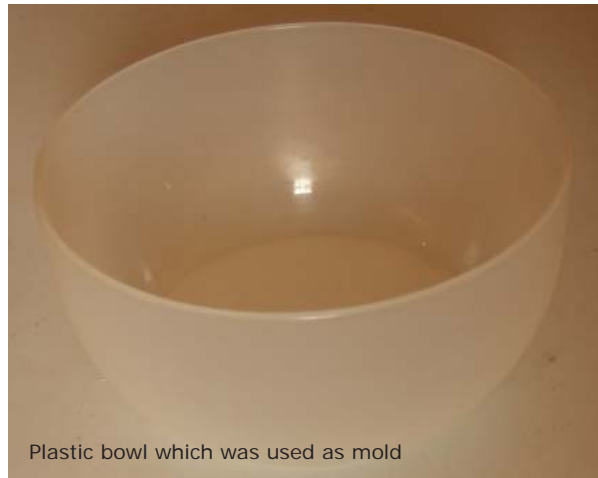
The resin reaches every fiber which is covered with the conducting mat. This means that without a conducting mat no vacuum bag process will succeed. The chopped strand mats don't act different from the double stitched chopped mats used in the previous test. The regular CS-mats can be used.

#### **results complex shapes**

In the bowl a cylinder was placed to make a complex shape. The tube with which the resin enters the mold was placed on top of this cylinder. The tubes for sucking out the air were placed on two sides of the brim of the bowl, opposite to each other.

The resin reached all the fibers covered by a conducting mat.

Removing the mold from the product was much more difficult because of the cylinder in the middle.



Plastic bowl which was used as mold



End product: shiny surface, resin is equally spread and edges are very sharp

## Appendix H: Asking the experts

### Mail contact with Taco Rison, Structural Composite Europe bv: expert in the field of composites

#### ***Mr. Taco Rison about the use of natural fibers in Cambodia:***

Polyester has a so-called fragile matrix. If this is used in combination with natural fibers (like jute) the matrix will break in short time. This is because natural fibers are usually hydrophilic. This means the fibers will suck up water. The fibers will swell and this eventually causes the matrix to break. All sorts of unhealthy chemicals can be used to overcome this problem, but than the advantages of using natural fibers over glass fibers are gone. A second option is to treat the material with heat to crystallize the material as to prevent the fibers from sucking up water. This will lead to high energy use which is certainly not convenient in Cambodia. If polyester is used, glass fibers are the best option.

#### ***Mr. Taco Rison about the use of vacuum bag laminating in Cambodia:***

Vacuum bag laminating presses the fibers together which result in a thinner material than when hand lay-up is used. This decreases the moment of inertia of the material. To overcome this problem more fiber layers have to be added, which will result in a heavier box. Of course the costs will increase as well.

### Mail contact with Bill O'Leary, Steppaboats Thailand: expert in the field of yacht building

At Steppaboat the boats are build with hand lay-up of glass fibers. They use the so-called 'Wet Out' procedure. Only one layer per day is applied and 'wetted out' with polyurethane resin. When the layer has dried, all imperfections are grinded out before adding the next layer. This continues until the desired thickness is reached.

#### ***Which materials do you use to make the negative mold? and which for the boat?***

We use polyurethane resins, woven roving, chopped fiberglass mats and mold making gelcoat to construct the negative (female) mold on top of our plug parts. The mold making gelcoat is also polyurethane based.

#### ***Is there a difference between the gelcoat for the mold and the gelcoat for the boat?***

Yes, I am not actually sure of the chemical differences but the mold making gelcoat has to be much harder than the boat gelcoat.

#### ***How long does it take to build the entire hull of the boat?***

It usually takes 2 to 3 weeks.

#### ***How many fiber layers are used and what kind of fibers?***

usually 8 to 10 layers. We use 350 and 450 gram chopped glass fibers and 600 gram woven roving.

#### ***Which actions are crucial for the quality of composite materials?***

The 'Wet Out' process and making sure there are no air pockets before adding the next layer.

#### ***In what temperature are you working? (In Thailand it is probably hotter than the ideal temperature of 20 C.)***

Bloody hot! It is like an oven, but resins now are designed to be worked at these temperatures and we can still regulate the curing process by the amount of hardener used as well as quantities of Styrene and Acetone etc.

#### **Niels Haarbosch, NPSP Composites in the Netherlands**

##### ***Mr. Niels Haarbosch about mold making***

We build the positive form from MDF, layer for layer. To achieve a shiny product the surfaces of the all molds, positive and negative, have to be perfectly smooth. This is done by sanding and polishing the positive form and the female mold. First, all globe like surfaces are polished very thoroughly. Than the female mold is produced. The globes in the positive form become caves in the female form and vice versa. The female form is polished also, but this time special attention is given to the globes of the female mold (the caves in the positive form). This process ensures that the final mold will be perfectly smoothened.

## Appendix I : Comparing production processes

The knowledge gained by analyzing the processes, tests with composites and interviewing some experts is used to make a choice for a production process. Table 4 below shows the score of each process on a certain factor.

Table 4: comparison of production processes

process	production time	healthiness	amount of necessities	amount of waste materials	costs	product appearance	availability of materials	use of natural fibers
hand lay-up	-	-	+	+	+	+	++	-
vacuum bag	+-	+	-	-	--	+	--	+
RTM	+	+	+-	+-	+-	++	--	+

minus = bad score on issue

plus minus = medium score on issue

plus = good score on issue

The hand lay-up and the vacuum bag process score different compared to each other on every issue. Vacuum bag laminating has a shorter production time, is healthier, and natural fibers can be used. However, vacuum bag processing is more polluting because of the waste materials and also more expensive than hand lay-up. If natural fibers are used the cheapest of the resins (polyester) cannot be used as a matrix.

The table above states that RTM is the best process, compared to the other two. It scores well on all issues. However, to set up this process first the vacuum bag process has to be successfully performed. The materials for both of these processes cannot be found within Cambodia. They can be imported but this will lead to higher costs.

For the present situation at Kamworks only hand lay-up is possible. The process needs to be perfectionated before trying the other processes. If Kamworks is able to produce good looking products with hand lay-up without difficulties, the other processes can be developed. Therefore, during redesign of the carrier this must be kept in mind.



## Appendix J: Stakeholders

**Government:** Renewable Electricity Action Plan (REAP) to reduce poverty in Cambodia by enabling their key requirement: sustainable and affordable energy for everyone.

**Kamworks and partners:**

*Kamwork:* Improving electrification in Cambodia, providing employment and creating a way to sell and promote the Kamunasal brand

*Pico Sol:* contributing to improvement of living situation in developing countries. They partially finance this project.

*The khmer foundation for peace, justice and development:* offering personnel and space to Kamworks

*ProSeed:* distribution of LED Lantarns. They are cooperating with Kamworks today.

**Energy management and providers**

Three main government institutions responsible for energy in Cambodia [Government of Cambodia, 2007]:

*Ministry of Industry, Mines and energy (MIME):* responsible for energy planning, policy and management. Promoting solar energy by brochures, articles in national press and tv programs on the subject of PV and organizing workshops for entrepreneurs, users, NGO's and international agencies.

*Electricity Authority of Cambodia (EAC):* responsible for regulating the electricity industry. Issuing Licenses, approving and enforcing Performance Standards for Licensees to ensure quality supply and better services for costumers.

*Electricity du Cambodge (EdC):* responsible for generation, transmission and distribution of power in nine areas of the country

*Rural Electricity Entrepreneurs (REE):* Limited financial resources and only 20% have trading activities as battery selling.

**Battery chargers**

Present in nearly every village to recharge car batteries. They often recharge them in a wrong way, which shortens the life of the battery.

**Possible competitors and partners**

*International Solar Companies and local Solar Companies:* Distributing and/or installing solar products.

**Aid organizations and NGO's**

*PPASME (Phnom Penh Association for Small and MEidium Enterprise):* Reducing poverty by helping development of activities of small entrepreneurs.

**Promotion**

*Ocean advertising:* Company that makes all kinds of shows and movies to promote and advertise.

**Production and assembly workshops**

*DonBosco Technical school, CKN school for electronics, DTW workshop for plastic injection molding and Centre Kram Ngoy workshop for electronics:* These workshops can be involved if Kamworks wishes to, due to circumstances.

## Appendix K1: Materials for the roof

### *Selection criteria*

Affordable | matching appearance | block rain and sun | good resistance against sun and rain

#### **Cloth (1)**

Cloth are not weather resistant and not waterproof. Sun and rain will decay the cloth so they have to be replaced at regular intervals. Also cloth do not match with the composite materials of the box.

#### **Sheet plastic (2)**

Plastic can be easily placed onto the roof construction. It is better resistant against the weather and therefore will not have to be replaced as often as the cloth. The appearance however, is not very modern. No complex forms are present and this does not match the forms of the cargo box.

#### **Tarpaulin (3)**

Tarpaulin is generally used in trucks. It is made from woven mats like polyethylene, which are coated with a kind of plastic. The material is almost as flexible as cloth but if treaded against ultraviolet light it can last for years exposed to the elements. Tarpaulin is waterproof and inexpensive. It's appearance does not match with the cargo box.

#### **Lid of MSK (4)**

The lid of the present prototype fits on the roof construction. This solution can also be used in the redesign of the MSK using the old mold or a new mold. Roof and lid will have the same shape, which makes them matching. Whether this solution will be applied depends on the future decisions regarding the opening of the box and the size of the lids and box. If the same mold is used for both lid and roof, there will be no extra mold costs.

#### **Fiber reinforced plastic (5)**

This solution requires to make an extra mold. More form freedom is possible than all the other solutions provide, but the existing roof construction is an important limiting factor. The rectangular bars will direct the form in a certain way.



materials for the roof

## Appendix K2: Solutions for opening the box

### *Selection criteria*

Affordability | Ability to see what is in the carrier | Waterproof | Rain and dust may not disable the opening mechanism | Ability to lock the lids | Easy and safe to open and close | Ability to survey the situation

### **Normal lids across (1) and normal lids in length (2)**

Solution 1 was applied in the MSK prototype. The lids can be easily opened if standing on the side of the tricycle. However, the lids block the sight if standing in front or at the back of the tricycle. The lids in solution 2 open in the length and make it hard to look into the carrier if standing on the side of the tricycle. Both solutions can be made waterproof and it is easy to install a lock. Finally, the opening mechanism is not susceptible to malfunction caused by rain and dust.

### **Hood-in-length (3) and hood-in-width (4)**

The hood-like lids open in the same way as the hood of a car. The lid in the length can be opened if standing at the side of the cargo box, whereas the other hood-like lid can be opened if standing in front of the cargo box. As solution 1 and 2, the hood-like lids are not very susceptible for malfunction due to dust and rain and they are easy to lock and to make waterproof. For costumers the hood-in-width is the best option because they can look into the box from three sides. There is also a possibility to use the opened lid as a display for products.

### **Like a garage door (5)**

This lid can be opened by lifting up first and then sliding it to the side of the carrier, like a garage door. The lid stays at the same height as the carrier which enables the costumers to look into the box from all sides. The mechanism is more difficult to produce and if dust comes in the rails the lid can get stuck. The lid is waterproof and can be easily locked.

### **Sliding lid that has to be lifted first (6)**

This lid slides over the box and stays at box-height if opened. Costumers can look into the carrier from all sides, but the lid also reduces the size of the opening, which makes it hard for the ME to pick up products and to show his products to the public. Also the mechanism is difficult to produce and dirt can cause problems.

### **Rolling lid (7) and foldable lid (8)**

The lids can be locked and are easy to open. If opened, these lids don't block sight. However, dirt can affect the opening of the lids. Also, these lids are hard to make waterproof, because the lids are below the surface of the box.

### **Rotating lid (9)**

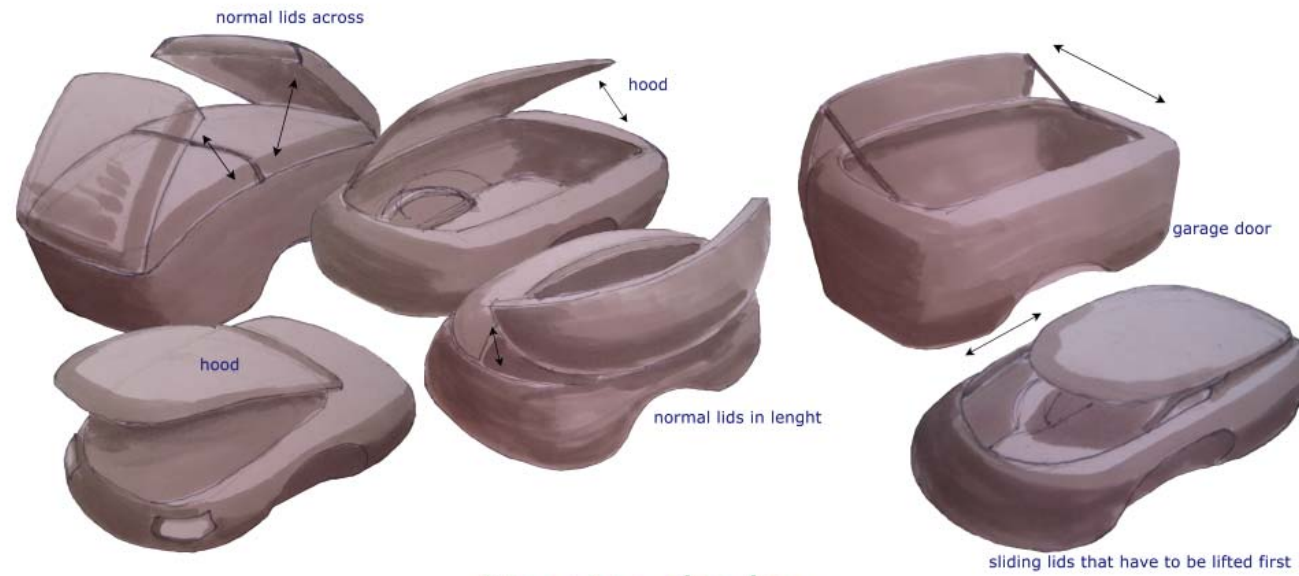
This lid is easy to make waterproof. Opening is also easy, but an opened lid will disable the costumers from getting closer.

### **Rolling and sliding lids (10) and harmonica lids (11)**

Dirt can easily affect the sliding mechanism and it is difficult to make it waterproof. The lids can be locked. If opened, the lids do not block sight and the inside is easy accessible by ME and customer. It has to be produced with other materials than the rest of the box. This influences the appearance.

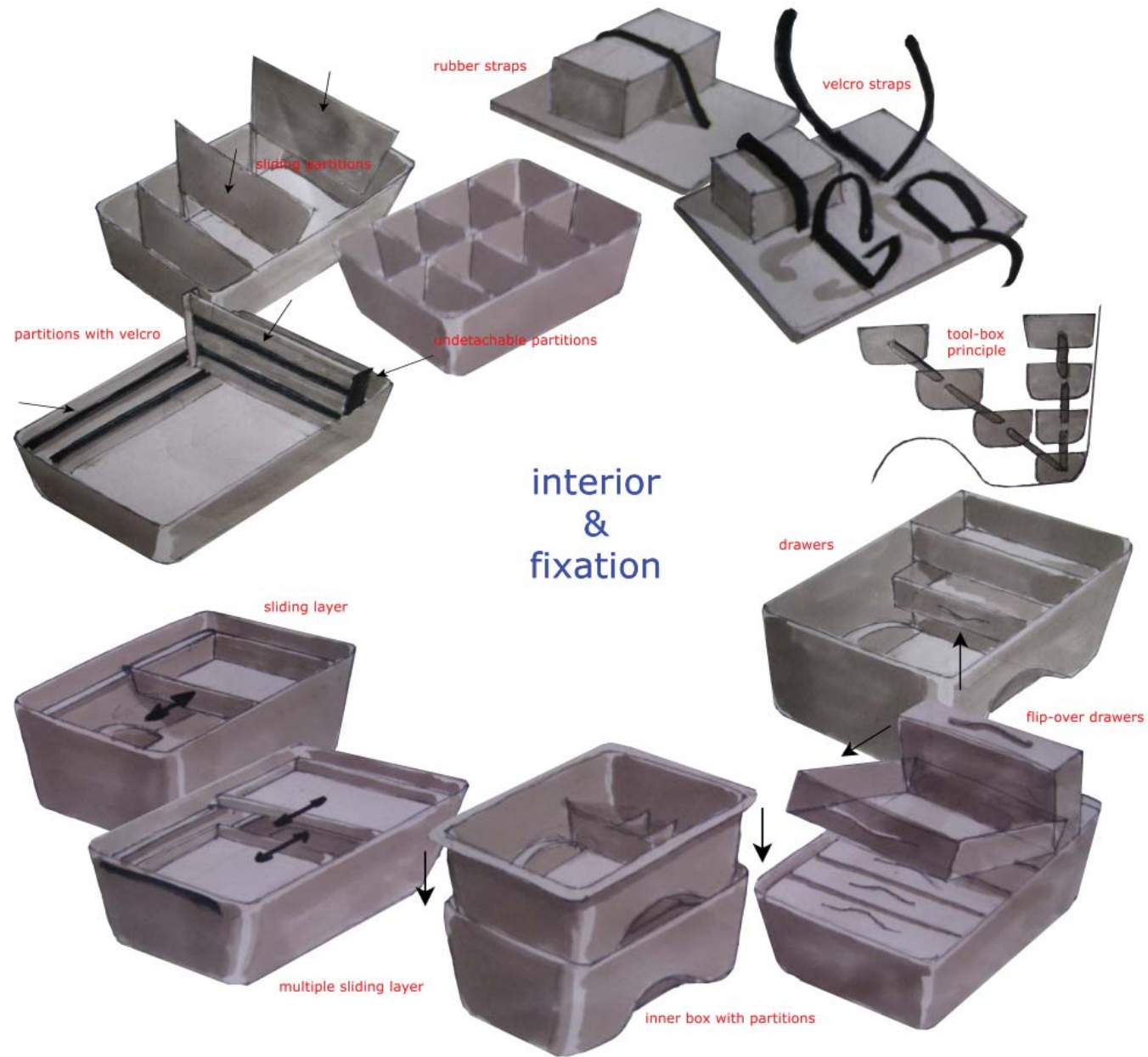
### **Sliding lids (12)**

This solution is known to Cambodians because it is used in many selling carts. The cart can be opened by sliding the lids on top of each other. This means only half of the surface of the box can be opened. This makes reaching the products on the inside more difficult for the ME and also showing the products to the costumers becomes harder if the opening is so small.



## Opening the box







## Appendix K3: Solutions for the interior and fixation of products

### *Selection criteria*

Affordability | Adjustable to changing product range | Ability to see what is in the carrier | Ability to display products | Ability to fix products | Preventing products from breaking | Ergonomically correct

#### **Partitions with Velcro (1)**

The Velcro makes it easy to remove partitions and adjust the interior to the products. There is no possibility to display the products properly and the products are loose while driving, which increases the chance of damaging the products.

#### **Sliding partitions (2)**

This solution has the same features as the partitions with Velcro. However, this one is harder to make and accuracy is really important during the production of the grooves and partitions because they have to satisfy tight margins.

#### **Undetachable partitions (3)**

This solution forces the ME to store his products in a way that he might find awkward. Also, if bigger products have to be stored the partitions will be in the way. Again, there is no possibility to display the product range in a proper way.

#### **Rubber straps (4) and Velcro straps (5)**

These solutions are suitable in almost every interior. They can be used on a layer, inside drawers or directly onto the walls of the box on the inside. The Velcro straps are adjustable to different sizes, whereas the rubber straps will form a problem fixating the really small products. This solution is also very cheap.

#### **Tool box principle (6)**

This solution makes use of the space rather uneconomical. This solution needs a lot of space to open and close. Also it is not adjustable to a changing product range and products cannot be displayed in a proper way.

#### **Drawers (7) and flip over drawers (8)**

Properties are the same as for the tool-box principle.

#### **Inner box with partitions (9)**

The advantage of this solution is that the inner surface has a nice and smooth finish. If detachable partitions are used, the inner box will be adjustable to a changing product range. However, displaying the products is not possible. Also this solution requires a lot of extra composite materials compared to the other solutions which makes it more expensive.

#### **Sliding layers (10) and multiple sliding layers (11)**

The layers enable the ME to display the products in a neat way. The layers do not have partitions which make them suitable for all kind of products. If used in combination with rubber or Velcro straps the products can be fixed onto the tray which prevents products from falling down the tray.

A single layer enables the ME to store the rest of the stock or his personal belongings underneath the layer. If the ME wants to get something from underneath the layer, he can move it to the side.

Space for moving the layer to the other side has to be reserved. If multiple sliding layers are applied this means that half of the cargo box cannot be filled, because otherwise the layers can not slide anymore.

## Appendix K4: Mud guard solutions

### *Selection criteria*

Affordable | Ability to clean | Protect driver and cargo box against dirt

#### **Detachable mud guards (1)**

The mud guards can be removed from the cargo box. This makes it easy to clean and conduct small repairs. The appearance is a bit old fashioned.

#### **Integrated mud guards (2)**

This type of mud guards is also applied in the MSK prototype. The space behind the wheels cannot be cleaned easily. Also these guards will not fully prevent the box from getting dirty.

#### **Covered wheels (3)**

These guards prevent the outer surface of the box from getting dirty. The dirt will stay on the inside of the mud guard, just like happens with the mud guards of a bicycle. Because the guards are not detachable it is difficult to remove the dirt. Regular cleaning with a water hose can solve this problem. The covering of the wheels make the box more stream lined.

#### **Integrated extended mud guards (4)**

This solution differs from the integrated mud guards (2) by only one addition: the extension. The extended guard ensures the mud will not spatter on the ME of on the bottom of the cargo box. The extension keeps the box cleaner than the integrated mud guard without extension.

#### **Box which narrows to the front with integrated mud guards (5)**

The wheels are easily accessible and the space behind the wheels can be cleaned easily with a hose. The appearance looks modern and because the box narrows towards the front the form of the box can be stream lined.



## Appendix L: Display try-out

To find out what is the best solution for fixing the products onto the display a try-out was performed. Three different methods were analyzed: Velcro straps, elastic bands and ropes. See figures L1 to L3.

Products like torches, small radios, USB devices and the Proseed lamp were used as substitutes for the future Kamunasal products. They range in weight from some grams to 2 kg. Also a shock test is performed to find out if the products remain attached while driving on bumpy roads.



Figure L1: Display with velcro straps



Figure L2: Elastic bands



Figure L2: Ropes



Figure L4: Super glue affecting the velcro straps

### Velcro straps

The Velcro straps are self-adhesive. The straps are attached on the board and on the products to display. Figure L1 shows the display with products attached to the Velcro straps. The straps stick very good together. Heavy products like the Proseed lamp are no problem for this type of Velcro. However, after a while the self adhesive straps began to loosen from the display and the products.

Super glue was used to solve this problem. However, the super glue reacted with the Velcro which resulted in non-sticking Velcro. See figure L4. Using glue to attach the velcro onto the board and products is not a good idea.

### Elastic bands

The second board has elastic bands for attaching the products. This works well for small products in their packing. Also the hand rewindable torches are easily attached onto the board without their rapping. See figure L2.

The heavy products, like the Proseed lamp cannot be attached on the display because the elastic bands are not tight enough and do not provide enough friction.

### Ropes

The ropes can be used in many different ways. Products can be tied to the board by one or more ropes. Figure L# shows that the ropes do not look very decently. It is also a bit hard to attach the products in such a way that they won't bump into each other when the lid is closed whilst driving on bumpy roads.

### Testing the displays with Micro-Entrepreneurs

The three different displays were tested by the Micro-Entrepreneurs as well. They all agreed very fast that the Velcro straps are the best solution, because this looks decently, is easy and products can be attached and removed very fast.

## Appendix M: Ergonomics

The contents of this appendix come from the MSK report [Reitenbach, 2007]

The selected sample consists of male and female subjects aged 25-45 years. Nineteen body dimensions were measured and the 5th, 50th and 95th percentile were indicated. The definitions of the body dimensions are based on the norm DIN 33 402. The selected region of South East Asia is composed of subjects from the countries: Birma, Brunei, Indonesia, Cambodia, Laos, Malaysia, Philippines, Singapore, Thailand and Vietnam. Table M1 contains the data.

Additional measurements were done with 8 subjects. Several body dimensions, such as stature, reach with the arm and length of the legs were measured. In order to cover a wide range the subjects were selected from a stature ranging from 155 cm to 174.5 cm. All body dimensions are given in cm. See table M2.

Dimension	Male			Female			Min	Max
	5th	50th	95th	5th	50th	95th		
Body height	1530	1630	1720	1440	1530	1620	1440	1720
Sitting height	790	840	900	750	800	850	750	900
Eye height sitting	680	730	780	660	700	740	660	780
Range of reach	730	780	820	690	730	780	690	820
Shoulder breadth (bideitoid)	380	410	430	340	380	410	340	430
Shoulder breadth (acromium)	320	370	420	300	335	370	300	420
Hip breadth	285	310	330	285	315	360	285	360
Knee height	465	495	525	430	460	485	430	525
Length lower leg	380	415	445	365	385	405	365	445
Elbow-grip-distance	300	325	360	280	305	340	280	360
Popliteal length	490	530	570	470	500	530	470	570
Buttock-foot length	910	970	1025	860	915	970	860	1025
Buttock breadth sitting	290	315	340	330	365	400	290	400
Length of hand	160	175	185	155	165	175	155	185
Breadth of hand	75	80	85	70	75	80	70	85
Foot length	220	235	250	210	220	235	210	250
Head circumference	530	565	595	500	530	560	500	595
Depth head	175	185	195	165	175	185	165	195
Breadth head	135	145	155	130	135	145	130	155

Table M1: body dimensions of South East Asian people.

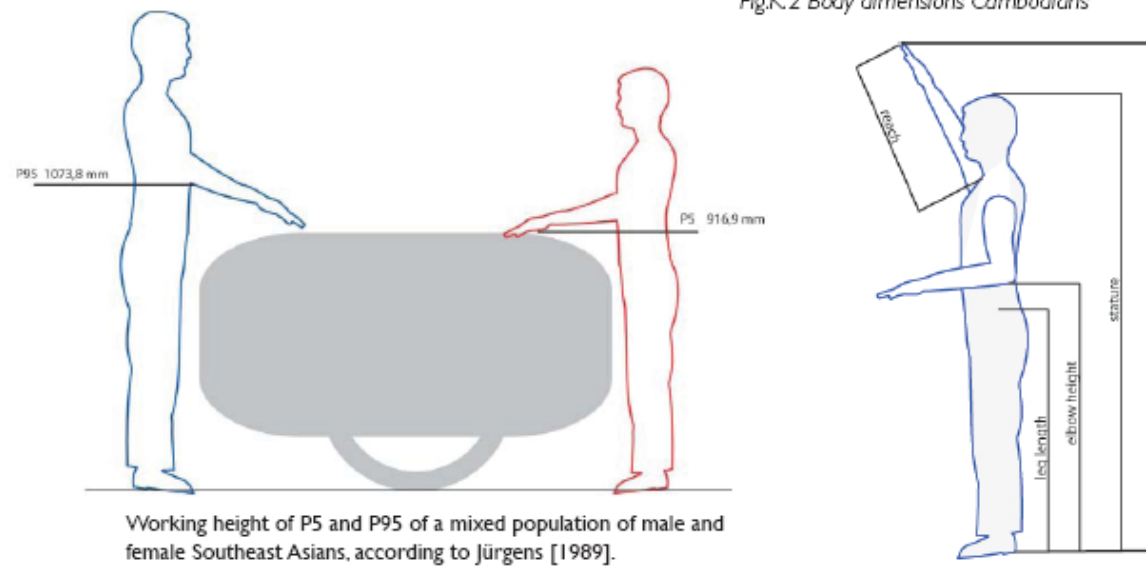
Source: Jürgens, H.W. , Aune, I.A. , Pieper, U. (1989) Internationaler anthropometrischer Datenatlas. Wirtschaftsverslag NW, Bremerhaven.

Table M2: body dimenions of eight Cambodian subjects.

Source: Design of a Mobile Solar Kiosk for Cambodian Micro-Entrepreneurs. Graduation report.  
Miriam Reitenbach

Name	Sex	Age	Stature in	Reach with arm over head	Reach shoulder to fingers	Elbow height	Length leg
Leap	Male	22	174,5	193	67	110	104
Phalla	Male	24	160	189	59	104	94
Sitha	Male	25	170	195	61	106	97
Seray	Male	28	161	194	60	105	95
Sarin	Male	27	162	190	57	102	95
Sopheak	Female	23	155	184	58	102	89
Tori	Male	15	156	185	53	103	93
Virak	Male	19	160	186	59	105	95

Fig.K.2 Body dimensions Cambodians





## Appendix N: Cost price analysis

The tables in this appendix are composed with data derived from the reports and cost estimations of Miriam Reitenbach and Jeroen Jansen.

### A. The frame

Jeroen Jansen estimated the costs of the bike frame and the components for propulsion of the MSK. Table N1 shows the cost price analysis.

Table N1: Cost price analysis for the frame. Source: Redesigning a Market Bike. Internship report. Jeroen Jansen

Cost price analysis											Material costs	272,97
Number of parts											Labour costs	\$31,83
											<b>Total price</b>	<b>\$304,80</b>
Product name	Product number	Number	Material	Dimensions	Length	Price per length	Place of production	Time of production (min)	Costs of production 1 dollar/h	Price	Way of approximating	
<b>Basic frame</b>	<b>1</b>	1						120	\$2,00	\$2,00	Estimation	<b>\$159,25</b>
Bike frame	a	1						15	\$0,25	\$15,25	Estimation	
Hub motor (24V, 250W)	b	1						0	\$0,00	\$38,00	Miriam	
Motor controller	c	1						0	\$0,00	\$17,00	Miriam	
Hand Gear	d	1						0	\$0,00	\$18,00	Miriam	
Key and light indicator	e	1						0	\$0,00	\$23,00	Miriam	
Sealed lead acid battery (12V, 7Ah)	f	2						0	\$0,00	\$28,00	Miriam	
Battery charger	g	1						0	\$0,00	\$18,00	Miriam	
<b>Roof</b>	<b>2</b>	1						180	\$3,00	\$3,00	Estimation	<b>\$19,89</b>
Roof bar	a	2	Steel	Pipe Ø 22	2,829	\$1,75	Kamworks	10	\$0,33	\$10,23	Estimation	
Roof support bar 1	b	1	Steel	Pipe Ø 18	0,31	\$1,50	Kamworks	5	\$0,08	\$0,55	Miriam	
Roof support bar 2	c	1	Steel	Pipe Ø 18	0,87	\$1,50	Kamworks	5	\$0,08	\$1,09	Miriam	
Roof support bar 3	d	1	Steel	Pipe Ø 18	0,82	\$1,50	Kamworks	5	\$0,08	\$1,31	Miriam	
Roof support bar 4	e	2	Steel	Pipe Ø 18	0,84	\$1,50	Kamworks	5	\$0,17	\$2,69	Miriam	
Roof support bar 5	f	1	Steel	Pipe Ø 28	0,14	\$2,00	Kamworks	5	\$0,08	\$0,36	Miriam	
Roof support plate	g	2	Steel	Plate 80x3	0,08	\$2,00	Kamworks	10	\$0,33	\$0,65	Miriam	
<b>Backframe</b>	<b>3</b>	1						120	\$2,00	\$2,00	Estimation	<b>\$9,85</b>
Main bar	a	1	Steel	Pipe Ø 28	0,76	\$2,00	Kamworks	5	\$0,08	\$1,60	Miriam	
Main stave	b	1	Steel	Pipe Ø 28	0,5	\$2,00	Kamworks	10	\$0,17	\$1,17	Miriam	
Support bar	c	12	Steel	Bar Ø 5	0,34	\$1,00	Kamworks	5	\$1,00	\$5,08	Estimation	

Product name	Product number	Number	Material	Dimensions	Length	Price per length	Place of production	Time of production (min)	Costs of production 1 dollar/h	Price	Way of approximating	
<b>Front frame</b>	<b>4</b>	1						60	\$1,00	\$1,00	Estimation	<b>\$8,65</b>
Horizontal bar	a	2	Steel	Rectangular 50x50	0,5	\$1,50	Kamworks	10	\$0,33	\$1,83	Estimation	
Cross bar long	b	2	Steel	Rectangular 50x50	0,4	\$1,50	Kamworks	10	\$0,33	\$1,53	Estimation	
Cross bar short	c	1	Steel	Rectangular 50x50	0,3	\$1,50	Kamworks	10	\$0,17	\$0,62	Estimation	
Cross plate	d	1	Steel	Plate 60x4	0,5	\$1,50	Kamworks	10	\$0,17	\$0,92	Estimation	
Steer holder	e	2	Steel	Hooked 60x60x4	0,07	\$3,00	Kamworks	10	\$0,33	\$0,75	Estimation	
<b>Steer</b>	<b>5</b>	1						60	\$1,00	\$1,00	Estimation	<b>\$8,11</b>
Steer plate	a	1	Steel	Plate 90x3	0,09	\$6,00	Kamworks	5	\$0,08	\$0,62	Estimation	
Steer plate holder	b	3	Steel	Plate 50x3	0,062	\$1,00	Kamworks	5	\$0,25	\$0,44	Estimation	
Steer plate flange	c	2	Steel	Plate 80x3	0,08	\$2,00	Kamworks	10	\$0,33	\$0,65	Estimation	
Ball bearing	d	2	Steel				Don Bosco			\$4,00	Miriam	
Inner tube	e	1	Steel	Bar Ø 20	0,07	\$5,00	Don Bosco			\$0,35	Miriam	
Outer tube	f	1	Steel	Bar Ø 80	0,07	\$15,00	Don Bosco			\$1,05	Estimation	
<b>Damping system</b>	<b>6</b>	1						60	\$1,00	\$1,00	Estimation	<b>\$33,05</b>
Spring holder 1	a	4	Steel	Plate 60x4	0,125	\$1,50	Kamworks	5	\$0,33	\$1,08	Estimation	
Spring holder 2	b	2	Steel	Plate 60x4	0,11	\$1,50	Kamworks	10	\$0,33	\$0,66	Estimation	
Leaf spring	c	1	Steel				Kamworks	30	\$0,50	\$25,50	Experience	
Block of wood	d	2	Wood	Plate 50x120	0,071	\$2,00	Kamworks	10	\$0,33	\$0,62	Estimation	
Spring holder 3	e	4	Steel	Bar Ø 12	0,3	\$2,00	Kamworks	20	\$1,33	\$3,73		
Protection plate	f	2	Steel	Plate 50x3	0,06	\$1,00	Kamworks	10	\$0,33	\$0,45	Estimation	
<b>Wheel Suspension</b>	<b>7</b>	1						60	\$1,00	\$1,00	Estimation	<b>\$68,00</b>
Grip plate	a	2	Steel	Plate 80x4	0,12	\$ 2,50	Kamworks	10	\$0,33	\$0,93	Estimation	
Axis holder	b	2	Steel	Hooked 60x60x4	0,18	\$ 3,00	Kamworks	20	\$0,67	\$1,63	Estimation	
Front axis	c	1	Steel	Bar Ø 22	0,88	\$ 4,00	Don Bosco		\$12,00	\$15,44	Experience	
Front wheels	f	2	Steel							\$45,00	Miriam	
Ball bearings	g	4	Steel							\$4,00	Miriam	

### ***B. Composite materials***

Component	material	Amount	Price/piece	Total price
<b>Plug/positive mold</b>				
Positive form	MDF	4 plates á 1.50x2.00 m	\$ 12.50/plate	\$ 50
	Glue	3 tins á 1 Liter	\$ 2.00/tin	\$ 6.00
	Varnish	3 liter	\$ 2.00/liter	\$ 6.00
	Putty	1 tin á 500 gram	\$ 1.50/tin	\$ 1.50
	Sanding papers	16	\$ 1/piece	\$ 16
Spray paint layer	Labour car-painter	1	\$ 150	\$ 150
<b>Price positive mold</b>				<b>\$ 229.50</b>
<b>Negative mold</b>				
Gelcoat		7 kg	\$ 5.50/kg	\$ 38.50
Pigment color		70 gram	\$ 15/kg	\$ 1.05
Polyester resin		20 kg	\$ 2.60/kg	\$ 52.00
Hardener		0.27 l	\$ 5.00/liter	\$ 1.35
Glass fiber mats		3.3 kg	\$ 2.70/kg	\$ 8.91
Mold release wax		1/2 tin	\$ 12.00/tin	\$ 6.00
Polishing paste		1/2 tin	\$ 10.00/tin	\$ 5.00
<b>Price negative mold</b>				<b>\$ 112.81</b>
<b>Final product</b>				
Gel coat		10 kg	\$ 5.50/kg	\$ 55.00
Pigment color		100 gram	\$ 15/kg	\$ 1.50
Polyester resin		20 kg	\$ 2.60/kg	\$ 52.00
Hardener		0.3 l	\$ 5.00/liter	\$ 1.50
Glass fiber mats		3.3 kg	\$ 2.70/kg	\$ 8.91
Mold release wax		1/2 tin	\$ 12.00/tin	\$ 6.00
Polishing paste		1/2 tin	\$ 10.00/tin	\$ 5.00
<b>Price final product</b>				<b>\$ 128.56</b>
<b>Total price</b>				<b>\$ 470.87</b>

Table N2: costs of composite materials. Some prices per piece are derived from the cost price analysis of Miriam Reitenbach.

### ***C. Electric components***

Component	Amount	Price/piece	Total price	Remarks
Hub motor 24V, 2550 W	1	\$ 38	\$ 38	pharith.kong@gmail.com
Motor controller and hand gear	1	\$ 35	\$ 35	
Key and light indicator	1	\$ 23	\$ 23	
Sealed lead acid battery	1	\$ 14	\$ 28	
battery charger	2	\$ 18	\$ 18	
Head lights	1	\$ 4.5	\$ 4.50	Toul Tom Pong
Direction lights	2	\$ 2.5	\$ 5	
Derection lights indicator/controller	1	\$ 2	\$ 2	
Horn	1	\$ 2	\$ 2	
<b>Total price</b>			<b>\$ 160</b>	

Table N3: the costs for the electronic components. Some entries are derived from the cost price analysis of Miriam Reitenbach.

### ***D. Roof materials***

Component	amount	Price/piece	Total price	Remarks
tuktuk fabric	3.4 meters	\$ 2	\$ 6.8	023 991 908
rings	0.25 bag	\$ 2	\$ 0.50	
ropes	3 meters	\$ 0.5 per meter	\$ 1.5	estimation
<b>Total price</b>			<b>\$ 8.80</b>	

Table N4: Estimated costs of the roof

### ***E. Materials for interior***

Component	Amount	Price/piece	Total price	Remarks
tray (wood)	1	\$ 1.00/m2	\$ 1.00	estimation
paint for tray	0.2 liter	\$ 3.00/liter	\$ 0.6	estimation
rails for tray	2	\$ 3.00/rails	\$ 6.00	estimation
<b>Total price</b>			<b>\$ 7.60</b>	

Table N5: Estimated costs of the interior. These components are neither produced, nor installed yet.

### ***E. Materials for finishing***

Component	Amount	Price/piece	Total price	Remarks
metallic ornaments	3 meters	\$ 3	\$ 3	
frog lock	1	\$ 5	\$ 5	Toul Thom Pong
hoses for rubber profiles	5 meter	\$ 1	\$ 5	
rubber sheet	2 meter	\$ 2.5	\$ 5	
hinges for lid	2	\$ 5	\$ 10	imported
gas spring	1	\$ 10	\$ 10	estimation
velcro	3 meters	\$ 1	\$ 3	
brand stickers	4	\$ 2.50	\$ 10	
reflectors	2	\$ 0.50	\$ 1	Tuol Thom Pong
<b>Total price</b>			<b>\$ 49</b>	

Table N6: Costs for finishing the box. The table also shows the gas spring for the opening mechanism of the box. This one is not installed yet.

### ***F. Promotional materials***

Component	Amount	Price/piece	Total price	Remarks
Flyers	20	\$ 0.65	\$ 13	estimation
<b>Total price</b>			<b>\$ 13</b>	

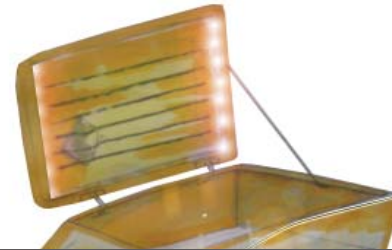
Table N7: Additional promotional materials. These flyers have not been designed yet, so the costs are estimated.



## Appendix O: Decoration and finishing

### Display

Putting lights in the display may help draw attention of the public. Either LED's or a tube-light can be used. LED's can be easily placed on a piece of wood which can be fastened in the lid. The LED's can be found in Phnom Penh. The tube-lights are a bit harder to find.



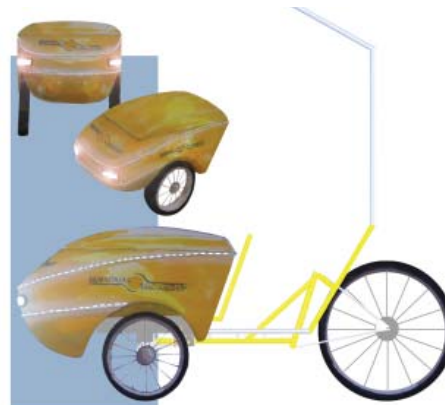
### Finishing touch

One has a chrome-like ornament on the mold division line whereas the other one has a tube-light on the mold division line. The chrome-like ornament can be easily applied because these are made of sticker strips which you can get at every corner in Phnom Penh. The tube-lights are harder to find and also harder to install because the mold has to be designed in such a way that the tube fits. The mold will no longer be drafting.



### Shape

The shapes differ only little from each other. The main difference is that the first shape has two curved lines where surfaces hit each other, whereas the second shape has only one curved line where surfaces hit each other. Both shapes can be produced with only one mold division.



## Appendix P: Materials for finishing the box

This appendix shows the materials which are already present at Kamworks. Due to lack of time not all the materials were applied/processed. Therefore, they are gathered in this appendix. This way future students can see which materials are present at Kamworks and are available in Cambodia.



Rings for the roof



Lock



Light indicator



Tarpaulin



Horn



Head light



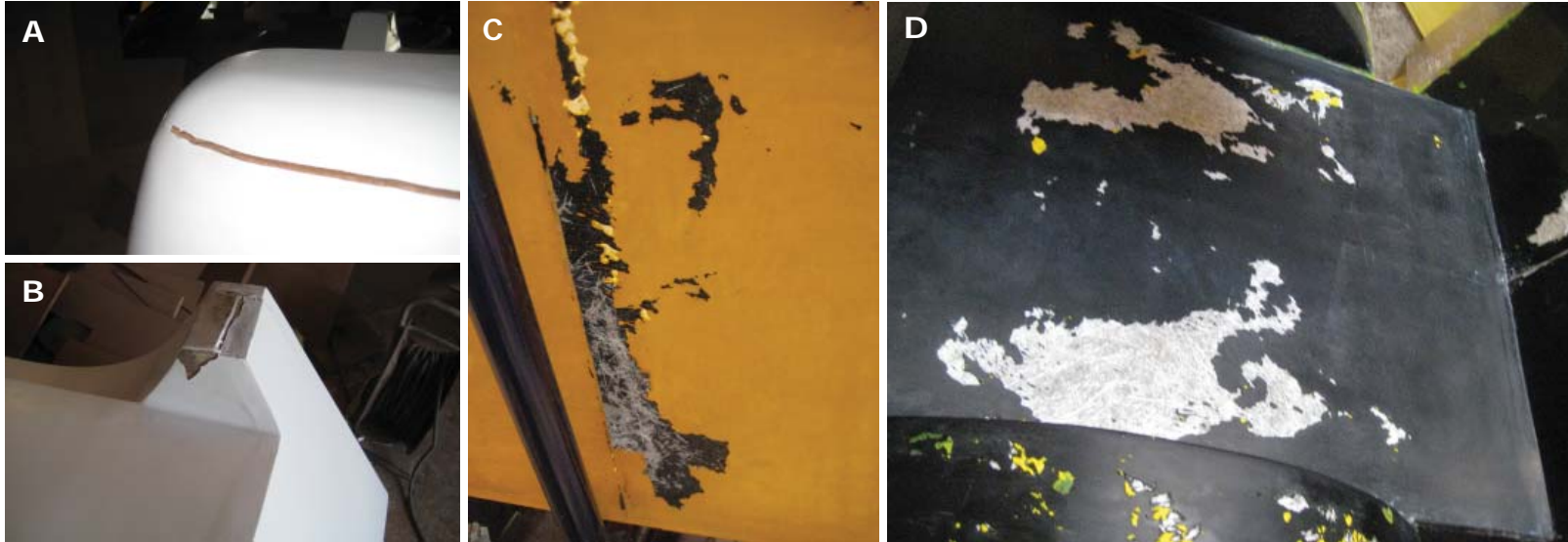
Reflector



Direction light

## Appendix Q: Prototyping problems

During the prototyping several problems occurred. This appendix shows pictures of the problems, and describes the possible causes.



**A+B** The car-painter uses water to sand the body. Because MDF cannot endure exposure to water, the plug was varnished from head to toe before handing it over to the car-painter. However, due to communicational problems, the car-painter placed the plug in a pool of water. For a couple of days, the box was standing in the water on the little triangular legs and the rounded front part. On these parts no primer was applied. Despite the varnish, the MDF still soaked up water, which resulted in expanding MDF plates and eventually in cracks in the paint layer. Therefore it is recommended to use waterproof MDF to build the plug. Waterproof epoxy glue can be used to fasten the plates to each other.



**C+D+E** The mold making procedure was set up as follows: First the upper mold would be made and after this, the bottom mold would be produced using the plug and the upper mold part as anti-shape (E). However, to make a clean-cut edge on the first mold, the procedure required to apply the gelcoat a bit further than the mold division line. The fibers were not applied further than the mold division line, because then the form would no longer be drafting. After the first mold was successfully removed from the plug, the paint of the small strip beneath the mold division line which was covered with gelcoat, began to wrinkle. Very tiny wrinkles, almost not visible for the human eye resulted in a less shiny surface. In figure E a dull strip can be seen on the plug just above the black mold. It seems that the gelcoat without contact with fiber mats affected the paint layer, during the chemical reaction. This also explains the problems of the sticking molds (C and D). The pieces of mold which stuck to the final product, were the places where air-pockets occurred or where the mold was not shiny. (The bottom part for instance, was not painted and sanded well by the car-painter. The surface quality was very bad.)

# MANUAL & PRODUCTION PLAN

GLASS FIBRE REINFORSED PLASTICS

VERSION 2  
September, 2008

## Composite safety tips

Use denatured alcohol, acetone or lacquer thinner to clean up small parts of the epoxy/polyester or vinegar for non-cured epoxy.

Clean hardener residue with warm soapy water.

Use the brush one time only or let it soak in acetone.

Do use a hand cream guard followed by latex gloves during the lay-up.

Don't use rubber gloves, use the thicker vinyl/plastic ones and change them as often as needed.

Wash your hands thoroughly after use.

Always wear a respirator (carbon filter mask) that filters vapour AND work in a well-ventilated area, for both lay-up and when sanding the cured material, especially partially cured material.

Protect your eyes from contact with resin, hardeners, mixed epoxy/polyester, and sanding dust by wearing appropriate eye protection. If resin gets in your eyes, immediately flush them with water under low pressure for 15 minutes.

Avoid breathing concentrated vapours and sanding dust.

In case of using epoxy resins. Avoid ingesting epoxy. Wash thoroughly after handling epoxy, especially before eating or smoking. If you swallow epoxy, drink large quantities of water, DO NOT induce vomiting.

DO NOT dispose of hardener in trash containing sawdust or other fine cellulose materials; they can spontaneously combust liquids.

Mix and cure waste resin and hardener to make a non-hazardous inert solid. Dispose of the solid mass only after it has completely cured and cooled.



# A

## Producing the plug

1 Use waterproof MDF to produce the positive form or so-called plug. For complex and rounded shapes build the form layer for layer, like in figure A1 to A4. Use waterproof glue, e.g. epoxy based glue, to fasten the layers to each other. Try to approach the desired shape in the rough, glued piece of MDF. If the glue has dried, shape the block of MDF as desired by sanding it with a sanding machine. See figure A3. Use rough sanding paper (80). If still large pieces have to be removed, a rasp can be used as this goes faster than sanding. For large shapes it is recommended to build in steps. Glue eight layers, then sand. Repeat this procedure until the desired shape is reached.

2 Consider a draft angle of  $1,5-3^{\circ}$  to reassure that the form gets out of mould.

3 To avoid problems due to future exposure to water, apply at least two layers of varnish to the plug.

4 Refine the shape of the plug by filling indents and lumps with putty. Use mercury putty with corresponding hardener (the yellow one) Mix as indicated on the label.

5 Once the plug is in the right shape, bring the plug to the car-painter. He will apply primer first, sand it again, use putty were required and paint it a few times. Let it be painted in a contrasting color to the to-be-produced molds. Make clear to the car-painter that, although waterproof MDF with a varnish layer is used, it is not allowed to place the plug in a pool of water for a few days. Tell him to apply the primer to all parts of the plug, before beginning the sanding process. Furthermore, it is recommended to dry the plug after a day of work and put it in a dry place. When picking up the plug at the car-painter, make sure the bottom is painted well and has a high surface finish. Just as high of the upper parts.

Figure A1: sawing MDF in shape



Figure A2: Glueing MDF to each other, layer for layer



Figure A3: Sanding MDF block in desired shape



Figure A4: Final shape, varnished and filled with putty

# B

## Preparing the plug

- 1 Remove all imperfections from the plug by sanding and polishing it. Use very fine sanding paper.  
  
When finished with sanding start with the polishing of the plug. Use a polishing paste and a piece of cloth. You can also use the polishing machine. Continue this process until the desired surface finish is achieved. Do not underestimate the polishin procedure: it may take a couple of days before a shiny surface finished is achieved.
- 2 Determine which mold parts you want to produce first.
- 3 Clean these parts of the plug with a wet piece of cloth, possibly use thinner. And dry the mould. Clean also the pieces of the plug which are connecting with or close to the mold devision line.
- 4 Before applying the wax, cut the glass fibre into appropriate pieces that fit in the mould. Rather use smaller and more pieces. Consider an overlap of 5-10cm.
- 5 Apply the mould release wax (or beeswax) with a piece of fabric. Let dry for a moment and polish up with a special polishing fabric. Always work on small pieces until the whole mould is done.
- 6 Apply up to four or five layers of wax, well buffed.
- 7 Additionally PVA (polyvinyl alcohol) can be added. Though, this may affect the final surface quality of the mold, as strikes from the brush remain visible. Using PVA is not reccomended. With enough wax layers it is not necessary to apply PVA.



Mold release wax

# C Applying gelcoat

1 If you are sure every spot of the plug is covered with at least four layers of wax, you can start applying the gelcoat. The gelcoat is used as top layer to avoid that the glass fibre will show on the surface. By adding pigment to this toplayer the product gets its color.

2 The mold needs to have a contrasting color to the final product and to the plug. This enables you to see airpockets and other odds much easier. For the production of the yellow Kamunasal box, a white plug with black molds was designed. If you are developing a product with multiple colors, like the SHS, it is wise to choose a color which is contrasting to both. For instance, red would be the most contrasting color to blue and yellow. As they are all three primary colors. If you are not sure which color you should give the mold you can use the circle of colors, on the next page. Add up to 5% of pigment to the gelcoat. Stir well. You can use a drill for this purpose, see figure C2. The gelcoat should be applied with rollers, see figure C3.

3 To lengthen the working time, add inhibitor to the mixture. Usually, 0.1-0.15% is recommended. However, depending on how much longer you want to make the processing time and the present whether conditions, the exact amount can differ a bit. Carry out some tests to find the appropriate mixing ratio.

4 Mix the hardener through the gelcoat (same hardener as for polyester) in a mixing ratio somewhere around 1.5% of the total amount of gelcoat. Be careful, when using too much hardener, as the laminate can get very hot, even burn.

6 Apply a layer of about 1mm of gel coat. Apply this in two to three layers.

7 Before the gel coat is fully cured and only remains a bit sticky, you can start with the following step. Once the gel coat is fully cured, no good connection between gel coat and polyester layer can be obtained.

		Pigment	Inhibitor		Hardener		Working time
	Amount	(5%)	(0.1-0.15%)	drops	(1.5%)	ml	minutes
<b>Gelcoat</b>							
	100 gram	5 gram	0.1-0.15 g	5 to 7.5	1.5 gram	1.5 ml	25 to 35
	500 gram	25 gram	0.5-0.75 g	25 to 37.5	7.5 gram	7.5 ml	10 to 15

Table C1: examples of mixing ratio. 0.1 gram inhibitor equals 5 drops of a syringe  
1.0 gram hardener equals 1.0 ml hardener



Figure C1: circle of colors. Find a contrasting color to the final product.

Figure C2: stirring gelcoat



Figure C3: applying gelcoat





# D

## Applying resin and fibers

Before starting the actual laminating try to find a working mate as, working together makes the process easier and faster.

1 Prepare several plastic cups with the right amount of polyester. Add inhobitor to each cup. Prepare corresponding cups with hardener for each resin/inhibitor mixture, but do not add it yet. For mixing ratio, see table D1.

2 Also prepare all the required tools, as brushes and rollers. Rollers work better to avoid enclosed air bubbles. When using brushes than apply polyester by dabbing instead of striking.

Optional: You can add up to 1-2% colour pigment to the polyester. However, this makes it harder to recognize airpockets.

3 Control if you have enough glass fibres in the right shape. For information about quantities of glass fiber, see section I.

4 Use special rollers with ribs to remove air bubbles from the laminate. You can make these rollers by yourself on the lathe. Nylon is an appropriate material as you can easily remove polyester from it.

5 Always work part for part. Apply the fibers and resin to the mold. Sometimes it is easiest to first apply the the fibers and than soak them with polyester. Other pieces of the mold are better workable when the resin is applied first and the fibers are rold over it with the special rollers.  
Don't use too much polyester, just enough to drench the glass fibre. The less resin used, the better the obtained strength of the material. The more glass fibre, the higher the mechanical strength of the product.  
Around the glass fibre is a certain chemical that releases when the polyester is applied and softens the glass fibre. Therefore after adding the polyester, work on another piece for 2-3 minutes and than roll the prior layer on the mould perfectly.  
Either use brushes or rollers one time or put them in acetone after use.

6 You can use airoxil or talcum powder (or silica) to thicken the polyester at vertical surfaces to keep it from sliding down.  
Also for difficult corners airoxil or talcum powder can be used to fill gaps before putting the glass fibre.  
Core mats can be used to reinforce weaker parts.

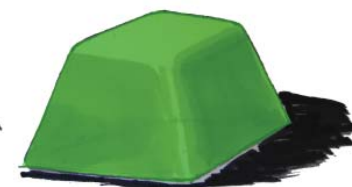
7 If any airpockets exist and cannot be removed with brushes or rollers, just let the layer dry and grind and sand it before adding the next layer.

8 Use two to three layers of fibers mats for the Kamunasal cargo box. Smaller products don't need three layers. Some small products are finished with only one layer.

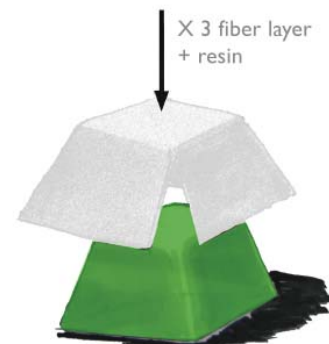
9 Leave a small overlap of the glass mat at the edges to make a flange.



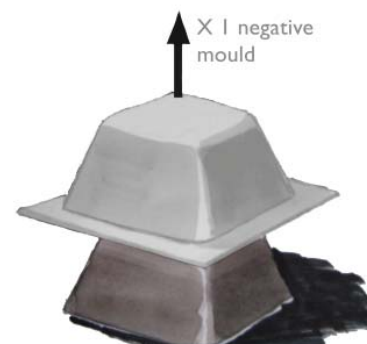
Step 1: produce the positive form. Grind well and polish carefully



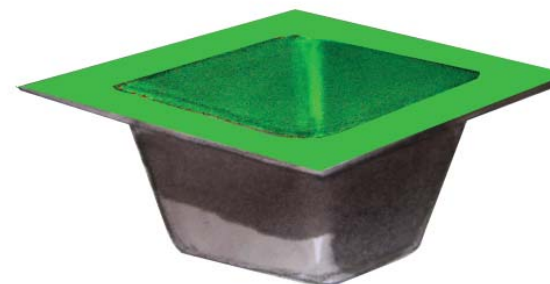
Step 2a: Apply gelcoat onto the positive form



Step 2b: Produce the negative mould by applying fiber layers and resin



Step 2c: Remove the mould from the positive form when resin is hardened



The negative mold with a coloured gelcoat

		Pigment	Inhibitor		Hardener		Working time
	Amount	optional	0.15-0.2 %	drops	1.5%	ml	minutes
<b>Polyester resin</b>							
	100 gram	-	0.15 - 0.2 g	7.5 to 10	1.5 g	1.5 ml	> 60 minutes
	500 gram	-	0.75 - 1.0 g	37.5 to 50	7.5 g	1.5 ml	15 to 25

Table D1: examples of mixing ratio. 0.1 gram inhibitor equals 5 drops of a syringe  
1.0 gram hardener equals 1.0 ml hardener

## E Removing the plug form the molds

- 1 If the polyester has fully cured you can start removing the mold (s) from the plug.
- 2 Insert wedges in between the two mold parts. Be careful not to damage the positive form.
- 3 You can also drill holes and pump in air. These holes can also made beforehand and filled with wax. See figure E1.
- 4 Remove the positive form.



Figure E1: pumping air in the molds with compressor

## F Attaching mold parts to each other

The first moldpart should have a flange onto which the second moldpart can be fastened. There are two options for making this flange.

- 1 The first option is to remove the first moldpart, put it on a foundation which follows the mold division line. See figure F1 Than apply the flange. Use the first mold part and the plug to produce the second mold part. See figure F3.
- 2 The second option is to apply a stencil on the mold division line, all around the white plug. Laminate the first mold part and flange in one part. See figure F2.
- 3 Fasten the mold parts to each other using screws. See figure F4. The holes for the screws can be drilled at the moment all parts are still on the white plug.

Figure F1: making flange using a curved foundation    Figure F2: making flange using a stencil



Figure F3: using plug and first mold part to produce the second moldpart



Figure F4: fasten moldparts with screws



# G

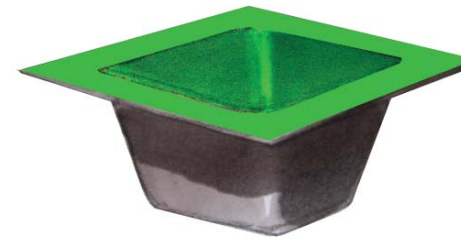
## Producing the composite product

The same procedure as under B, C, D and E applies on the production of the final product.

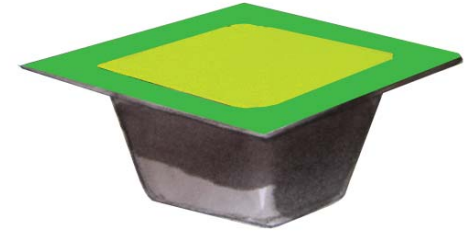
Very important"Remove all imperfections from the mold by sanding and polishing it. Use very fine sanding paper.

When finished with sanding start with the polishing of the molds. You can polig with the hand, using a piece of cloth. You can also use the polishing machine. Continue this process until the desired surface finish is achieved. Do not underestimate the polishin procedure: it may take a couple of days before a shiny surface finished is achieved.

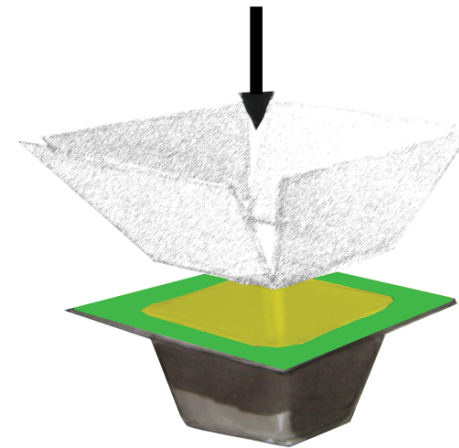
Screw the two mould parts of the negative mould onto each other and start the same as under B, clean the molds, apply wax, et cetera. Continue the procedure in B, C, D and E.



1 Clean the mold and wax it. Apply at least four to five layers of wax. See section B.

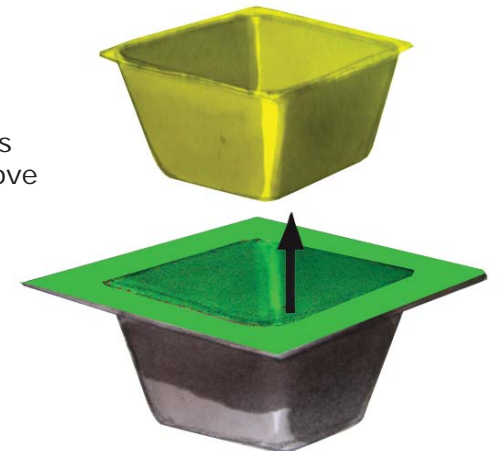


2 Apply the gelcoat. Apply two to three layers. See section C.



3 Apply the fibers. Use brush and roller to apply the resin and fibers to the mold. See section D.

4 Wait until the resin has fully cured. Then remove the product from the mold. See section E.



## H Finishing the product

Use an angle grinder to flatten the edges of the form. Use sanding paper to smoothen the edges.

Clean the product and sand any imperfections. Thereafter, polish it until the surface is shiny.

Clean the product again and apply ornaments, e.g. brandstickers using soapy water.



Figure H1: Applying brandstickers on the polished final product.

## Information about glass fiber mats

Before getting started, the glass mats should be cut into the right form (with scissors). When being put in the form, always reckon with an overlap of 5 - 10, for smaller laminates 1- 2 cm.

About 1 kg glass mat per m<sup>2</sup> should be used. To find out the weight of the glass mat, cut out a m<sup>2</sup> and weigh it.

The most common glass mat is CHOPPED STRAND MAT (CSM) that is available in three different weights, one, one and half, and two ounces per square foot. Metric equivalents are 300g, 450g, and 600g per square meter.

Glass silk can be used for parts that undergo higher wear.