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GRADO EN INGENIERÍA EN TECNOLOGÍAS INDUSTRIALES

TRABAJO FIN DE GRADO

RE-DESIGN OF A CONTROL REMOTE CAR

Autor: Javier Laguna Núñez

Director: Leon Liebenberg

Madrid

Junio de 2019

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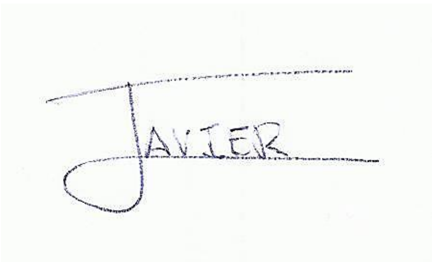

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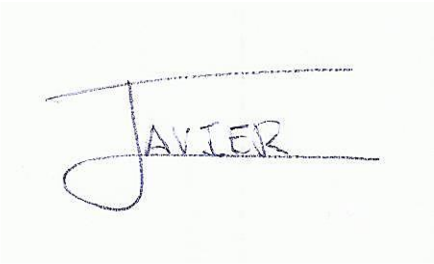

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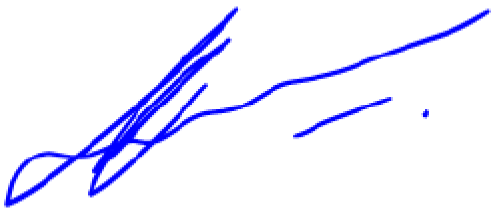

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REDISEÑO DE UN COCHE RADIOCONTROL

Autor: Laguna Núñez, Javier.

Director: Liebenberg, Leon.

Entidad colaboradora: UIUC - University of Illinois at Urbana-Champaign

RESUMEN DEL PROYECTO

Introducción

El objetivo de este proyecto es rediseñar un producto actual de una compañía y optimizarlo en diversas áreas. Esto es posible aplicando los conocimientos adquiridos en distintas áreas como el diseño mecánico, procesos de optimización y en técnicas de fabricación.

Un coche radiocontrol de la compañía Hangzhou Bold Toys fue seleccionado para este proyecto. Un componente o subconjunto importante de este producto se rediseñará para mejorar el proceso de fabricación y ensamblaje.

Motivación

En la actualidad estos procesos de optimización son continuos en todas las empresas, que intentan mejorar su producto actual en términos de calidad, eficiencia, funcionalidad, etc. Además, las empresas realizan estos procesos con el fin de conseguir un producto más barato o rápido de producir para que su beneficio se vea aumentado.

Objetivos

Los objetivos de este proyecto son reducir el tiempo y coste de fabricación y montaje del producto así como incrementar la durabilidad del producto actual. Uno de los problemas más importantes de la empresa es reducir los costes de fabricación para obtener más ingresos en cada producto. Al ser un producto más barato, la cantidad de ventas aumentará y, por lo tanto, la empresa tendrá más beneficios. Esto se logrará mediante el diseño de técnicas de fabricación.

Además, para ahorrar tiempo en la línea de montaje, se evaluará la combinación o reducción de componentes, así como los métodos actuales de ensamblaje del producto para optimizar el proceso. Esto se logrará haciendo un análisis de diseño para ensamblaje (DFA) en el producto original.

Finalmente, el propósito de hacer que un producto sea más duradero es la mejora imagen de la empresa dentro del mercado en el que se encuentra el producto. Las opiniones del producto serán mejores y habrá más ventas. Como consecuencia del aumento en la durabilidad del producto, habrá menos devoluciones del producto y, por lo tanto, menos dinero devuelto a los clientes debido a la garantía.

Metodología

Primero, se analizará el producto original para decidir qué áreas deben mejorarse. Para ello, el producto debe ser desmontado con el fin de analizar los procesos de fabricación de todos sus componentes.

A continuación, debe hacerse un estudio del mercado del producto para comprender la situación actual dentro de su entorno. Además, se analiza la situación de la empresa en diversos aspectos: geográfico, económico, etc. Con la colaboración de dicha empresa se profundizará más detenidamente en los procesos de fabricación de la compañía.

Los requisitos del cliente de este tipo de producto serán analizados para saber en qué áreas se debe mejorar el producto actual. Además, el producto de la compañía se comparará con los de otras compañías competidoras. Se utilizará una matriz House of Quality (HOQ) para identificar los requisitos clave de los clientes y traducirlos en requisitos de diseño cuantificados. Los requisitos de diseño más importantes serán identificados para establecer las áreas de trabajo y mejora.

Una vez que se realizan estas investigaciones y se seleccionan las áreas de trabajo, se realizará un análisis de diseño para fabricación y ensamblaje (DFMA) para determinar cómo deben fabricarse los componentes del producto o si alguno de ellos se puede combinar o eliminar para ahorrar costos de manufactura y tiempo de ensamblaje. Más adelante, se realiza un proceso de ideación para seleccionar un componente o ensamblaje y se crean diversos diseños para este componente. Se analizarán los diseños a través de una Pugh Matrix para seleccionar cual es el mejor desde el punto de vista de las necesidades de los usuarios.

Cuando se elija el diseño final, el nuevo componente será modelado en 3D para imprimir el primer prototipo. Se comprobará que este componente no pierde ninguna de las características que tenía el producto original. Si fuese necesario se podrán realizar más prototipos con el fin de que el nuevo componente se adapte perfectamente al producto.

Este proyecto tiene un presupuesto de $60 (€52.62) para fabricar el prototipo del componente rediseñado.

Finalmente, se llevará a cabo un análisis de costes del nuevo componente, así como el tiempo de montaje del nuevo producto. Los dos productos (original y nuevo) se compararán para evaluar si los resultados obtenidos concuerdan con los objetivos del proyecto.

Resultados

Después de realizar todos los pasos anteriormente explicados se llegaron a las siguientes conclusiones. El producto tiene muchos componentes (138) algunos de los cuales se pueden eliminar o combinar entre ellos. Además, los requisitos de los usuarios son la durabilidad del producto, la resistencia contra los golpes que pueda tener y el coste del producto final.

Por ello, se eligió rediseñar la estructura externa del coche ya que así se podría mejorar tanto la resistencia contra los impactos durante su uso como la durabilidad del producto así como su tiempo y coste de fabricación y montaje.

La estructura exterior del coche tiene cuatro paneles de 0,5 mm hechos de plástico ABS. Uniendo todos los paneles conseguimos que el coste de fabricación y el tiempo empleado en el montaje del producto disminuyan considerablemente. Además, se reducen 10 de los 16 tornillos utilizados en esta parte del coche reduciendo aún más el coste final del producto. Por otro lado, se aumentó el grosor del panel de 0,5 mm a 2 mm con el fin de hacer el nuevo coche más resistente contra los impactos a los que se verá sometido durante su uso.

	Original	Rediseñado
Grosor (mm)	0,5	2
Nº Componentes	4	1
Nº Tornillos	16	6
Coste	$1,03 / €0,91	$0,37 / €0,33
Inversión	$82632,86 / €72609	$29066,2 / €25540
Tiempo de montaje (sec)	658,5	589,5

Conclusiones

Como podemos ver en la tabla, el número de componentes empleado en esta zona del producto se reduce considerablemente. El coste de fabricación de la estructura externa del coche se reduce aproximadamente 1/3 de su valor y la inversión inicial de la maquinaria se reduce notablemente de $82632,86 (€72609) a $29066,2 (€25540). Al reducir el número de componentes utilizados se reduce el tiempo total de montaje del producto reduciéndolo aproximadamente 69 segundos en cada unidad, una reducción importante en un producto que se monta manualmente.

Tras realizar un estudio sobre el material que se debe utilizar para este producto, se necesita un material barato y resistente a los impactos. La conclusión fue que el material actual (ABS) es adecuado para este tipo de productos.

Recursos

Durante este proyecto se utilizaron algunos recursos para hacer análisis, modelos y estudios. Para modelar el componente en 3D los recursos utilizados son Creo Parametric y SolidEdge. Las licencias de software son impartidas por University of Illinois at Urbana-Champaign y Universidad Pontificia de Comillas respectivamente.

Respecto al análisis de costes, el software seleccionado es aPriori. La licencia de software es impartida por University of Illinois at Urbana-Champaign. Este software ayudará a calcular el coste de fabricación y el proceso de fabricación de los componentes que deben ser rediseñados.

Finalmente, el análisis del material se realizará con CES Edupack. Con esta herramienta, elegiremos el material correcto para el producto en función de las características del producto y los requisitos del cliente. Las licencias de software son impartidas por Universidad Pontificia de Comillas.

RE-DESIGN OF A CONTROL REMOTE CAR

Autor: Laguna Núñez, Javier.

Director: Liebenberg, Leon.

Collaborating entity: UIUC - University of Illinois at Urbana-Champaign

PROJECT SUMMARY

Introduction

The aim of this project is redesign a current product of a company and optimize it in different areas. This is possible by applying the knowledge acquired in different areas such as mechanical design, optimization processes and design for manufacturability.

A radio control car from Hangzhou Bold Toys Company was selected for this project. An important component or sub-assembly in this product will be redesigned to improve manufacture and assembly process.

Motivation

Currently, these optimization processes are continuous in all companies, which try to improve their current product in terms of quality, efficiency, functionality, etc. In addition, companies carry out these processes in order to get a product cheaper or faster to produce so their benefit is increased.

Objectives

The objectives of this project are reduce the time and cost of manufacturing and assembling as well as increasing the durability of the current product. One of the most important problems of a company is to reduce the manufacturing costs to obtain more revenue in each product. Being a cheaper product, the amount of sales will increase and, therefore, the company will have more benefits. This will be achieved by design for manufacturing techniques.

In addition, to save time on the assembly line, the combination or reduction of components will be evaluated, as well as the current methods of product assembly to optimize the process. This will be achieved by making a design for assembly (DFA) analysis on the original product.

Finally, the purpose of making a product more durable is to improve the image of the company within the market in which the product is located. The opinions of the product will be better and there will be more sales. As a consequence of the increase in the durability of the product, there will be less returns of the product and, therefore, less money returned to the customers due to the guarantee.

Methodology

First, the original product will be analyzed to decide which areas should be improved. For this, the product must be disassembled in order to analyze the manufacturing processes of all its components.

Next, a study of the product market should be done to understand the current situation within its environment. In addition, the situation of the company is analyzed in various aspects: geographical, economic, etc. With the collaboration of the company, the current manufacture processes will be more closely studied.

The customer requirements of this type of product will be analyzed to know in which areas the current product should be improved. In addition, the company's product will be compared with those of other competing companies. A House of Quality (HOQ) matrix will be used to identify key customer requirements and translate them into quantified design requirements. The most important design requirements will be identified to establish the areas of work and improvement.

Once these investigations are carried out and the work areas have been selected, a design for manufacture and assembly (DFMA) analysis will be carried out to determine how the components of the product should be manufactured or if any of them can be combined or eliminated to save manufacturing costs and assembly time. Later, an ideation process is performed to select a component or assembly and various designs are created for this component. The designs will be analyzed through a Pugh Matrix to select which is the best from the point of view of the customer requirements.

When the final design is chosen, the new component will be modeled in 3D to print the first prototype. It will be verified that this component does not lose any of the characteristics that the original product had. If necessary, more prototypes can be made in order for the new component to adapt perfectly to the product.

This project has a budget of $60 (€57,62) to manufacture the prototype of the redesigned component.

Finally, a cost analysis of the new component will be carried out, as well as the assembly time of the new product. The two products (original and new) will be compared to evaluate if the results obtained agree with the aim of the project.

Results

After carrying out all the steps previously explained, the following conclusions were reached. The product has many components (138) some of which can be eliminated or combined among them. In addition, the customer requirements are the durability of the product, the resistance against impact that may have and the cost of the final product.

Therefore, it was chosen to redesign the external structure of the car since this could improve both the resistance against impacts during use and the durability of the product as well as its time and cost of manufacture and assembly.

The exterior structure of the car has four panels of 0.5 mm made of ABS plastic. By joining all the panels, we achieve that the manufacturing cost and the time spent in the assembly of the product decrease considerably. In addition, 10 of the 16 screws used in this part of the car are reduced by further reducing the final cost of the product. On the other hand, the thickness of the panel was increased from 0.5 mm to 2 mm in order to make the new car more resistant against the impacts.

	Original	Redesigned
Thickness (mm)	0,5	2
Nº Components	4	1
Nº Screws	16	6
Cost	$1,03 / €0,91	$0,37 / €0,33
Investments	$82632,86 / €72609	$29066,2 / €25540
Time of Assembly (sec)	658,5	589,5

Conclusion

As we can see in the table, the number of components used in this area of the product is considerably reduced. The manufacture cost of the external structure of the car is reduced by approximately 1/3 of its value and the initial investment of the machinery is significantly reduced from $82632,86 (€72609) to $29066,2 (€25540). By reducing the number of components used, the total assembly time of the product is reduced approximately 69 seconds in each unit, a significant reduction in a product that is assembled manually.

After conducting a material study that should be used for this product, a cheap and impact resistant material is needed. The conclusion was that the current material (ABS plastic) is suitable for this type of products.

Resources

During this project some resources were used to make analysis, models and studies. To model the 3D component, the resources used were Creo Parametric and SolidEdge. Software licenses are taught by University of Illinois at Urbana-Champaign and Universidad Pontificia de Comillas, respectively.

Regarding the cost analysis, the selected software is aPriori. The software license is taught by University of Illinois at Urbana-Champaign. This software will help calculate the manufacture cost and the manufacture process for the components that must be redesigned.

Finally, the material analysis will be done with CES Edupack. With this tool, the right material will be chosen for the product based on the characteristics of the product and the customer's requirements. Software licenses are taught by Universidad Pontificia de Comillas.

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1. Disassemble. Make a Bill of Materials.

Disassemble

This project consists on analyze and redesign the following RC (remote control) car.

Figure 1: Car view

Attach in Appendix I are some 3D images of the product provided by the company.

This product has a lot of components so it will be dissembled to see what kind of components the product has.

First, the battery box and the structure of the car are dissembled. The car structure is joined to the battery by 4 screws which are in the following photo. In the reverse of the battery box it is the electronic board which is connect to the remote control in order to move the car. The cables of the electronic board are connected to the front and rear wheels.

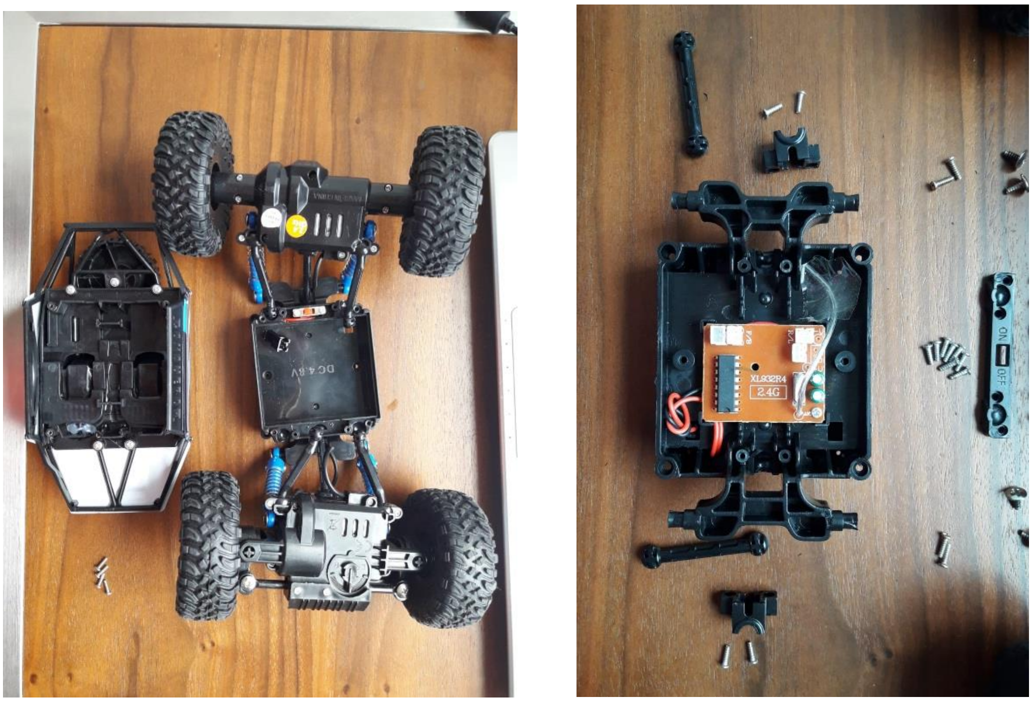


Figure 2: Car structure dissemble

The next step is disconnect the suspension and the transmission of the car unscrewing these parts from the box battery. This step must be repeated for the front and rear wheels.

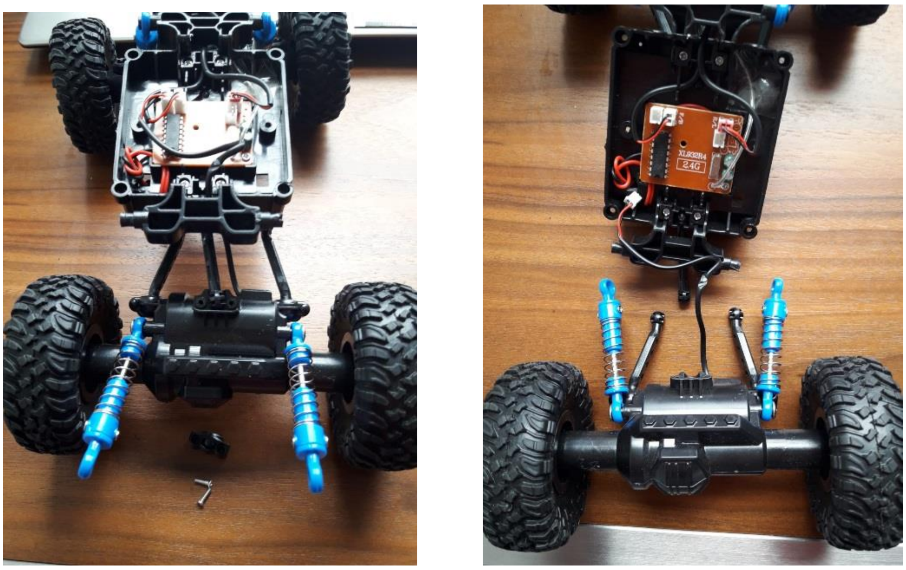


Figure 3: Transmission dissemble

Once the drive shafts are dissembled, the wheels and the springs are removed to get the motor and the transmission which are going to move and turn the electric car.

Figure 4: Wheel dissemble

To get an idea of all the pieces of the product and their layout, the following image shows the breakdown of the product as it was assembled.

Bill of Materials

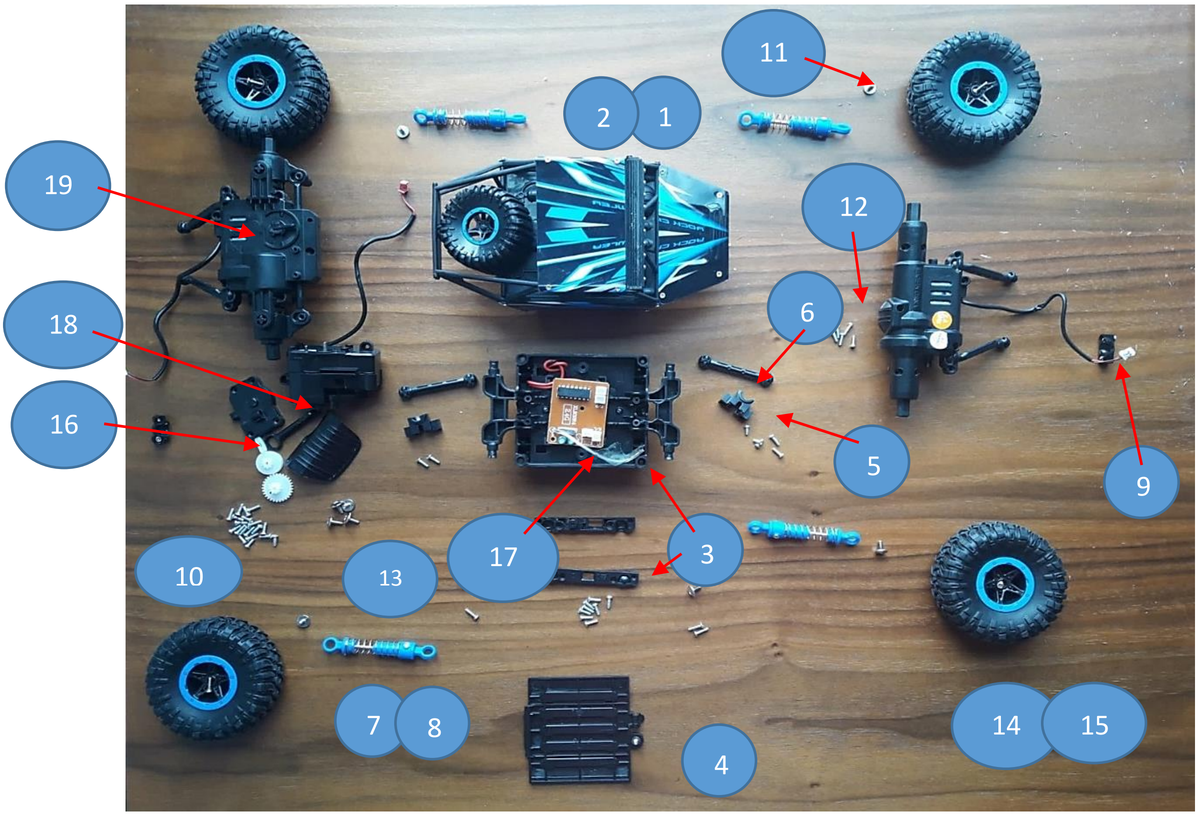


Figure 5: Bill of materials

Part Number	Part Name	Quantity	Material	Manuf. Process	Weight (each) (g)
1	Car structure	1	ABS	Plastic molding	49
2	Panels	4	ABS	Plastic molding	2,5
3	Battery box	1	ABS	Plastic molding	35
4	Cover of battery box	1	ABS	Plastic molding	10
5	Shafts join	4	ABS	Plastic molding	0,75
6	Transmission shafts	6	ABS	Plastic molding	1
7	Suspensions	4	ABS	Plastic molding	3,5
8	Springs	4	Steel	Bending	
9	Cables	5	Cooper	Purchased	1
10	Screw DIN 7983 M2x6	58	Steel	Purchased	0,1
11	Screw DIN 7982 M2x3	16	Steel	Purchased	0,05
12	Screw DIN 7981 M2x4	7	Steel	Purchased	0,25
13	Screw DIN 7981 M3x6	12	Steel	Purchased	0,5
14	Wheels	4	ABS	Plastic molding	3
15	Tire of wheel	4	Rubber	Pressurized molding	23
16	Motor	2	Multiple	Purchased	22
17	Electric board	1	Multiple	Purchased	10
18	Motor box	2	ABS	Plastic molding	10
19	Transmission shafts	2	ABS	Purchased	69
Total:		138			462,35

Table 1: Bill of materials

2. Technical specifications and market.

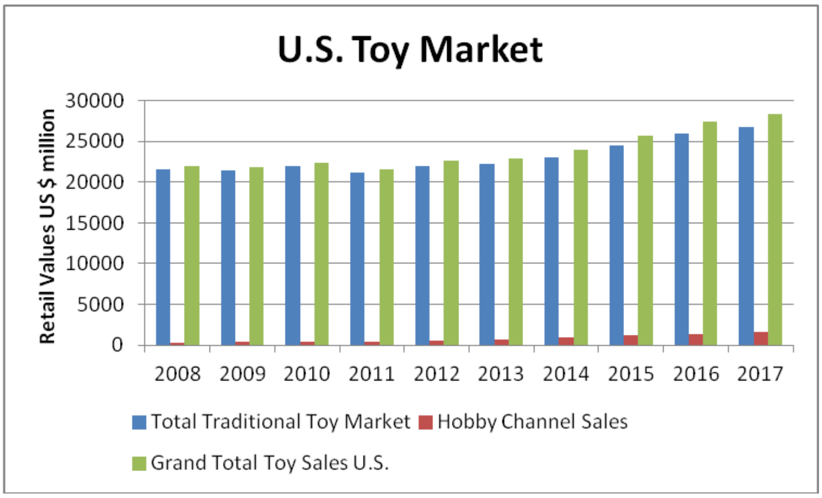
Technical specifications

- Material: ABS (plastic) shell and electronic elements
- Remote type: 2,4 GHz
- Control distance: 100 meters
- Climb angle: >45º
- Drive type: Four-wheel drive
- Control battery: 3x1.5V "AA"
- Car battery: 4.8 V 700 mAh
- Product size: 27x15x13 cm
- Weight: 465 grams
- Charging time: 2 hours
- Playing time: 15 minutes
- Maximum Speed: 12 km/h
- Motor type: brushed
- Engine type: electric
- Model craft type: crawler
- Scale: 1:18

Toy market

Toy market moves high quantities of money every year. As long as people are raising children, the need for toys will continue to exist and increasing revenues (Graphic 1). According to KidComplishment website, Americans spend close to $22 billion on children´s toys every year. To get an idea, Amazon has an estimated $4.5 billion in United States toys sales during 2017 (12% more than the year before).

As it can be seen, toy market is a very eye-catching market because of the money it generates. In addition to be a very striking market, toy market is very competitive and it´s really difficult to maintain a place in the market. This is the case of the famous and largest toy store retailer, Toys "R" Us, declared bankruptcy in 2017 as Amazon´s market share kept growing.



Graphic 1: US Toy Market
Source: Klosters Retailer Panel

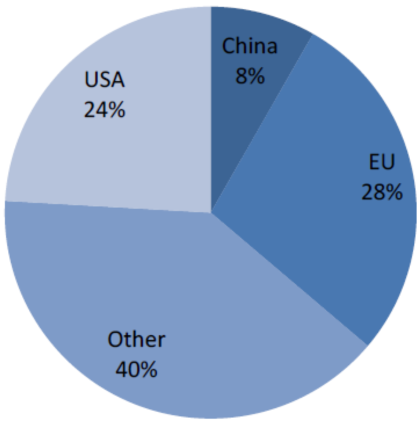
How about other countries outside U.S.? The European Union has the largest single market for goods and service worldwide. The UK, France, Germany, Italy and Spain are the largest toy markets in the EU. It is estimate that this market was worth EUR 15.8 billion ($17.8 billion) in 2011 while U.S. got EUR 14 billion ($15.7 billion). Although Chinese market represented sales of EUR 4.8 billion ($5.4 billion), this market has a high potential if income levels continue to rise. All these data are collected in the next table.

Country	Consumption in million €	Production in million €	Direct employment (# employees)
EU 28			
EU 28 Total	**15,828.40**	**5,833.61**	**50,902**
Other			
United States	13,971.70	4,382.33	35,037
China	4,802.80	16,011.30	128,012
Japan	5,201.10	2,200.08	17,590

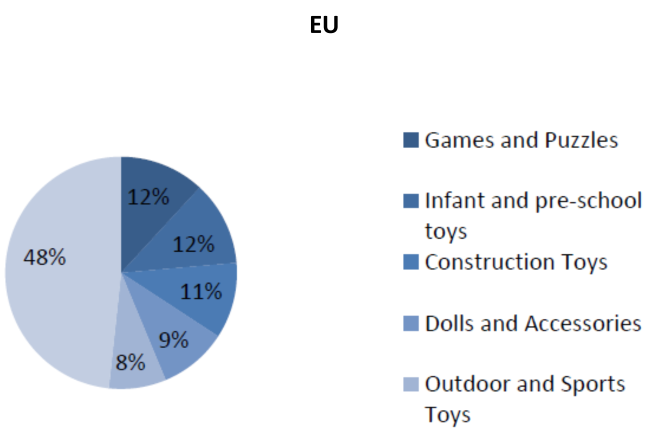
Table 2: Toy sales and productions
Sources: Eurostat, Euromonitor, and own estimations by Ecorys.

In the last column of this table it can be observed the number of employees each market has. It is striking the number of employees in China (128,012) despite the volume of their market.

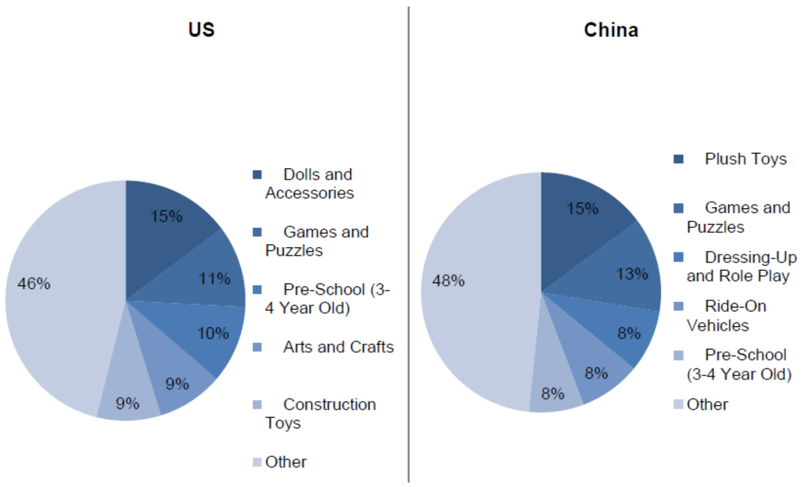
In the next pie chart, it is represented the percentage of the market each country has. As it said before, in 2011 EU has the biggest single market (28%) following by USA (24%) and China (8%). Behind this chart, there are others which shows the traditional toys (electric vehicles not include) sales in EU, USA and China.



Graphic 2: Distribution of sales
Source: Euromonitor; Ecorys estimates.



Graphic 3: Types of toys in EU
Source: Euromonitor.



Graphic 4: Types of toys in US and China
Source: Euromonitor.

All the indirect employments generated by the toy industry are related by the supply of materials and components and the distribution of them and the final product. In the next figure it is showed indirect employment depend on the kind of toy the company produce.

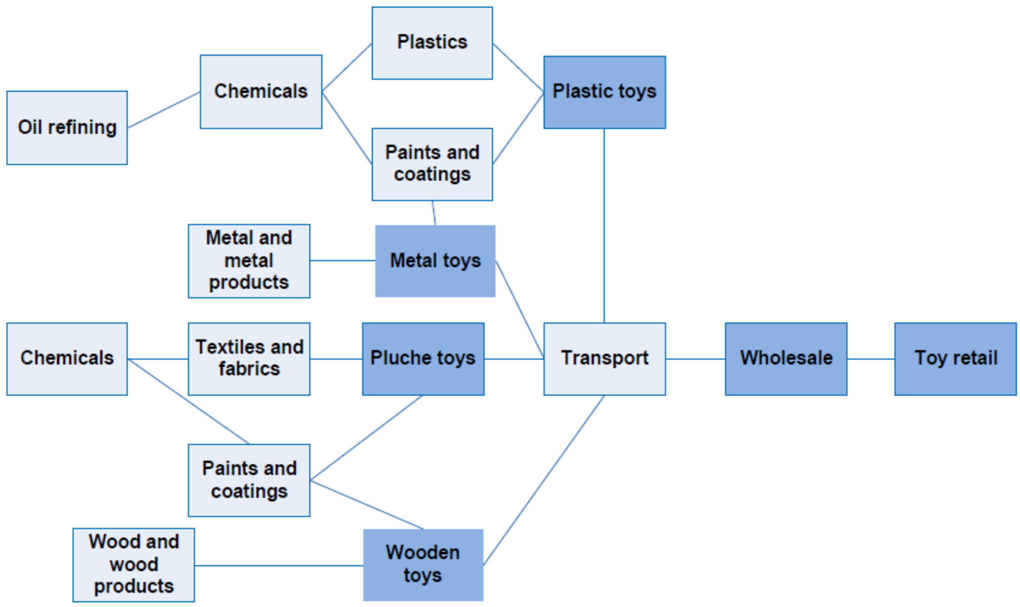
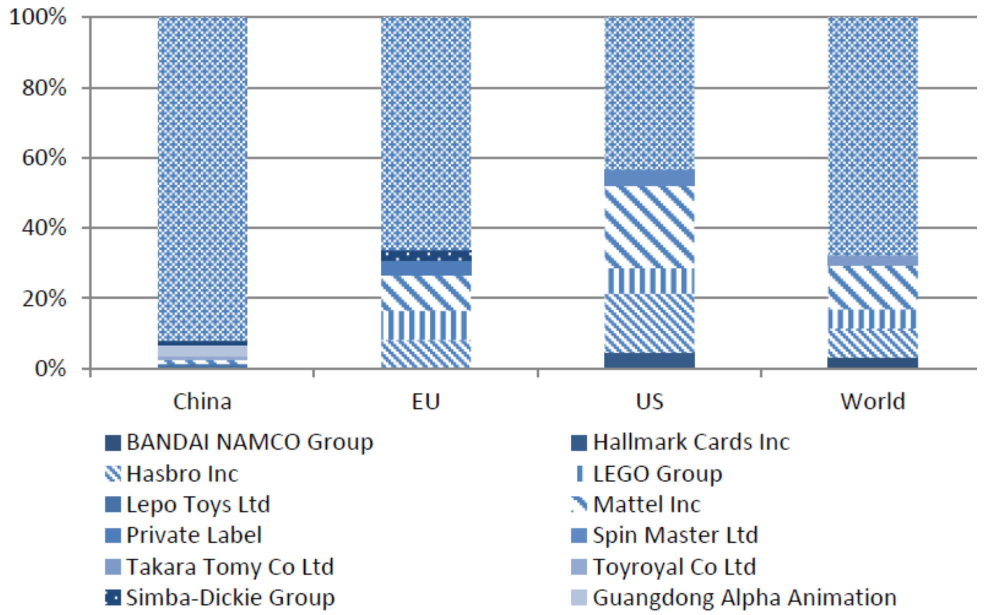


Figure 6: Indirect employments of toy market
Source: Ecorys.

Although indirect employment and costs are difficult to estimate, there is some data that should be analyzed. According to the EU, production and manufacture value is around 40% of the product value. The other 60% of the product value is linked to materials, supplies and components, hence to indirect employment.

Moving to another point, in a big economic market there is always big companies which accumulate a large part of the income. In toy market, the biggest companies around the world are Mattel Inc, LEGO Group and Hasbro Inc as it is explained in the next graph.



Graphic 5: Main companies in toy market
Source: Euromonitor.

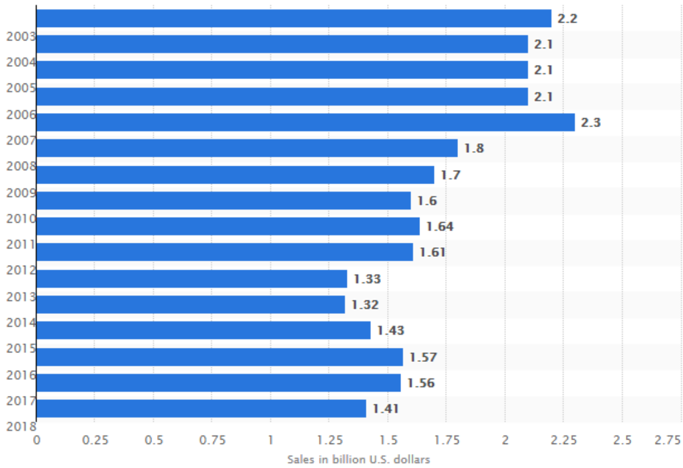
In a market that moves EUR 15.8 billion in 2011, how much these big companies which control the market earn in that year in EU? For example, Mattel Inc had EUR 1343.6 million sales in 2011 that represents around 10% of the total toy market. Other companies such as LEGO Group or Hasbro Inc earns around EUR 1100 million which is an 8% of the total toy market in EU. The tenth biggest companies in the toy market manage almost half the money it is moved in the European Union in this industry.

Company	€ million	% of total
Mattel Inc	1343.6	10.08
LEGO Group	1108.5	8.32
Hasbro Inc	1084.9	8.14
Private Label	575.2	4.32
Simba-Dickie Group GmbH & Co KG	386.2	2.90
Giochi Preziosi SpA	375.7	2.82
Geobra Brandstätter GmbH & Co KG	316.8	2.38
VTech Holdings Ltd	296.9	2.23
Ravensburger AG	234.1	1.76
Takara Tomy Co Ltd	203.6	1.53
Other	7403.9	55.55

Table 3: Revenue of the main companies
Source: Euromonitor.

Toy vehicles market

In 2018, sales of toy vehicles in the U.S. amounted to $1.4 billion (€1.23 billion). As it is showed in the next graph, the sales in the toy market in U.S. has decrease from 2.3 to 1.4 billion dollars from 2007 to 2018.



Graphic 6: Electric toy car revenues per year
Source: Statista

To understand why vehicles toy market is decreasing, this table shows sales changes in the last three years.

Traditional Toy Categories	2016	2017	2018	2016 vs 2017 % change	2017 vs 2018 % change
Grand Total	$21.50	$22.01	$21.57	2%	-2%
Action Figures & Accessories	$1.48	$1.41	$1.55	-5%	10%
Arts & Crafts	$1.00	$0.96	$0.99	-4%	3%
Building Sets	$2.01	$1.91	$1.82	-5%	-5%
Dolls	$3.00	$3.14	$3.36	5%	7%
Games/Puzzles	$2.08	$2.17	$2.14	4%	-1%
Infant/Toddler/Preschool Toys	$3.26	$3.31	$3.15	2%	-5%
Youth Electronics	$0.58	$0.60	$0.61	2%	3%
Outdoor & Sports Toys	$4.06	$4.18	$4.00	3%	-4%
Plush	$1.28	$1.37	$1.23	7%	-10%
Vehicles	$1.57	$1.56	$1.41	-1%	-10%
All Other Toys	$1.16	$1.40	$1.32	21%	-6%

Table 4: Sales of different types of toys
***Source:** Copyright 2019. The NPD Group, Inc.*

It is significant that the toy market is increasing, and the toy vehicles market is decreasing. This process happens because now there are more variety of toys: newest, cheapest and more fashionable than actual toy vehicles. This means that each kind of toy has less profit but, altogether, toy market has more profit because there are many more types of toys.

Predictions

According to Research and Markets (Toys Market - Global Outlook and Forecast 2018-2023), toy market will reach a $120 billion (€105.44 billion) by 2023, growing 4% during 2019-2023. The reasons why this study assure these goals are the following. First of all, the development of economies in areas such as South America, Middle East and Africa will create opportunities for leading players operating in the market. The second reason is companies will get a lot of data about new trends, locations and age group in social media, growing demand and selling more specific products learning the needs of consumers.

This market research advances a segmentation market divide by age range, location, distribution channels and categories. Because of this, more kind of products are created and concentrates in the age range that most children contain in the country.

Finally, online sales in toy market will still growing and toy stores will be forced to move their company online or close their store because they won´t have clients as is easier for them buy a toy in an online platform such as Amazon.

3. Company, manufacturing cost and manufacturability techniques.

As a background, this electric car is produced and manufactured by Hangzhou Bold Toys Co. To know more about the product, next paragraphs give data of the company and the product.

The head office of the company is in Hangzhou City, China, and they have only one factory in Shenzhou city, also in Zhejiang province. They are specialized in RC (remote control) car products. This company sold their products in high quantities (minimum order of 100 pieces) and they produce between 800-1000 pieces per day of this electric toy car. As they haven´t got any stock, they work under request and ask for a 30% deposit of the total value of the request. The company sells and ship the good to the customer´s destination around the world.

The information the company share is the following: each electric toy car has a manufacture cost of $7.7 (€6.77) and it has a FOB (free on board) of $8.5 (€7.47). This company sells this product for $15 (€13.2) in his website (wholesale). This means the company has a revenue of $6.5 (€5.71) for each product. If you want to buy an individual item, you need to pay around $35 (depend of the website) so the seller revenue will be $35 - $15 = $20 (€17.6) per piece.

Move to the manufacture techniques, most of the pieces are made by plastic molding, a really cheap manufacture process the company want to do this product as cheap as possible in order to increase their profit. Only few pieces such as electric motors and screws must be purchased from a supplier. The company confirms they use a close mold for each piece and then they assemble the piece together. Finally, the company pack the product for sale. In this way, it is able to verify that they use plastic molding to make their pieces and the specific technique (close mold) they use was founded out.

More detailed:

- Buy the material and put it into the mold machine
- Assemble the electronic circuit board with the car together
- Test if the car works well.
- Send the product to the test organization (SGS, TUV, etc)
- Follow the customer´s request
- Usually the goods lead time is 45days after received the customer's deposit

4. Quality Function Deployment, House of Quality matrix

House of quality matrix use will help to decide the areas to concentrate the design. The customer requirements are based in online reviews of actual products and are the followings: easy to use, lightweight, durable, fast, lot of battery, fast charge, transportable and low cost. These requirements have a weight or importance based on online reviews and opinion websites were different products were analyzed based on these requirements. Other customer requirements like safety or aesthetic aren´t included in the table because are less important for the customers than the others. In addition, it is supposed that the product will be safety because this type of toys must pass some tests before sell them.

The columns of the matrix are the design requirements. These requirements will be correlate each one with the others in a positive or negative way. Furthermore, customer requirements will have more or less relationship with each design requirements.

In the right and back area of the matrix, there are ratings of our product and competitor's products in terms of customer requirements. The criteria used to choose competitor products was different in each competitor. The first competitor (Traaxas xo-1) was selected because is the fastest RC car, this toy has a maximum velocity of 100 mph (160 km/h). The second competitor (HPI Racing E10) was selected because has a great overall review in some many websites: good life span, good velocity and good battery life.

With these customer requirement and design requirement will be seen which should be changed in order to make the product more attractive for the buyers.

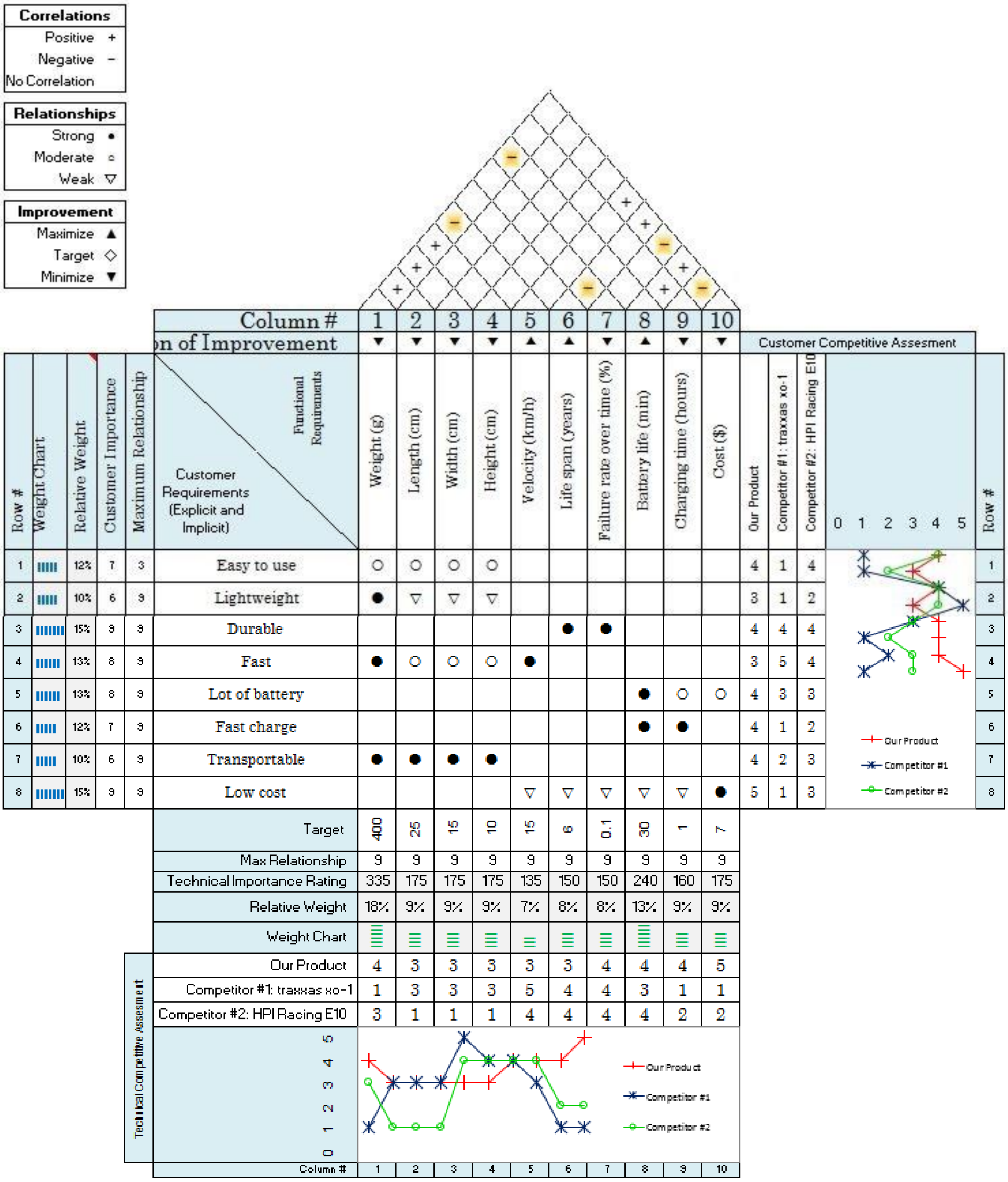


Figure 7: House of Quality

5. Customer requirements.

Making some internet searches, here are some of the most popular reviews. There are many of them that are in the original HOQ so the ones that are underlined will be included.

- Dimensions (transportable)
  - Length
  - Width
  - Height
- Weight
- Structure
  - Aerodynamic
  - Strong cover material
- Velocity
  - Four wheels driveway
  - Off road traction
  - Handle at lower top speed
- Jump
  - Good suspension for shock absorption
  - Swift and smooth suspension system
- Cost
  - High price-quality ratio
  - Affordable price
- Waterproof
- Durable
  - Easy to repair
  - Replacements easy to find
- Battery
  - Long battery use
  - Quick charge
- Remote control
  - Large radio control range
  - No interferences
  - Smooth remote control
- Camera
- Control via Android
- Attractive design

Once the customer requirements are selected a new HOQ is created with the three design requirements.

Row #	Weight Chart	Relative Weight	Customer Importance	Maximum Relationship	Column #	11	12	13
					…on of Improvement	▲	▲	▲
					Customer Requirements (Explicit and Implicit) / Functional Requirements	Elastic constant (N/m)	Yield Strength (Mpa)	Distance control - car (m)
9		27%	6	9	High Jump	●		
10		36%	8	9	Large radio control range			●
11		36%	8	9	Strong cover materials		●	
					Target	1.94	55	120
					Max Relationship	9	9	9
					Technical Importance Rating	245	327	327
					Relative Weight	27%	36%	36%
					Weight Chart			

Figure 8: New customer and design requirements

Later, the rest of design requirements are added to see how the relationship between the customer and the design requirements is.

Row #	Weight Chart	Relative Weight	Customer Importance	Maximum Relationship	Column #	1	2	3	4	5	6	7	8	9	10	11	12	13
					…on of Improvement	▼	▼	▼	▼	▲	▲	▼	▲	▼	▼	▲	▲	▲
					Customer Requirements (Explicit and Implicit) / Functional Requirements	Weight (g)	Length (cm)	Width (cm)	Height (cm)	Velocity (km/h)	Life span (years)	Failure rate over time (%)	Battery life (min)	Charging time (hours)	Cost ($)	Elastic constant (N/m)	Yield Strength (Mpa)	Distance control - car (m)
9		27%	6	9	High Jump	●					▽	▽				●		
10		36%	8	9	Large radio control range										○			●
11		36%	8	9	Strong cover materials						▽	○			○		●	
					Target	400	25	15	10	15	6	0.1	30	1	7	1.94	55	120
					Max Relationship	9					1	3			3	9	9	9
					Technical Importance Rating	245	0	0	0	0	64	136	0	0	218	245	327	327
					Relative Weight	16%	0%	0%	0%	0%	4%	9%	0%	0%	14%	16%	21%	21%
					Weight Chart													

Figure 9: Customer requirements effect in design requirements

6. Improved House of Quality matrix

With the results obtained in the previous section, a new HOQ is filled to select the areas to concentrate the design.

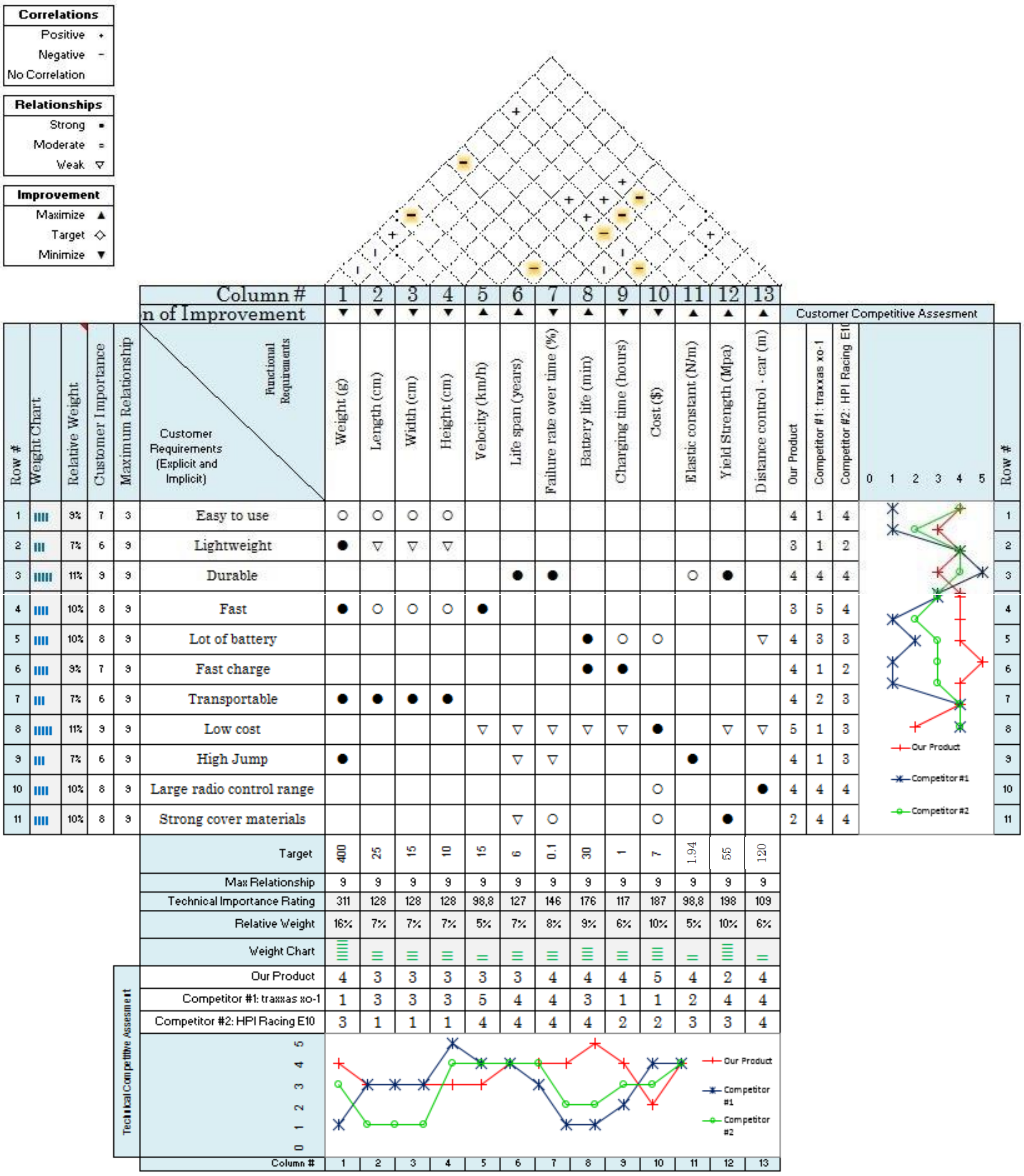


Figure 10: Improved House of Quality

Once House of Quality matrix is completed, the most important design requirements need to be identified. These requirements are related with customer requirements so, improving design requirements, this product will have more sales.

Column #	1	2	3	4	5	6	7	8	9	10	11	12	13
Target	400	25	15	10	15	6	0.1	30	1	7	1.94	55	120
Max Relationship	9	9	9	9	9	9	9	9	9	9	9	9	9
Technical Importance Rating	311	128	128	128	98,8	127	146	176	117	187	98,8	198	109
Relative Weight	16%	7%	7%	7%	5%	7%	8%	9%	6%	10%	5%	10%	6%
Weight Chart													
Technical Competitive Assesment: Our Product	4	3	3	3	3	3	4	4	4	5	4	2	4
Competitor #1: traxxas xo-1	1	3	3	3	5	4	4	3	1	1	2	4	4
Competitor #2: HPI Racing E10	3	1	1	1	4	4	4	4	2	2	3	3	4

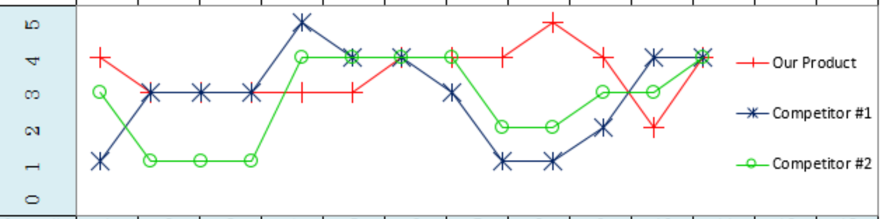


Figure 11: Design requirements weight

First row, Target, is the ideal value of each technical specification in their units. Second row, Max Relationship, is the maximum relation value of each design requirement with all customer requirements. As it can be seen, all have a 9 which is the maximum value because all design requirement have at less one strong relation with one customer requirement.

The following three rows shows the important or weight of each design variable. The highest weight means these requirements should be improved. In this case, weight, yield strength and cost have the highest weights with 16%, 10% and 10% respectively.

7. Design areas based on design for manufacturability.

As it can be seen in HOQ, the top three design requirements in order of importance are weight, cost and yield strength. Improving these requirements, the product will be lightweight (weight), transportable (weight), low cost (cost), durable (yield strength) and strong against impart (yield strength). These are the customer requirement a new design will have. The customer importance of these requirements are 6, 6, 9, 9 and 8 respectively.

To improve market share based on design for manufacturability it should be considered the following.

As the RC car has almost all pieces of plastic, the pieces must be manufactured with injection molding. This manufacturing process consist on inject molten plastic into a mold. You can introduce elastomers, thermoplastic and thermosetting polymers. Material is fed into a heated barrel, mixed and injected into a mold cavity, where it cools and hardens to the configuration of the cavity.

Production levels in injection molding are very high, even with complicated shapes and the manufacture parts require few finishes. Furthermore, the costs are low, especially if the injection process is outsourced. However, the initial cost in molds is high. Hence, this manufacture process is oriented to medium or long series.

For injection molding process there is two main molds: hot-runner molds and cold-runner molds. Hot-runner molds eliminates waste (no runners), have faster cycle time, can accommodate larger parts and higher volume of production, have better quality and use less pressure to push the molten mixture (less energy). However, cold-runner molds are cheaper to produce, and this mold has less maintained equipment. For these reasons, although hot-runner molds are faster and no plastic waste, cold-runner molds must be chosen for this process because the cost of manufacturing want to be reduced.

If cold-runner molds are used, plastic waste can´t be eliminated but this waste must be eliminated. When the molten material is injection to the cavity, some material should be cut and is useless for the product. If the company reduce this plastic waste, they will use less plastic and, consequently, less money. This waste can be reduce minimizing the length between the nozzle and the mold cavity (distribution channel).

Other ideas to reduce cost of manufacture are eliminate undercuts (inability to slide the part or the mold away to each other), design self-assembled parts, use a multi-cavity mold, get rid of unnecessary forms and reduce the finishes and aesthetic aspects.

The company use ABS material. All injection molding components are made of this material. ABS has 3 monomers: acrylonitrile, butadiene and styrene. The acrylonitrile blocks provide rigidity, resistance to chemical attacks and stability at high temperature as well as hardness. The blocks of butadiene, which is an elastomer, provide toughness at any temperature. This is especially interesting for cold environments, in which other plastics become brittle. The styrene block provides mechanical strength and rigidity.
The advantage of ABS is that a variety of modifications can be made to improve impact resistance, toughness, and heat resistance. The last properties of the process will influence the final product. Molding at a high temperature improves the gloss and heat resistance of the product whereas molding at a low temperature is where the highest impact resistance and strength are obtained.

To make sure ABS is the best material for the product, a material analysis will be done with CES Edupack software. To see the process explanation see Appendix II. The final material list is composed of four materials: ABS (high-impact, injection molding), ABS (rubber modified, injection molding and extrusion), ABS (transparent, injection molding) and PE-HD (polyethylene high-density). Some data about each material is showed below.

	ABS (high-impact)	ABS (rubber modified)	ABS (transparent)	PE-HD
Density (kg/m^3)	1010-1050	1030 - 1190	1070 - 1090	952 - 965
Price (EUR/kg)	2.35 - 2.59	2.35 - 2.59	2.26 - 2.49	1.4 - 1.54
Yield Strength (MPa)	18.5 - 40.7	40.1 - 44.2	32 - 37	26.2 - 31
Impact strength (KJ/m^2)	590 - 600	590 - 600	590 - 600	590 - 600

Table 5: Comparison of material

ABS materials have same price and similar density and yield strength. PE-HD has less yield strength than ABS and less cost and density.

ABS is used in drain pipe systems, plastic clarinets, golf club heads, automotive parts, common appliances in a kitchen, LEGO bricks, and many other products. However, the primary uses of polyethylene are plastic bags, plastic films, containers including bottles, and geomembranes. For all these reasons, the best material for the product is ABS.

Moreover, Hangzhou Bold Toys Co assemble all the pieces manually. This is a lot of staff, salary and time. The company should create an automatic assembly line to reduce time, workers and time. This idea will have a great initial investment but, in long-term, the company will get more profit of the product. This idea could be applicable in a technology develop country where the salaries is an important cost in the production process. However, in China, labor cost is smaller, and the big investment of an automatic assembly line make this method almost impossible. If the company's plans are open a new factory in a country developed technically, they should consider an automatic assembly line.

8. Product Design Specification (PDS)

1) Performance

   The main functions a RC car must have are fast (velocity), easy to use (weight), durable (life span) and strong against impact (yield strength).

   The product should be fast as this is what children expect of an electric toy car. However, the car shouldn't have a big speed because it can hurt people. The car should have a speed to be safe for unprepared users and be entertaining for them.

2) Environment

   Not all plastics can be recycled, and the waste plastic are deposited in the environment, causing damage on it. The refrigeration liquid use to cool the mold is harmful to the environment. Furthermore, during transportation, there will be CO2 which will contaminate the atmosphere. During the use of the product there is no danger but when the product life ends, the item should be recycled.

   Other issue is that this is a children toy and many children are inclined to stick objects in their mouth. Although this is outside the scope of the project, the company should take into consideration the toxicity of the different materials being used.

3) Life in service

   This car should have a relatively long service life. This product will work until one of the components fails. When this happen, the customer can change the component and still use the product.

4) Maintenance

   An electric toy car hasn´t any special maintenance. This is great as the users of this product are children who are not familiar of the product maintenance. The user only needs to charge the battery. This component is accessible to facilitate this work. However, if one of the other components fail, the user should replace this part, that´s why all the components are accessible. Users don't need any special tool to dissemble the product.

5) Target product cost

   This product is one of the cheapest RC cars in the market. This item is cheap to manufacture ($7.7). The project aims to reduce this manufacture cost.

The company hasn´t stock. The company should consider have stock as the time between the order of the product and the delivery would be less. However, the target product cost is cheaper than his competitors.

6) Timescales

After having made the analysis of the actual product and a market study, a working area will be selected, and a piece will be chosen for it redesign. This step is estimated to be complete before 04/12/2019.

The final step will be to create a new component in CREO and printed to verify the new component works well.

7) Packaging

There is no need of special packaging. The product only needs a box to be easier to ship and protect the product against some hit in the shipping process. The packing must be durable to prevent damage of the components within.

The components inside the shipping box are the controller, the car, the battery, the charger for the battery and an instruction manual for the user. The main idea of the box is to have spaces where these items fits securely. The current packaging method has all these requirements.

8) Shipping

The company ship domestically as internationally. The vehicle hasn´t any special care in handling. They usually ship in commercial boats in Shenzhen / Ningbo/ Shanghai ports.

9) Quantity

The company produce between 800 – 1000 pieces per day depending on the demand. They don´t have stock. As they don´t have stock, the goods lead time is 45days after received the customer’s deposit.

10) Manufacturing facility

The company has only one factory. They have their own machines and assembly line to manufacture the electric toy cars. The actual assembly line is manual, but they should consider make an automatic assembly line as it was said in point 3.

Some components like motors, screws and cables are sub-contract components.

11) Size and weight

Although there is no restriction in size and weight, the product should be small and lightweight to sell them. If the product has less weight, it´s easy to achieve high speeds. Furthermore, a lightweight product is easy to use for a child and the shipping cost will be less.

The redesigned component should not increment so much the weight of the product.

12) Aesthetics

This is not the most important point of the product. The car structure is decorated in different colors, giving the customer the possibility of choosing between blue, green and red designs.

13) Materials

ABS is the main material of the car. Most of the pieces are made by plastic injection and ABS is the material the company use. This is a common material the company gets from a provider.

Why the company use ABS as their material? ABS has 3 monomers: acrylonitrile, butadiene and styrene.

The acrylonitrile blocks provide rigidity, resistance to chemical attacks and stability at high temperature as well as hardness.

The blocks of butadiene, which is an elastomer, provide toughness at any temperature. This is especially interesting for cold environments, in which other plastics become brittle.

The styrene block provides mechanical strength and rigidity.

14) Product life span

This product is always marketable. There isn´t a specific time between the manufacture and the sale of the product because any of the product components will decrease the quality.

However, toy market is so demanding and has a large variety of products. This variety is always increasing, and the traditional toys lost sales and decide to have a new toy as a target. In this case, the electric toy car has been in the toy market during more than 15 years and will continue to be in the market but with less sales because new toys (drones, tablets, etc.) are entering in the toy market.

15) Standards

The company has passed ISO9001-2008 and the production is strictly implemented in accordance with national laws and regulations and industry standards, and has been certified by CCC, CE, RoHS, FCC and other relevant domestic and international certifications.

In addition of this standards, the company include a warranty of 2 years. This allows the user to replace the product if it clogs unexpectedly.

16) Ergonomics

There is not high risk in this company. Workers are controlling the machines or assembling the components. The factory is adapted to help workers be comfortable during the labor time.

17) Quality and reliability

The product must have a minimum life span of one year. This feature ensures a quality of the product as the company don't want to have returned items.

Most common failure modes are break the car structure in a shock or a component failure. The first mode is hard to solve as the structure is an important part in the product. The second one can be solve replacing the damage component and the car will be perfect again.

18) Shelf life

This product hasn´t any requirements for long storage times. The product has only two requirements. The first one is don't have a direct exposure with sun as the plastic properties could be affected. The second one is don't have an extended period of time without use the batteries because the batteries could corrode and cause failure of the product.

19) Processes

The manufacturing process is simple. They use a close mold for injection the ABS melt material and use a refrigeration system to cool the material until it is solidified. When they have all the pieces, they assemble each one manually.

20) Testing

All pieces are testing before they sell the product. They check all works well such as the motor or the wheels movement. The product must pass SGS, TUV… tests. After including the redesigned component, the product functions must be the expected.

21) Safety

This product is recommended for children more than 6 years old because the product contains little components that could damage the user. As the car travel at relatively high speed, the user needs to be careful while he is playing with the product.

22) Company constraints

The main company constraint of this product is the money and the capital. The company is small, and they have a limited production each day. Also, they have only one factory and the assembly line is manual, so they waste a lot of time in the process.

23) Market constraints

As this product is design for kids, the product must accomplish some requirements so as not to harm the user. For example: not flammable, not exploitable, not toxic materials, etc.

24) Intellectual property

This product hasn´t any special patent or copyright. Furthermore, the manufacturing and assembling process hasn´t any intellectual property. The process and the product are simple, and the competitors have the same process and similar products.

25) Ethics and society

This car could be use in no ethic ways. If someone add a camera, he can spy other person, and this is not ethic. Moreover, this item can be used to place bombs or explosives with fatal consequences to the population.

However, this product was designed to play with it and with the goal of make children have fun.

26) Disposal

When the user stop using the product, this item should be recycled. The car has almost all pieces of plastic and this material can be reused to make other products. These pieces could be returned to the company to reduce them in future products. Other components like motors, cables and screws can be used for other kind of product.

27) Customer

The target customer of this product is young children. This should be kept in mind during the design process as the final product must be easy to use for the children. The product should achieve all the standards before selling them because one of the most important issues of this product is the safety.

28) Competition

There are many companies who sell this type of toys. Some of them were analyzed in point's 4 and 6 (House of Quality matrix). The product should have something different of the other products. This different can be the cost, the design structure, colors, speed, etc.

After analyzing the competitors, it was decided that the feature that will make this car most competitive within the market are reducing the cost of the product and the number of components.

9. Design for Manufacture and Assembly (DFMA) analysis

Design for Manufacture Analysis

Part Number	Part Name	Quantity	Material	Manuf. Process	Weight (each) (g)
1	Car structure	1	ABS	Plastic molding	49
2	Panels	4	ABS	Plastic molding	2,5
3	Battery box	1	ABS	Plastic molding	35
4	Cover of battery box	1	ABS	Plastic molding	10
5	Shafts join	4	ABS	Plastic molding	0,75
6	Transmission shafts	6	ABS	Plastic molding	1
7	Suspensions	4	ABS	Plastic molding	3,5
8	Springs	4	Steel	Bending	
9	Cables	5	Cooper	Purchased	1
10	Screw DIN 7983 M2x6	58	Steel	Purchased	0,1
11	Screw DIN 7982 M2x3	16	Steel	Purchased	0,05
12	Screw DIN 7981 M2x4	7	Steel	Purchased	0,25
13	Screw DIN 7981 M3x6	12	Steel	Purchased	0,5
14	Wheels	4	ABS	Plastic molding	3
15	Tire of wheel	4	Rubber	Pressurized molding	23
16	Motor	2	Multiple	Purchased	22
17	Electric board	1	Multiple	Purchased	10
18	Motor box	2	ABS	Plastic molding	10
19	Transmission shafts	2	ABS	Purchased	69
Total:		138			462,35

Table 6: Bill of materials

Most of the components are manufactured by plastic molding injection. According to the company, these components are made of ABS plastic in closed molds and then assemble together.

In addition, this product has many screws divided in three types: M2x6, M2x3, M2x4 and M3x6 screws both made of steel alloy. These are standard screws and they are purchased.

Finally, the company purchase other components such as motors, electric boards, transmission shafts and cables.

Design for Assembly Analysis

One Design for Assembly Analysis was made for the original product following the instructions in Appendix III. The following table has the results.

Assembly Table

								Handling and Alingment		Insert and Secure		
Operation Number	Times Operation is Carried Out	Part Description	Part Required	Alpha (deg)	Beta (deg)	Size (mm)	Thickness (mm)	Description	Time (sec)	Description	Time (sec)	Total Time (sec)
1	1	Car structure	Yes	360	360	175	65	0,5+(360+360)/360	2,5	0,5+0,3	0,8	3,3
2	4	Panels	Yes	360	360	78	0,5	0,5+(360+180)/360+0,3	2,8	0,5+0,3	0,8	14,4
3	1	Battery box	Yes	360	180	115	40	0,5+(360+180)/360	2	0,5+0,3	0,8	2,8
4	1	Cover of battery box	Yes	360	360	70	3	0,5+(360+360)/360+0,1	2,6	0,5+0,3	0,8	3,4
5	4	Shafts join	Yes	360	360	20	12	0,5+(360+360)/360	2,5	0,5+0,3	0,8	13,2
6	6	Transmission shafts	Yes	360	360	50	8	0,5+(360+360)/360	2,5	0,5	0,5	18
7	4	Suspensions	Yes	180	180	68	10	0,5+(180+180)/360	1,5	0,5+0,3	0,8	9,2
8	4	Springs	Yes	180	180	68	10	0,5+(180+180)/360+0,4	1,9	0,5+0,4	0,9	11,2
9	5	Cables	Yes	180	180	130	3	0,5+(180+180)/360+0,3	1,8	0,5	0,5	11,5
10	58	Screw DIN 7983 M2x6	Yes	360	0	6	2	0,5+(360+0)/360+0,5	2	0,5+0,3+1+2	3,8	336,4
11	16	Screw DIN 7982 M2x3	Yes	360	0	3	2	0,5+(360+0)/360+0,5	2	0,5+0,3+1+2	3,8	92,8
12	7	Screw DIN 7981 M2x4	Yes	360	0	4	2	0,5+(360+0)/360+0,5	2	0,5+0,3+1+2	3,8	40,6
13	12	Screw DIN 7981 M3x6	Yes	360	0	6	3	0,5+(360+0)/360+0,5	2	0,5+0,3+1+2	3,8	69,6
14	4	Wheels	Yes	180	0	35	25	0,5+(180+0)/360	1	0,5	0,5	6
15	4	Tire of wheel	Yes	180	0	70	30	0,5+(180+0)/360	1	0,5	0,5	6
16	2	Motor	Yes	360	360	50	25	0,5+(360+360)/360	2,5	0,5	0,5	6
17	1	Electric board	Yes	180	180	40	10	0,5+(180+180)/360	1,5	0,5+0,3	0,8	2,3
18	2	Motor box	Yes	360	360	55	30	0,5+(360+360)/360	2,5	0,5+0,3	0,8	6,6
19	2	Transmission shafts	Yes	180	180	140	3	0,5+(180+180)/360+0,3	1,8	0,5+0,3	0,8	5,2
										Total AssemblyTime		658,5

Table 7: Assembly time original product

The assembly time estimation is 658.5 seconds. This means the time spend assemble all the components of the car is around 11 minutes. In the next paragraphs, a DFA analysis will be done to decide which parts can be combined or reduced. Reducing the number of components, the assembly time will be reduced and the company can sell more products and decrease the time between order and delivery of the product.

To know which components can be combined or reduced, three questions must be answered.

- Question 1: Does a part move simultaneously (direction doesn´t matter) with another part?

  Wheels, tires of wheels and transmission shafts move simultaneously and in the same direction. These parts are the responsible to change the electric power of the motor in kinetic power to move the car.

  Joins, suspensions and springs move simultaneously when the car is working.

— Question 2: Can the part be the same material as this other part?

In one hand, transmission shafts shouldn´t be made of ABS because is a plastic and the material has less yield strength (46 MPa) than steel (350 MPa). The transmission shaft will have more possibilities to fail so this material can´t be changed.

Wheels can be made of steel (like transmission shafts) but the weight of the product will increase. ABS is a light material (1.06 g/cm^3) compare to steel (7.85 g/cm^3), this means the weight of the wheels will be more than 7 times the actual one. One of the design requirements should be minimized is weight so the wheel material can´t be changed.

Tires of wheels are made of rubber. This material is used because has good elastic deformation, an important factor because the wheels will be in contact with ground (off-road). If the tires were made of ABS, the wheel will have hits and deformation due to the contact with ground.

— Question 3: Can the manufacturing method and tolerance be the same for these parts?

Joins, suspensions and springs move simultaneously. However, the manufacture method for springs is different of the joins and suspensions. Spring manufacture process is bending while suspensions and joins are made by injection molding (ABS plastic). Springs have high accuracy but joins and suspensions can have more tolerance in this product.

The conclusion with this method is that there isn´t any components that can be assembled together. However, in the first question, only moving components are take in account. Now, nonmoving components will be analyzed.

Looking the bill of materials can be conclude that the car structure and battery box can be assembled together. The car structure has 4 different components added to the main structure to protect this component. If these four pieces are assembled together, the main block of the car will be one piece which will make the car structure strong against impacts. Also, the number of screws which are used to assemble both components will be eliminated, and the cost of the produce will decrease. Combine these pieces the number of components will be reduced in 3 panels and 10 M2x3 screws.

Adding a column in bill of materials, it´s easy to visualize how the components can be combined (assembled) or eliminated.

Part Number	Part Name	Quantity	Material	Manuf. Process	Weight (each) (g)	Opportunity to Combine/Eliminate
1	Car structure	1	ABS	Plastic molding	49	Combine
2	Panels	4	ABS	Plastic molding	2,5	Combine/Eliminate
3	Battery box	1	ABS	Plastic molding	35	Combine
4	Cover of battery box	1	ABS	Plastic molding	10	
5	Shafts join	4	ABS	Plastic molding	0,75	
6	Transmission shafts	6	ABS	Plastic molding	1	
7	Suspensions	4	ABS	Plastic molding	3,5	
8	Springs	4	Steel	Bending		
9	Cables	5	Cooper	Purchased	1	
10	Screw DIN 7983 M2x6	58	Steel	Purchased	0,1	Eliminate
11	Screw DIN 7982 M2x3	16	Steel	Purchased	0,05	Eliminate
12	Screw DIN 7981 M2x4	7	Steel	Purchased	0,25	Eliminate
13	Screw DIN 7981 M3x6	12	Steel	Purchased	0,5	Eliminate
14	Wheels	4	ABS	Plastic molding	3	
15	Tire of wheel	4	Rubber	Pressurized molding	23	
16	Motor	2	Multiple	Purchased	22	
17	Electric board	1	Multiple	Purchased	10	
18	Motor box	2	ABS	Plastic molding	10	
19	Transmission shafts	2	ABS	Purchased	69	
Total:		138			462,35	

Table 8: Opportunity to combine/eliminate components

10. CAD Modeling of the Existing Product

The main part under investigation is the car structure (#1 in bill of materials). This component will be analyzed and represented in a 3D program (CREO Parametric). This piece was decided because it is the most prone to receiving blows. One of the customer requirements was make the structure stronger against impacts. Also, in the next questions, the design will be redesign in order to make the component lighter and with lower cost than the original one.

Piece Number 1:

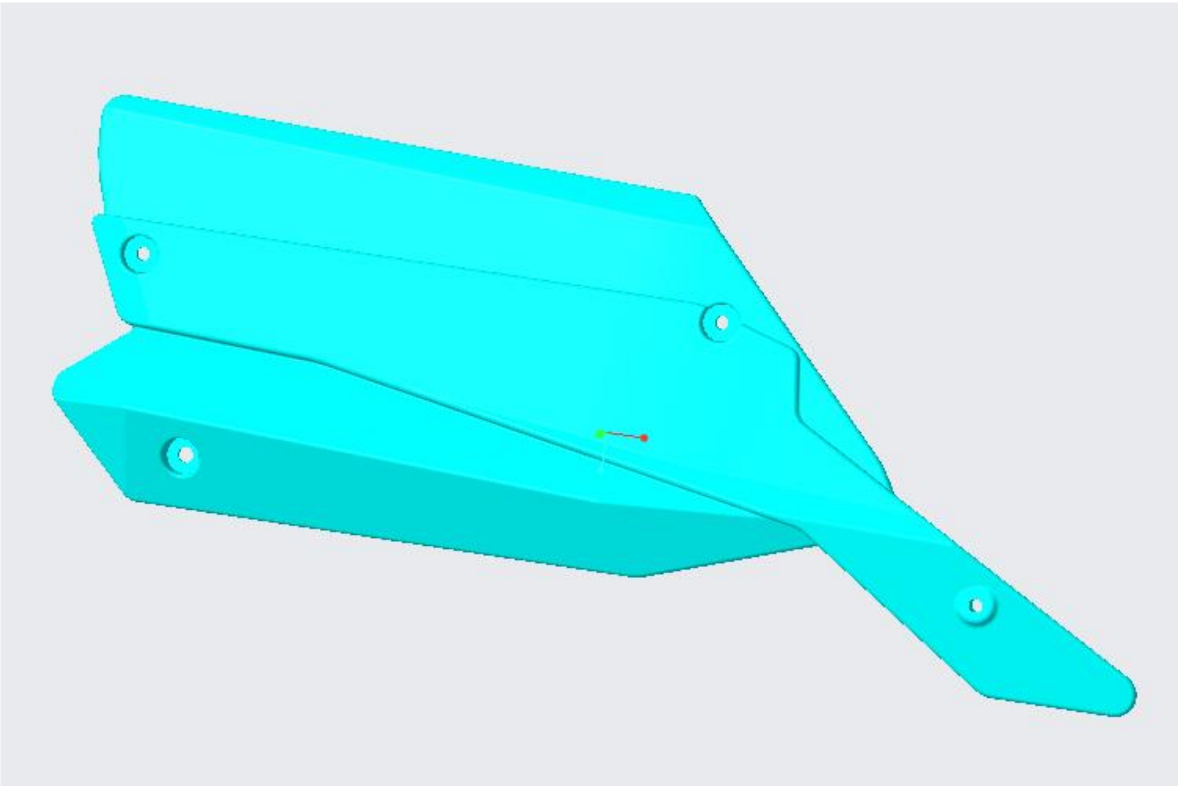


Figure 12: Car structure right panel

Piece Number 2:

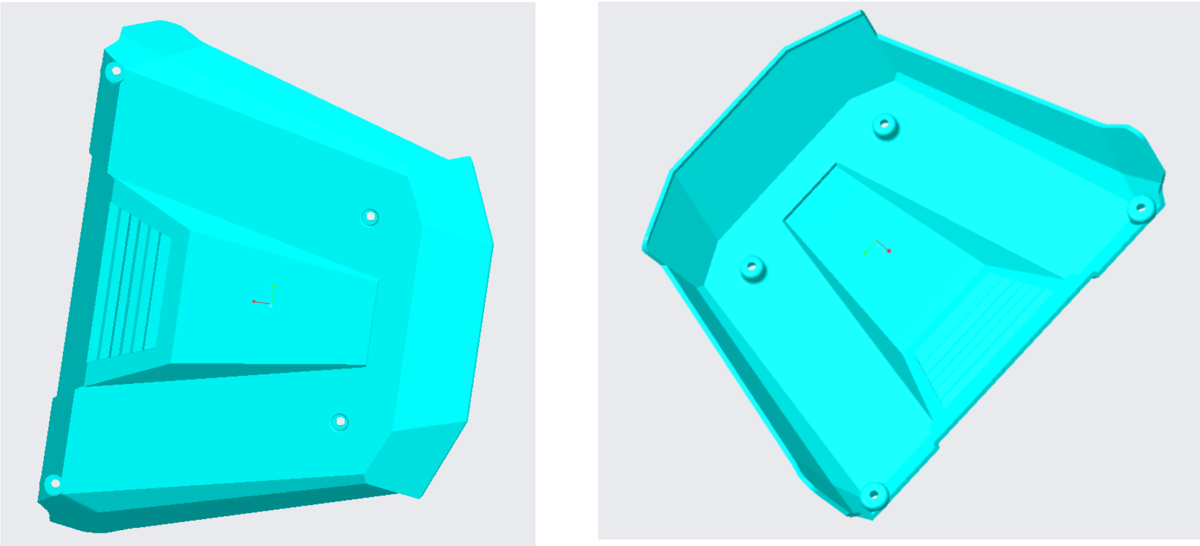


Figure 13: Car structure front panel

Piece Number 3:

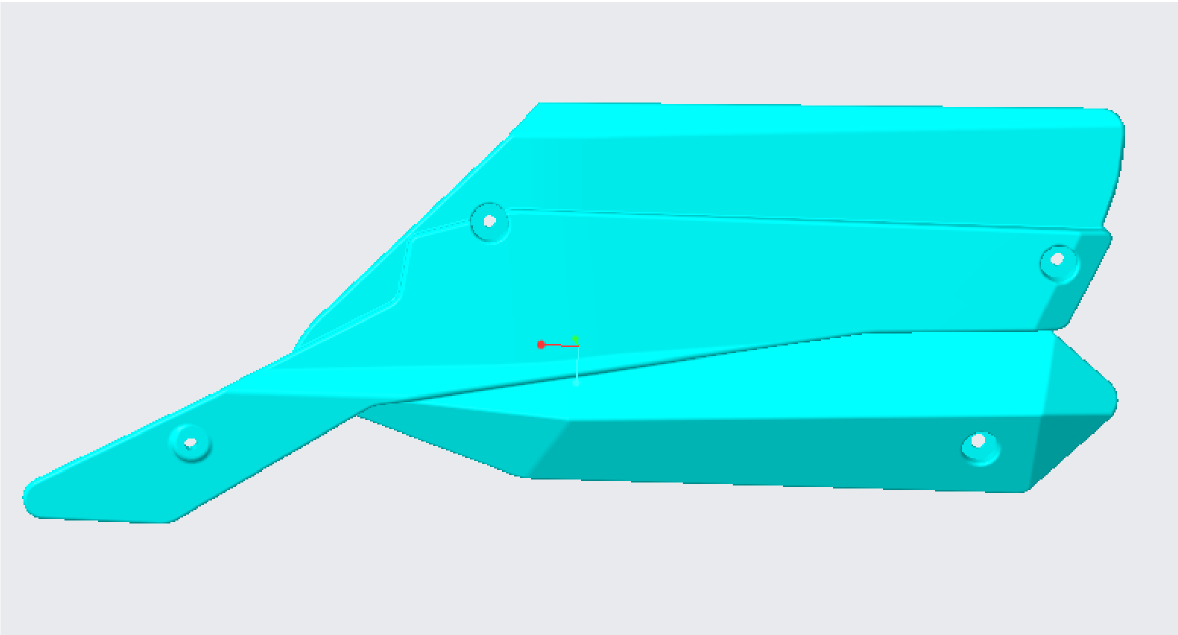


Figure 14: Car structure left panel

Piece Number 4:

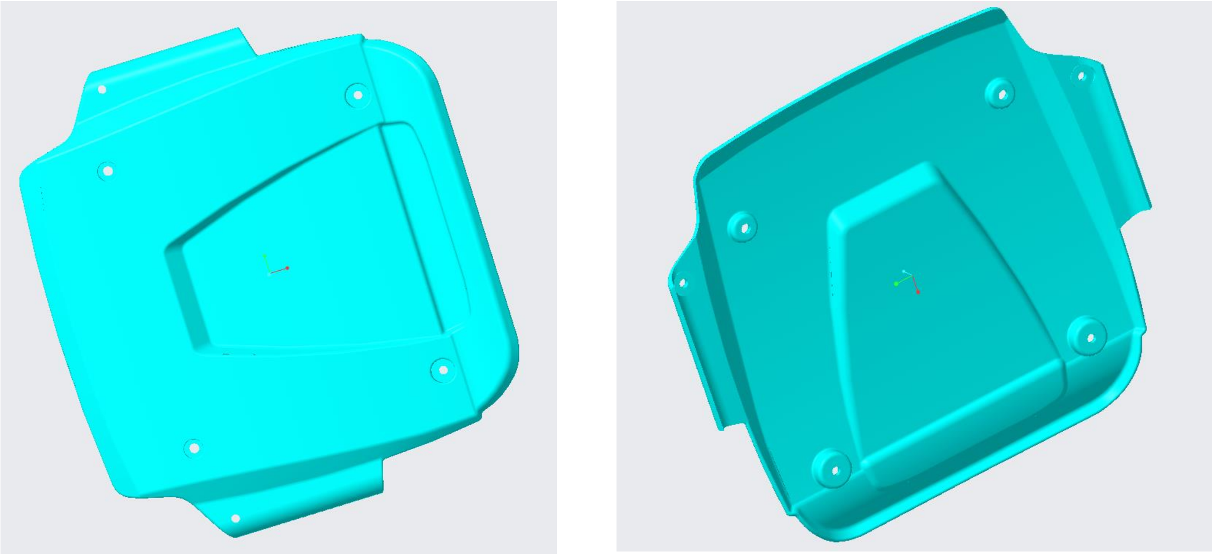


Figure 15: Car structure top panel

Once all pieces of the structure are created, all of them are assembled together. This assembly was made using the real dimensions of the product.

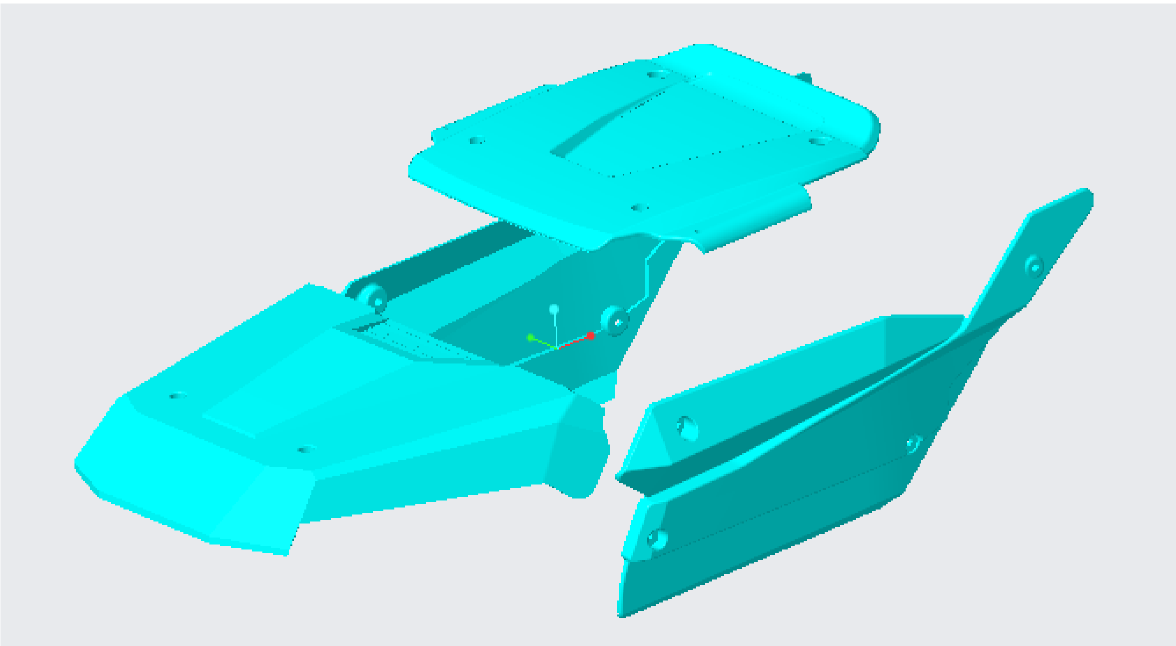


Figure 16: Car structure assembly

11. Manufacture Cost Analysis of the Existing Product

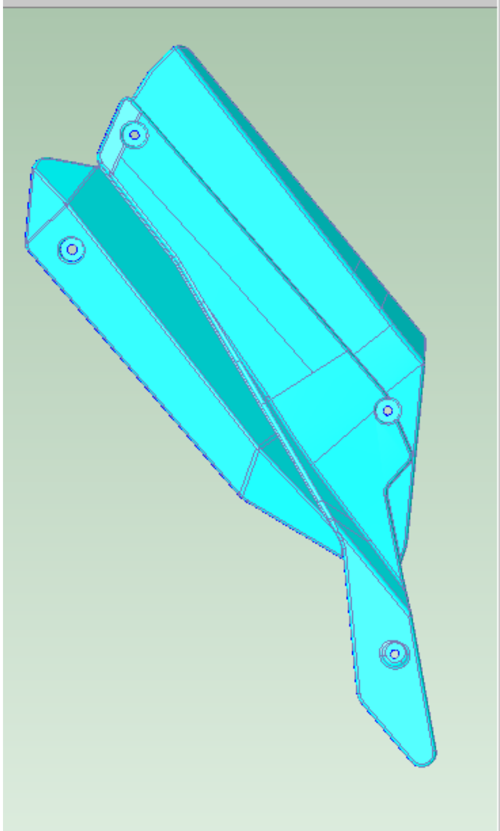
Using aPriori software, the cost of these pieces will be estimated. Once each estimation is made, a global cost for the total component will be made to compare with the new design of this component.

All the next results are made for pieces of ABS plastic manufacture by injection molding process. Company data provided indicate the annual production of this item is between 50000 and 100000 units depend of the year. An average of 75000 units per year was introduced in the software.

The final step to run the analysis is introduce the number of years these pieces will be manufacture. As the toy market is really big and new technologies arrive in the market, this product will be improved or eliminate from the market in an estimation of 5 years.

Introducing all this data in the software, these are the results for each piece.

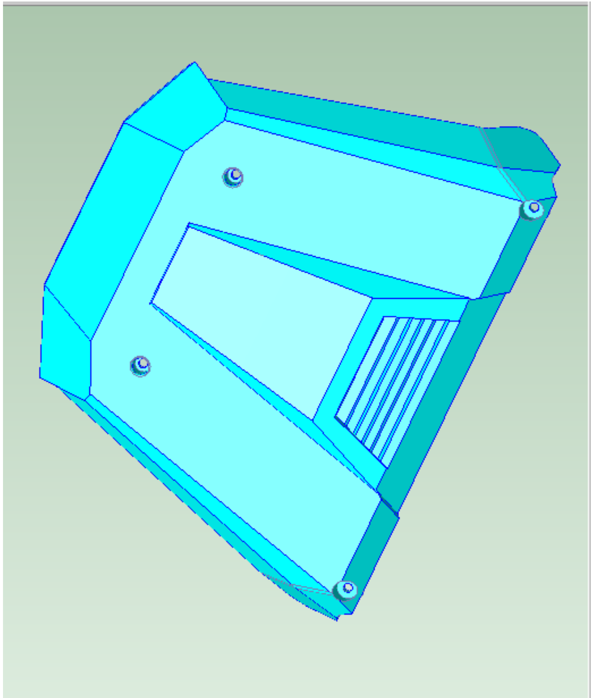
Piece Number 1:



Variable Costs	Current (USD)
Material Cost	0.05
Labor	0.04
Direct Overhead	0.06
Amortized Batch Setup	0.01
Logistics	0.00
Material Overhead	<0.01
Expendable Tooling	0.00
Additional Direct Costs	0.00
Extra Costs	0.00
Other Direct Costs	<0.01
Total Variable Costs	0.16
Period Costs	
Indirect Overhead	0.04
SG&A	0.02
Margin	0.00
Piece Part Cost	0.22
Fixed Costs	
Hard Tooling (amortized)	0.07
Fixture Cost (amortized)	0.00
Programming Cost (amortized)	0.00
Additional Amortized Investments	0.00
Total Amortized Investments	0.07
Fully Burdened Cost	0.29
Capital Costs	
Hard Tooling	26,306.90
Fixture Cost	0.00
Programming Cost	0.00
Total Capital Investments	26,306.90

Figure 17: aPriori car structure right panel

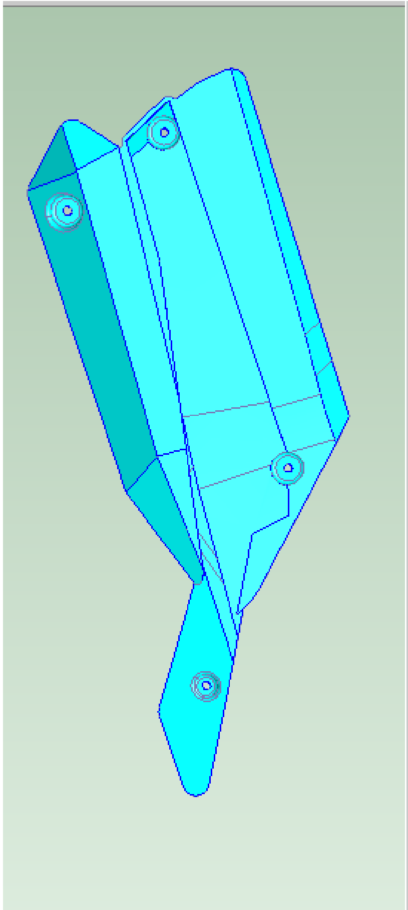
Piece Number 2:



Variable Costs	Current (USD)
Material Cost	0.08
Labor	0.04
Direct Overhead	0.01
Amortized Batch Setup	0.01
Logistics	0.00
Material Overhead	<0.01
Expendable Tooling	0.00
Additional Direct Costs	0.00
Extra Costs	0.00
Other Direct Costs	<0.01
Total Variable Costs	0.14
Period Costs	
Indirect Overhead	0.04
SG&A	0.01
Margin	0.00
Piece Part Cost	0.20
Fixed Costs	
Hard Tooling (amortized)	0.04
Fixture Cost (amortized)	0.00
Programming Cost (amortized)	0.00
Additional Amortized Investments	0.00
Total Amortized Investments	0.04
Fully Burdened Cost	0.24
Capital Costs	
Hard Tooling	15,099.74
Fixture Cost	0.00
Programming Cost	0.00
Total Capital Investments	15,099.74

Figure 18: aPriori car structure top panel

Piece Number 3:



Variable Costs	Current (USD)
Material Cost	0.05
Labor	0.04
Direct Overhead	0.06
Amortized Batch Setup	0.01
Logistics	0.00
Material Overhead	<0.01
Expendable Tooling	0.00
Additional Direct Costs	0.00
Extra Costs	0.00
Other Direct Costs	<0.01
Total Variable Costs	0.16
Period Costs	
Indirect Overhead	0.04
SG&A	0.02
Margin	0.00
Piece Part Cost	0.22
Fixed Costs	
Hard Tooling (amortized)	0.07
Fixture Cost (amortized)	0.00
Programming Cost (amortized)	0.00
Additional Amortized Investments	0.00
Total Amortized Investments	0.07
Fully Burdened Cost	0.29
Capital Costs	
Hard Tooling	26,306.91
Fixture Cost	0.00
Programming Cost	0.00
Total Capital Investments	26,306.91

Figure 19: aPriori car structure left panel

Piece Number 4:

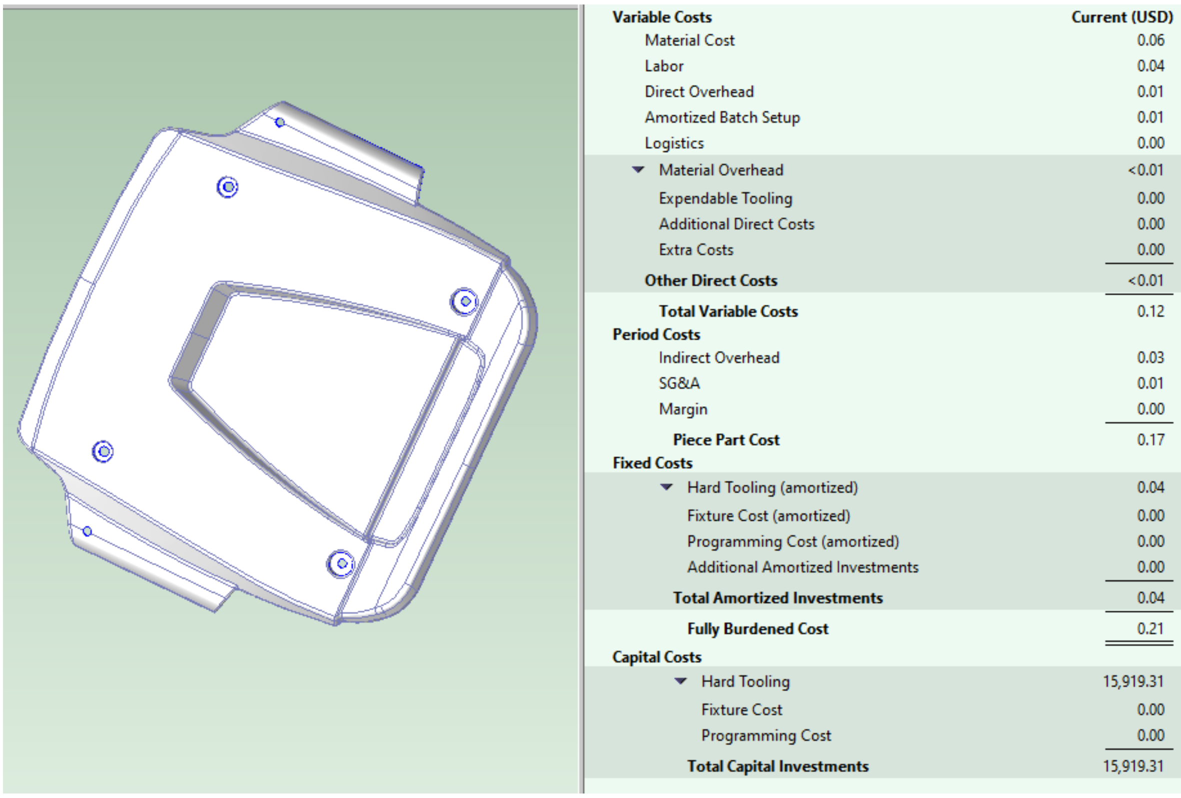


Figure 20: aPriori car structure top panel

In the next table, the most important costs of each product are shown, and, in the final column, it is the cost of create all these pieces (without counting the cost of assembly).

	Piece 1	Piece 2	Piece 3	Piece 4	Assembly
Total Variable Cots	0.16	0.14	0.16	0.12	0.58
Piece Part Cost	0.22	0.2	0.22	0.17	0.81
Total Amortized Investments	0.07	0.04	0.07	0.04	0.22
Fully Burdened Cost	0.29	0.24	0.29	0.21	1.03
Total Capital Investments	26306.9	15099.74	26306.91	15919.31	83632.86

Table 9: Total cost of the actual component

Other purchased components cost are the followings: cables ($2.46 per meter), M2x6 screws ($0.133 each), M3x6 screws ($0.059 each) and springs ($0.73 each). These costs have been seen in McMaster online catalog. This catalog has a profit selling these components so the manufacture cost of these components may be ¼ the sell cost.

12. Generate and Evaluate New Concepts

Higher resistance against impact, lower cost and lighter product are some of the customer requirements about this electric toy car. The new product should be more attractive for buyers than the actual one which means more sales and more profit for the company.

The components that will be redesign are the car structure of point 10. These components are important because the majority of the impacts during the use of the product are in this area. An improvement of the final cost and resistance against impact will be the goal when these components are redesigned.

In this section, some sketches will be done in order to maximize strength against impact and minimize cost and weight.

Sketch 1

The first sketch is the union of all the structure pieces to make only one. The advantage to make only 1 piece is that the structure will be strong against impact because in the original model, there were areas with no protection. In addition, the thickness of the actual components will be increased to make the car structure stronger against impacts.

Combine the four components, the cost will be reduced as the company only needs one mold to manufacture the car structure instead of four. Furthermore, the four components used four M2x3 screws each, 16 screws in total. This sketch only uses 6 screws because the union between the components is enough to hold this new car structure.

Furthermore, the time and cost of assembly will be reduced as these components don´t need to be assemble each one to the main block.

In this way, the company will reduce the cost of the product and the time between the order and the delivery of the product.

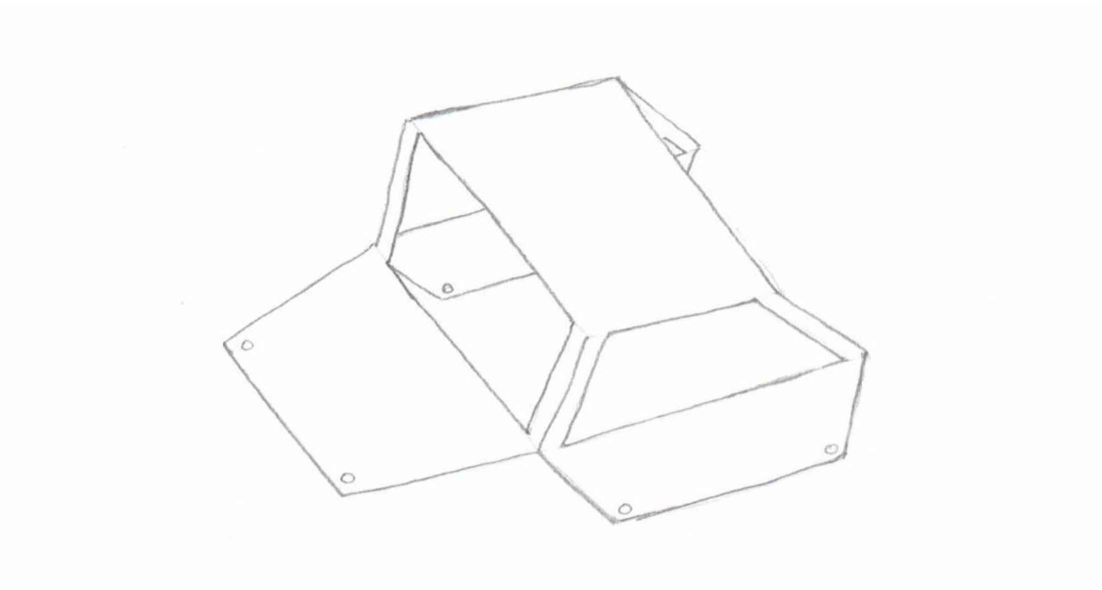


Figure 21: Sketch 1

Sketch 2

This sketch has an aerodynamic cover to protect the internal components. It´s really simple, just a curve of the material with one little window. The cost of manufacture and assemble will be reduced as there is only one piece. Furthermore, this sketch only uses 2 screws to join the component to the main block and combine four components in one reducing the cost of manufacture in the car structure.

It´s easy to manufacture but the main problem is the car will not be seen like a car any more. This aesthetic aspect will be included in the Push Matrix to get a conclusion.

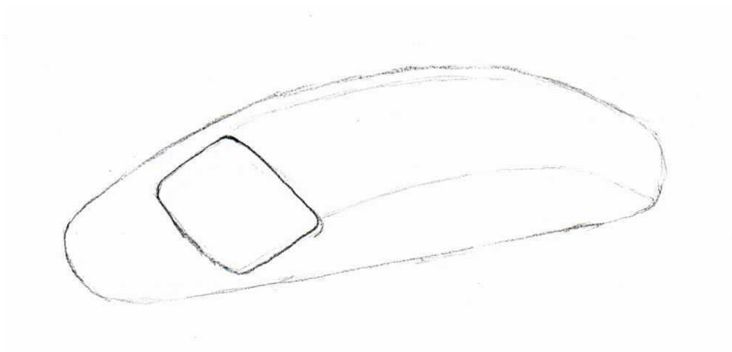


Figure 22: Sketch 2

Sketch 3

Like the actual components, this draw has four car panels using 16 screws to hold these components. The difference between this sketch and the actual components is that this panels are simple without any complex shape to make the mold easier and reduce the final cost of manufacture. In addition, the thickness of the actual components will be increased to make the car structure stronger against impacts.

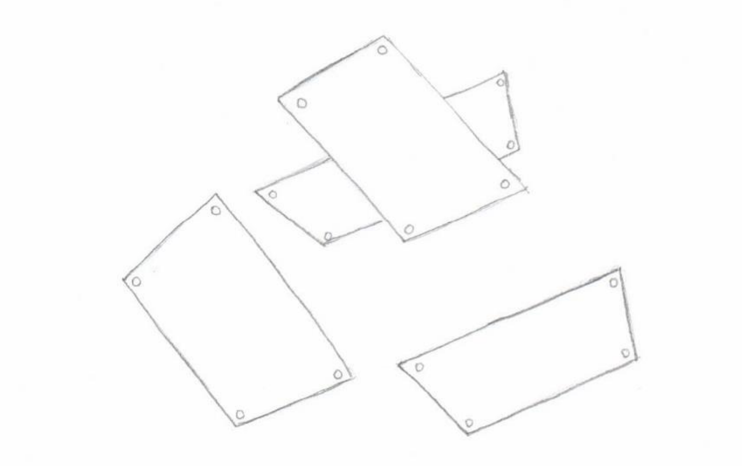


Figure 23: Sketch 3

Once the sketches are done, they will be analyzed using a Pugh Matrix to choose the best one based on the customer requirements. The best design will be modeling in a 3-D software in the next point to compare the actual product with the new one.

Customer Requirements	Weight	Sketch 1	Sketch 2	Sketch 3
Easy to use	7	0	0	0
Lightweight	6	-0,5	-0,5	0
Durable	9	0,5	1	0,5
Fast	8	0	0	0
Lot of battery	8	0	0	0
Fast charge	7	0	0	0
Transportable	6	0,5	1	-0,5
Low cost	9	0,5	1	0,5
High jump	6	0	0	0
Large radio control range	8	0	0	0
Strong cover materials	8	1	1	0
Aesthetic	7	1	-1	1
Scores:		24	22	13

Table 10: Pugh Matrix

This table represent the gain or loss of a customer requirements for each sketch. When the table is completed, the results saw that the best design based on the customer requirements is the first one.

Using this redesigned component, the number of components in the bill of materials will be reduced in 10 M2x3 screws and 3 car panels of the car structure. Furthermore, the time and cost of assembly will be reduced as these components don´t need to be assembled each one to the main block.

Increasing the thickness of the component, the product will be stronger against impact. The consequence of increase the thickness is that the number of refunds will be reduced because the car will last longer and will have less probabilities of fail.

The first sketch will improve durability, transportability, cost, aesthetic and resistance against impact. These are basic requirements for the customer and will help to increase sales of this product and the profit of the company.

In the next section, sketch 1 will be design with a 3-D software.

13. CAD Modeling of the New Product

As it was decided in the previous point, the redesigned model for the car structure is the first sketch. In this sketch, the number of panels will be reduced from 4 to 1 and the number of screws from 16 to 6.

The cost of manufacture will be reduced as the company only need one mold and less screws to hold this component. Furthermore, the time and cost of assembly will be reduced as this component doesn´t need to be assemble each one to the main block.

The thickness of the panels will be increased from 0.5 mm to 2 mm to be stronger against impact. Also, if the thickness is longer, it will be easier to print the component in the next point.

The following images show how the model looks in a 3-D software. In this case, the chosen software was CREO.

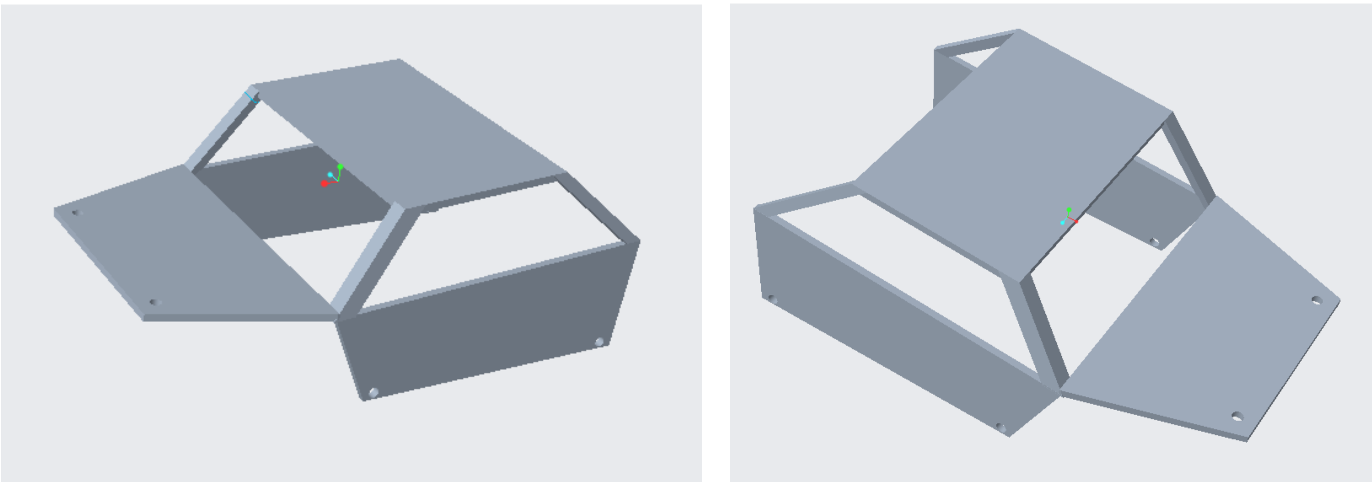


Figure 24: Cad model

With the intention to facilitate the understanding of the piece, some different views were made with the main dimensions of the product. All dimensions are in millimeters and the holes´ dimension is the radius.

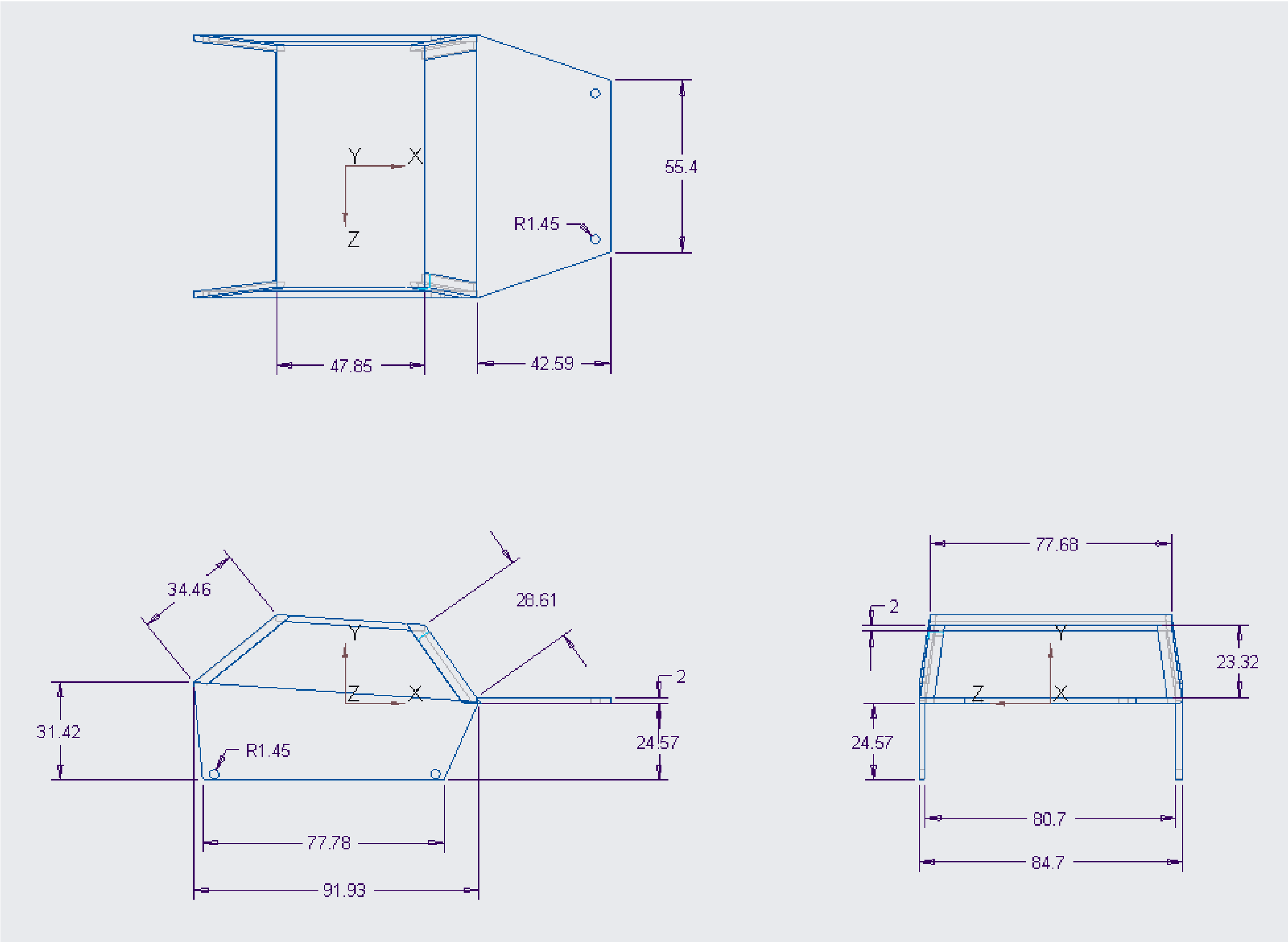


Figure 25: Cad model views

14. Physical Prototype

The first physical prototype is important for the new product. To make this first prototype fast and cheap, the model will be printed by a 3-D printer.

Fused Deposition Modeling (FDM) or 3D printer is a low-cost process to get a prototype or proof-of-concept. A filament of plastic (ABS, PLA, HIPS, Nylon, etc.) is fed into an extruder, melted and deposited on a platform based on instructions (G-Code) from a computer.

This process was made in the Innovation Studio of the University of Illinois at Urbana-Champaign. A $60 (€57.62) card was given to print the component.

The 3D printer used for this project was Lulzbot TAZ 6. These are the technical specifications of this 3D printer:

- Tool Head: TAZ Single Extruder Tool Head v2.1, 0.50mm nozzle
- Layer Resolution: 0.05 mm - 0.4 mm (0.002 in - 0.02 in)
- Max Hot End Temperature: 290°C
- Print Surface: Borosilicate Glass/PEI
- Max Print Surface Temperature: 120°C
- Leveling: Automatic Z-Axis Compensation
- Certifications: FCC, CE, WEEE, OSHWA, FSF-RYF
- Print Volume Dimensions: 280 mm x 280 mm x 250 mm (11.02" x 11.02" x 9.80")
- Print Volume: 19,600 cm³ (1,185 in³)
- Cost: $2500 (€2197)

Figure 26: Lulzbot TAZ 6 3D printer

The 3D printing filament chosen for this prototype was PLA and the support material was Brim. The software to generate the G-Code was Cura. The position of the component was chosen to use the least amount of support material. However, the total weight of the prototype was 61 grams (30 grams of support material and 31 grams of useful material). The printing time was about 3 hours and 20 minutes. All this information is in the next figure.

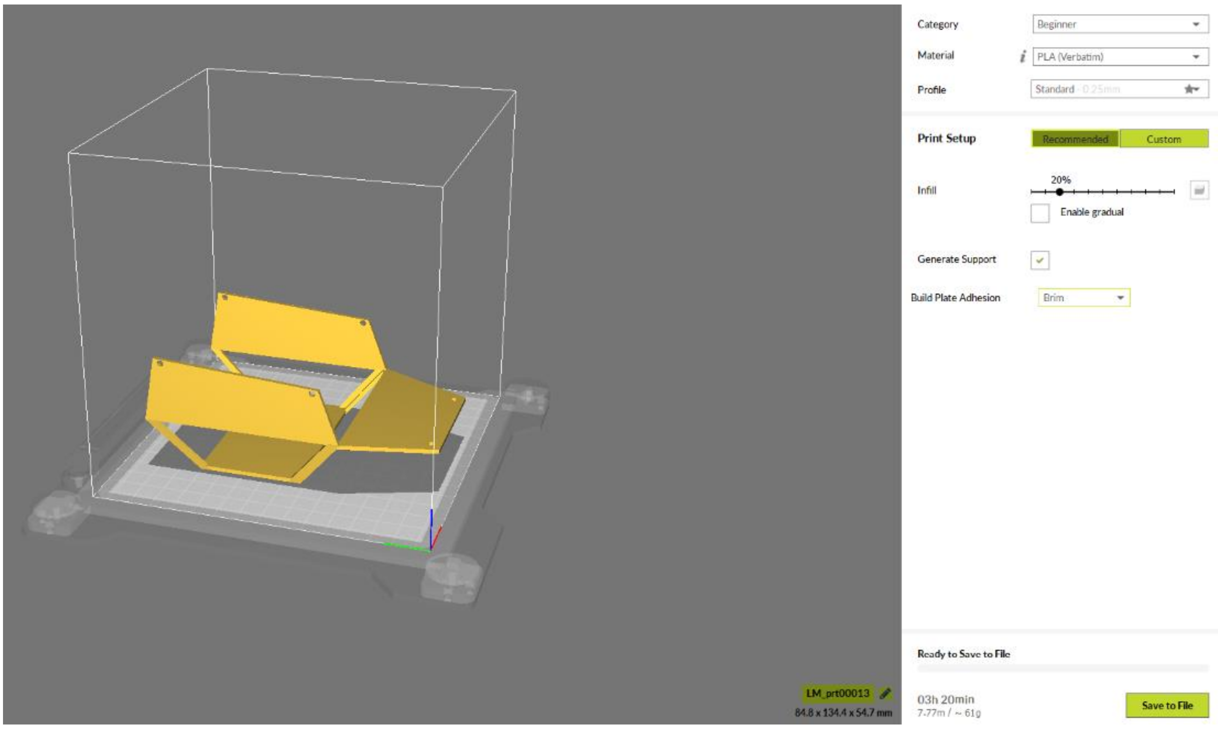


Figure 27: Cura software

In the next images it is showed how the machine print the prototype with the support material and the final result of this first prototype after removing the support material.

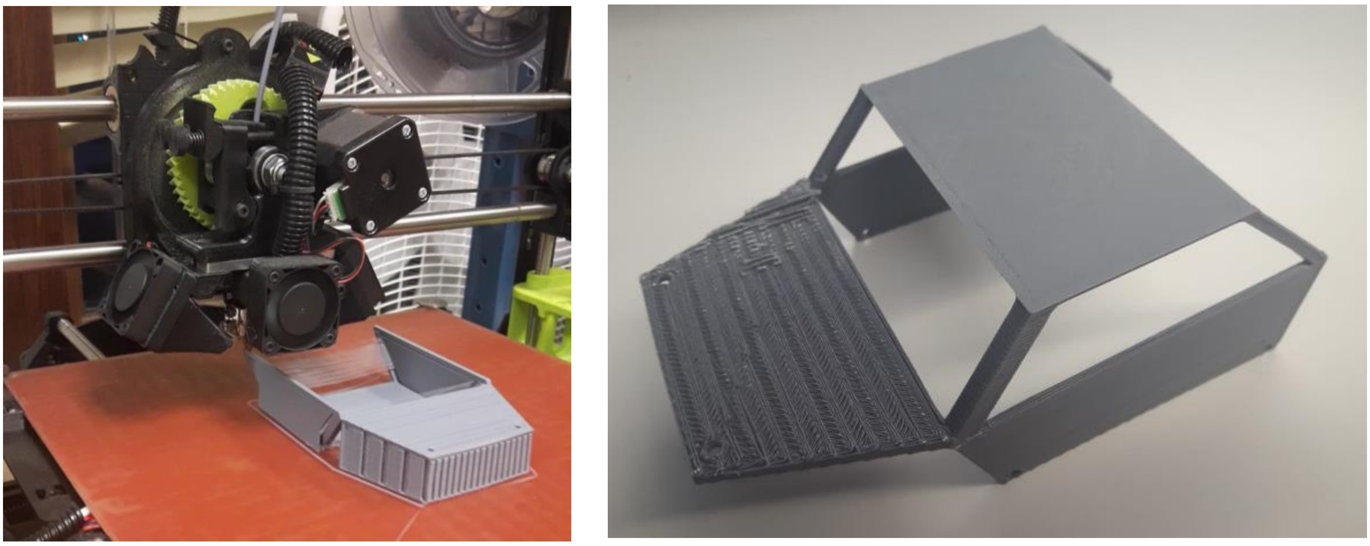


Figure 28: 3D printing process

Figure 29: Printing process and first prototype

When it was tried to make the union with the car structure, it was seen that it did not fit well. Therefore, it was decided to repeat the printout by scaling the z-axis to 90 mm instead of 84.7 mm. Only the scale of impression was changed, no other dimension. Once the panels were printed, could be verify that this model fits well. Bellow there are some images to see the second prototype.

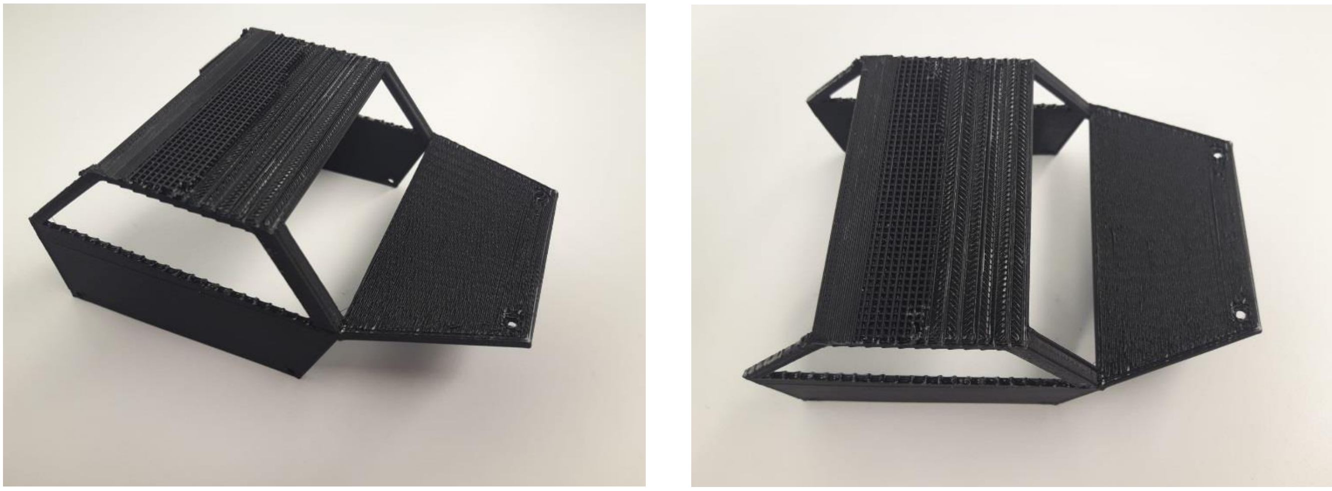


Figure 30: Second prototype

15. Design of experiment analysis

In this point a design for experiment analysis will be done. The output variable selected is assembly time and the input variables are number of screws, number of components without screws and weight of the product. This point will determinate which of these design requirements affect assembly time and which don´t affect. These design requirements are denominated x1, x2 and x3 respectively.

The range chosen for each design requirement is based in the original product (High) and the redesigned product (Low). The original product has 93 screws and 45 components and the final product has 83 screws and 42 components (10 DIN 7983 M2x6 screws and 3 panels less). Product weight range is between 400 grams and 600 grams.

Variable	Variable Description	Low (-1)	High (+1)
x1	Nº Screws	83	93
x2	Nº Components (without screws)	42	45
x3	Weight	400	600

Table 11: Input variables

In the next table, 3 trials will be done in each situation to know how much the assembly time changes if one input variable change from Low (-1) to High (1). Trial units are seconds, all between 585 and 669. These times are similar to the assembly time calculated in point 9 (658,5 seconds). Average, standard deviation and variance of these trials will be calculated.

Test	x1	x2	x3	Trial 1	Trial 2	Trial 3	Avg. Defects	Std Dev	Variance
1	-1	-1	-1	594	585	589	589,33	4,51	20,33
2	1	-1	-1	651	649	642	647,33	4,73	22,33
3	-1	1	-1	597	601	604	600,67	3,51	12,33
4	1	1	-1	669	649	657	658,33	10,07	101,33
5	-1	-1	1	591	586	593	590,00	3,61	13,00
6	1	-1	1	648	653	643	648,00	5,00	25,00
7	-1	1	1	605	598	602	601,67	3,51	12,33
8	1	1	1	661	656	660	659,00	2,65	7,00

Table 12: Assembly time trials

Using the average column, the next table is fixed. The first row is the effect value, which is ordered from highest to lowest. The effect value is calculated using the next formula. Some examples are the followings:

$$E_1 = \frac{1}{4}[(-1 * 589{,}33) + (1 * 647{,}33) + (-1 * 600{,}67) + (1 * 658{,}33) + (-1 * 590) + (1 * 648) + (-1 * 601{,}67) + (1 * 659)] = 57{,}75$$

$$E_{12} = \frac{1}{4}[(-1 * -1 * 589{,}33) + (1 * -1 * 647{,}33) + (-1 * 1 * 600{,}67) + (1 * 1 * 658{,}33) + (-1 * -1 * 590) + (1 * -1 * 648) + (-1 * 1 * 601{,}67) + (1 * 1 * 659)] = -0{,}25$$

$$E_{123} = \frac{1}{4}[(-1 * -1 * -1 * 589{,}33) + (1 * -1 * -1 * 647{,}33) + (-1 * 1 * -1 * 600{,}67) + (1 * 1 * -1 * 658{,}33) + (-1 * -1 * 1 * 590) + (1 * -1 * 1 * 648) + (-1 * 1 * 1 * 601{,}67) + (1 * 1 * 1 * 659)] = -0{,}083$$

Where E_1 is the effect value of x1 interaction, E_{12} is the effect value of x1 and x2 together and E_{123} is the effect value of all variables together.

To calculate the probability, the following equation is used:

$$P_i = \left(\frac{100 * (i - 0.5)}{2^n - x}\right)$$

Where: i = the rank of the effect, n = the total number of variables varied in the experiment (i.e., three in our case), $(2^n - x)$ tells the number divisions out of 100% were needed to make. In this case, it was needed 7 divisions to account for all the residual values.

So, $(2^n - x) = 7 \rightarrow x = 1$.

The standard deviation is calculated with

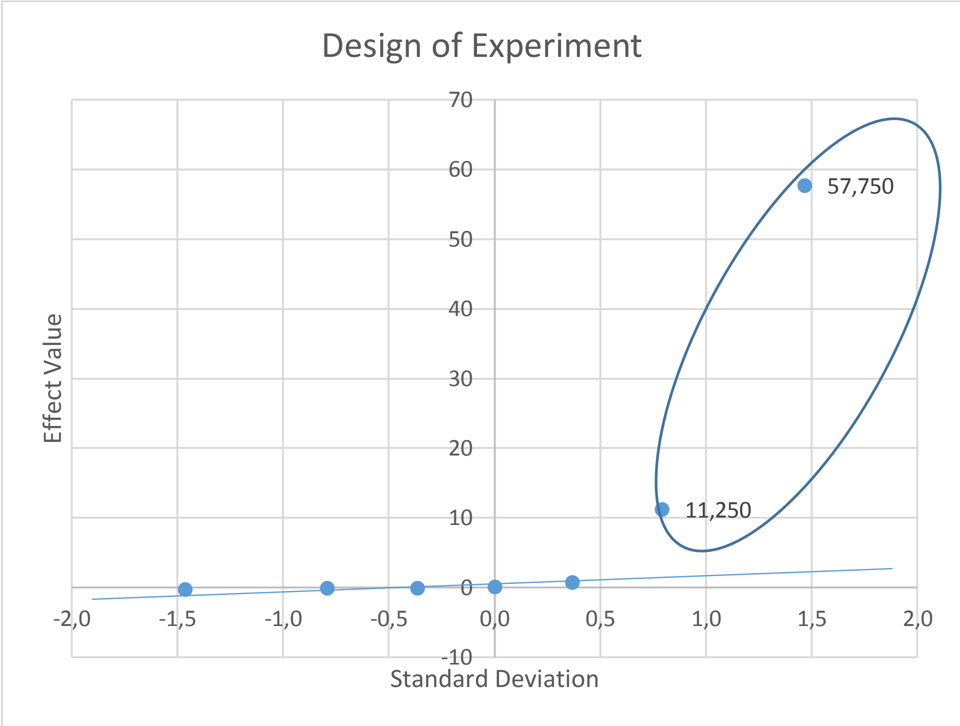
NORM.INV(%_value_decimal,mean(=0),standard_deviation(=1)) command in Excel

using the probability calculated above.

Rank	1	2	3	4	5	6	7
Effect Value	57,750	11,250	0,750	0,083	-0,083	-0,083	-0,250
Probability	92,857	78,571	64,286	50,000	35,714	21,429	7,143
Standard Dev.	1,465	0,792	0,366	0,000	-0,366	-0,792	-1,465
Effect	E1	E2	E3	E23	E13	E123	E12

Table 13 : Design of experiment probabilities

Plotting the probability and the standard deviation of Table 11, the input variables which affect the assembly cost can be known.



Graphic 7: Design of experiment plot

On this plot, a straight line was drawn which goes through the middle point and the point immediately adjacent that gives the most shallow (smallest in magnitude) slope. If all data points appear to be randomly distributed along a line drawn through the data, and the line passes on/near the intersection of the mean effect and 0.00 standard deviations (50% probability), the fit of the data to the normal distribution is considered good. Any points falling on or near this line should be considered insignificant effects. Any points above this line in the right half plane or below the line in the left half plane are considered significant.

In this case, there are two significant points which have an effect value of 57.75 and 11.25. In Table 11, these effect values correspond to E1 and E2 respectively. Other values are near the line was drawn and are insignificant for the analysis. E1 and E2 are the effect of variables x1 and x2. This means the number of screws and components of the product have significant effect in the assembly time but product weight hasn´t any significant effect in this output variable.

16. Comparing both components

As it can be seen in the next figures, the second prototype is assembled to the main block. The Cad model has the right dimensions and the screws can be screwed to fix the piece to the main block.

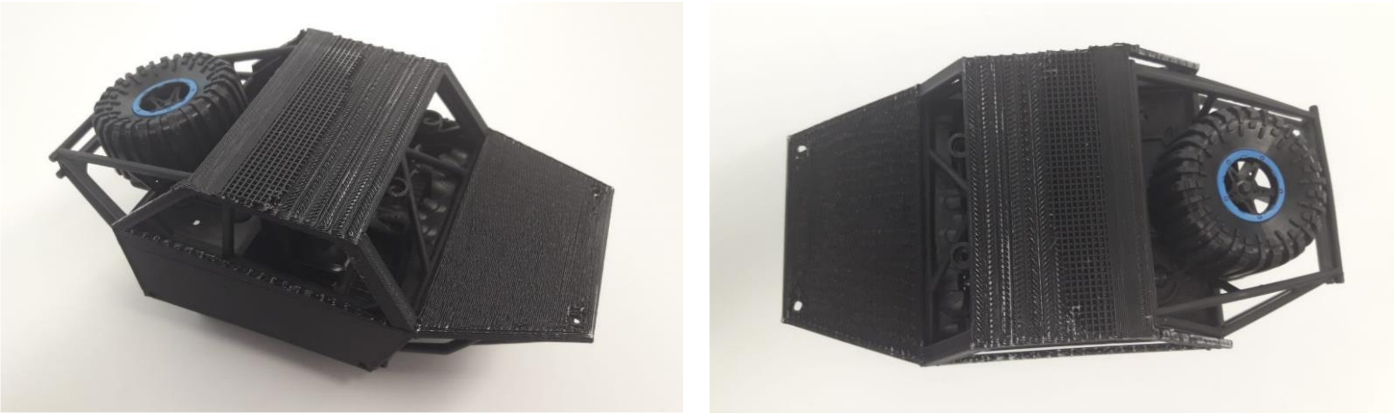
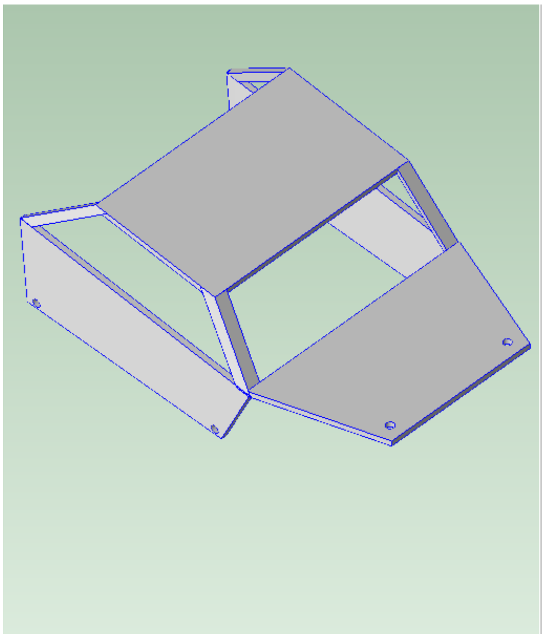


Figure 31: Redesigned component assembly

Once it's verified that the prototype is correct, a cost analysis will be done to know how much cost manufacture the redesigned component. The entry data for the aPriori software are 75000 cars per year during 5 years as it was explained in the point 11. The material chosen is ABS and the manufacturing process is plastic molding. The results of the analysis are explained in the next figure.



Variable Costs	Current (USD)
Material Cost	0.09
Labor	0.05
Direct Overhead	0.06
Amortized Batch Setup	0.01
Logistics	0.00
Material Overhead	<0.01
Expendable Tooling	0.00
Additional Direct Costs	0.00
Extra Costs	0.00
Other Direct Costs	<0.01
Total Variable Costs	0.22
Period Costs	
Indirect Overhead	0.05
SG&A	0.02
Margin	0.00
Piece Part Cost	0.29
Fixed Costs	
Hard Tooling (amortized)	0.08
Fixture Cost (amortized)	0.00
Programming Cost (amortized)	0.00
Additional Amortized Investments	0.00
Total Amortized Investments	0.08
Fully Burdened Cost	0.37
Capital Costs	
Hard Tooling	29,066.20
Fixture Cost	0.00
Programming Cost	0.00
Total Capital Investments	29,066.20

Figure 32: aPriori redesigned product

Finished the analysis of the redesigned component, a comparison between the original and the new component can be made. The next table shows the different between both in some important aspects.

	Original	Redesigned
Thickness (mm)	0,5	2
Nº Components	4	1
Nº Screws	16	6
Cost	$1,03 / €0,91	$0,37 / €0,33
Investments	$82632,86 / €72609	$29066,2 / €25540

Table 14: Components comparison

The first row shows the thickness of each component. The new design has 2 mm instead of 0.5 mm. This makes the car structure stronger against impact. The thickness has increase 4 times the original one so it is more difficult to break the structure in a crash. The main consequence of this change is that the life span of the product will increase considerately. The users reviews say most of the electric toy cars failure because a crash, when the main block breaks. Number of refunds will decrease and the company will be recognized for making reliable and durable cars.

The second and third row show the number of components and screws respectability. The redesigned component has only one while the original component had four. This means the number of components are reduced in a factor of 4.

Furthermore, the screws number used to assemble the original components were 16 while the new assembly only needs 6 of them. Also, will be easier to dissemble if the user have to repair or maintain the product. Obviously, the assembly cost and time will be reduced because it is faster assemble one component with six screws than assemble four panels with sixteenth screws. In addition, the actual assembly line is manual and this different is greater than if the assembly line was automatic. This is because two pieces can´t be assembled at the same time in a manual assembly line but in an automatic assembly line it is possible. Later, a DFM analysis of the new product will be done to compare the assembly time of both products.

In terms of environmental effects, this component is like the original one. Both has the same material and should be recycled when the useful life ends. Almost all components of the product can be recycled or reused in other products.

The last two rows are prices. The cost of manufacture the four original panels were $1.03 (€0.91) as it was calculated in point 11. In the cost analysis of the new component, at the beginning of this point, shoes that the redesigned component cost $0.37 (€0.33). The cost was reduced almost 1/3 of the original cost.

Moreover, the capital investment the company must make to by machines, molds, etc. for the plastic molding process will be reduced from $82632,86 (€72609) to $29066,2 (€25540). The first number is the sum of all the investment and can be different depends on number of machines or if the company uses multi-cavity molds. Even so, the capital invested to realize the new component will be lower than the current one.

The next step is make a DFM analysis to verify the assembly time of the redesigned product is less than the original assembly time. The next table shows the results of this analysis following the instructions shown in Appendix III.

Assembly Table

								Handling and Alingment		Insert and Secure		
Operation Number	Times Operation is Carried Out	Part Description	Part Required	Alpha (deg)	Beta (deg)	Size (mm)	Thickness (mm)	Description	Time (sec)	Description	Time (sec)	Total Time (sec)
1	1	Car structure	Yes	360	360	175	65	0,5+(360+360)/360	2,5	0,5+0,3	0,8	3,3
2	1	Panels	Yes	360	360	78	2	0,5+(360+180)/360+0,1	2,6	0,5+0,3	0,8	3,4
3	1	Battery box	Yes	360	180	115	40	0,5+(360+180)/360	2	0,5+0,3	0,8	2,8
4	1	Cover of battery box	Yes	360	360	70	3	0,5+(360+360)/360+0,1	2,6	0,5+0,3	0,8	3,4
5	4	Shafts join	Yes	360	360	20	12	0,5+(360+360)/360	2,5	0,5+0,3	0,8	13,2
6	6	Transmission shafts	Yes	360	360	50	8	0,5+(360+360)/360	2,5	0,5	0,5	18
7	4	Suspensions	Yes	180	180	68	10	0,5+(180+180)/360	1,5	0,5+0,3	0,8	9,2
8	4	Springs	Yes	180	180	68	10	0,5+(180+180)/360+0,4	1,9	0,5+0,4	0,9	11,2
9	5	Cables	Yes	180	180	130	3	0,5+(180+180)/360+0,3	1,8	0,5	0,5	11,5
10	58	Screw DIN 7983 M2x6	Yes	360	0	6	2	0,5+(360+0)/360+0,5	2	0,5+0,3+1+2	3,8	336,4
11	6	Screw DIN 7982 M2x3	Yes	360	0	3	2	0,5+(360+0)/360+0,5	2	0,5+0,3+1+2	3,8	34,8
12	7	Screw DIN 7981 M2x4	Yes	360	0	4	2	0,5+(360+0)/360+0,5	2	0,5+0,3+1+2	3,8	40,6
13	12	Screw DIN 7981 M3x6	Yes	360	0	6	3	0,5+(360+0)/360+0,5	2	0,5+0,3+1+2	3,8	69,6
14	4	Wheels	Yes	180	0	35	25	0,5+(180+0)/360	1	0,5	0,5	6
15	4	Tire of wheel	Yes	180	0	70	30	0,5+(180+0)/360	1	0,5	0,5	6
16	2	Motor	Yes	360	360	50	25	0,5+(360+360)/360	2,5	0,5	0,5	6
17	1	Electric board	Yes	180	180	40	10	0,5+(180+180)/360	1,5	0,5+0,3	0,8	2,3
18	2	Motor box	Yes	360	360	55	30	0,5+(360+360)/360	2,5	0,5+0,3	0,8	6,6
19	2	Transmission shafts	Yes	180	180	140	3	0,5+(180+180)/360+0,3	1,8	0,5+0,3	0,8	5,2
											Total AssemblyTime	589,5

Table 15: Assembly time redesigned product

The original product assembly time was around 658.5 seconds, around 11 minutes. Changing the panels' number from 4 to 1, the thickness of these panels from 0.5 mm to 2 mm and the number of DIN 7983 M2x6 screws from 16 to 6, the obtained result is an assembly time of 589.5 seconds for the redesigned product. This means using the new component, the company save around 69 seconds assembling each product.

All in all, a new component was created which improve the resistance against impact, with the same material as the original component, cost almost 1/3 less than the original one and save 69 second of assembly in each product. Using this redesigned component, the final product will be durable, more transportable, cheaper and stronger against impact which means more revenue, life span and less failure rate.

Bibliography

Question 2

- Toy market
  - Renee, Michelle. "Pricing Structure in the Toy Industry." Small Business - Chron.com, http://smallbusiness.chron.com/pricing-structure-toy-industry-34444.html.
  - Deena M. Amato-McCoy. February 8, 2018. “Study: Toys were big play for Amazon in 2017“. Chainstorage.com. https://www.chainstoreage.com/technology/study-toys-big-play-amazon-2017/
  - Desmond, Edward. 2017. “Economic Impact Data”. Toyassociation.org http://www.toyassociation.org/ta/research/data/impact/toys/research-and-data/data/economic-impact-data.aspx
  - ECSIP Consortium. Rotterdam, August 30, 2013. “Study on the competitiveness of the toy industry”. https://webcache.googleusercontent.com/search?q=cache:IV-LpJHKmBMJ:https://ec.europa.eu/docsroom/documents/6653/attachments/1/translations/en/renditions/native+&cd=1&hl=en&ct=clnk&gl=us
- Toy vehicle market
  - Toy Industry Association. (n.d.). Sales of toy vehicles in the U.S. from 2003 to 2018 (in billion U.S. dollars). In Statista - The Statistics Portal. https://www.statista.com/statistics/247415/toy-sales-in-the-us--toy-vehicles/.
- Predictions
  - Gottlieb, Richard. Global Toy Experts. November 13, 2017. “10 predictions for the toy industry in the year 2022”. Spielwarenmesse.de. https://www.spielwarenmesse.de/magazine/article-detail/10-predictions-for-the-toy-industry-in-the-year-2022/language/1/
  - Aritzon. October 2018. “Toys Market-Global Outlook and Forecast 2018-2023”. Researchandmarket.com. https://www.researchandmarkets.com/research/wlc6s2/global_toys?w=5

Question 3

- Caroline, Hangzhou Bold Toys Co. E-mail: bold@tuarisata.com Telephone: 13750876992
- Liebenberg, Leon. “Lecture Notes 7 – Plastic Molding”. University of Illinois at Urbana-Champaign. March 14, 2019.

Question 4

- Battles, Christopher. April 21, 2010. “Full_HOQ_0.9”. www.uw-s.com/wp-content/uploads/2014/01/Full_HOQ_0.9.xlsx

Question 5

- Jackson, Ethan. April 28, 2019. “Best Remote Control Cars 2019 – Top 10 Best RC Cars Reviews”. Staplesearch.com. https://staplesearch.com/best-remote-control-cars/

Question 6

- Battles, Christopher. April 21, 2010. “Full_HOQ_0.9”. www.uw-s.com/wp-content/uploads/2014/01/Full_HOQ_0.9.xlsx

Question 7

- Midstate Mold. January 23, 2017. “Most common thermoplastics used in injection molding”. Midstatemold.com. https://www.midstatemold.com/common-thermoplastics-injection-molding/
- Tempelman, Erik; Shercliff, Hugh and Ninaber Van Eyben, Bruno. 2014. “Manufacturing and Design”
- https://www.protolabs.es/servicios/moldeo-por-inyeccion/moldeo-por-inyeccion-de-plasticos/
- Worth, Jill. The Rodon Group. August 28, 2018. “Injection Molds 101: Cold Runner vs. Hot Runner Molds. Rodongroup.com. https://www.rodongroup.com/blog/injection-molds-101-cold-runner-vs-hot-runner-molds

- MDI. May 26, 2016. "Injection Molds – Cold Runner Vs. Hot Runner" Moldeddevices.com. https://www.moldeddevices.com/2016/05/26/injection-molds-cold-runner-vs-hot-runner/
- Universidad Pontificia de Comillas, Madrid (2019). CES EduPack (2013)
- Caroline, Hangzhou Bold Toys Co. E-mail: bold@tuarisata.com Telephone: 13750876992

Question 8

- Caroline, Hangzhou Bold Toys Co. E-mail: bold@tuarisata.com Telephone: 13750876992

Question 9

- Liebenberg, Leon. "Lecture Notes 10 - Designing for Assembly". University of Illinois at Urbana-Champaign. April 23, 2019.

Question 10

- University of Illinois at Urbana-Champaign (2019). CREO Parametric (2.0)

Question 11

- University of Illinois at Urbana-Champaign (2019). aPriori.

Question 13

- University of Illinois at Urbana-Champaign (2019). CREO Parametric (2.0)

Question 14

- https://innovationstudio.mechse.illinois.edu/tools/3d-printers/
- https://www.lulzbot.com/store/printers/lulzbot-taz-6
- University of Illinois at Urbana-Champaign (2019). Cura LulzBot Edition (3.6.3)

Question 15

- Liebenberg, Leon. "Lecture Notes 8 - Statistical Design of Experiments". University of Illinois at Urbana-Champaign. April 2, 2019.
- Flachsbart, Bruce. October, 2018. "Lab 5 – Instructions for IM Lab – Week 1" University of Illinois at Urbana-Champaign. April 9, 2019.

Question 16

- Liebenberg, Leon. "Lecture Notes 10 - Designing for Assembly". University of Illinois at Urbana-Champaign. April 23, 2019.
- Liebenberg, Leon. "Design for Assembly - Tabulation Approximations". University of Illinois at Urbana-Champaign. April 16, 2019.
- University of Illinois at Urbana-Champaign (2019). aPriori.

Appendices

Appendix I

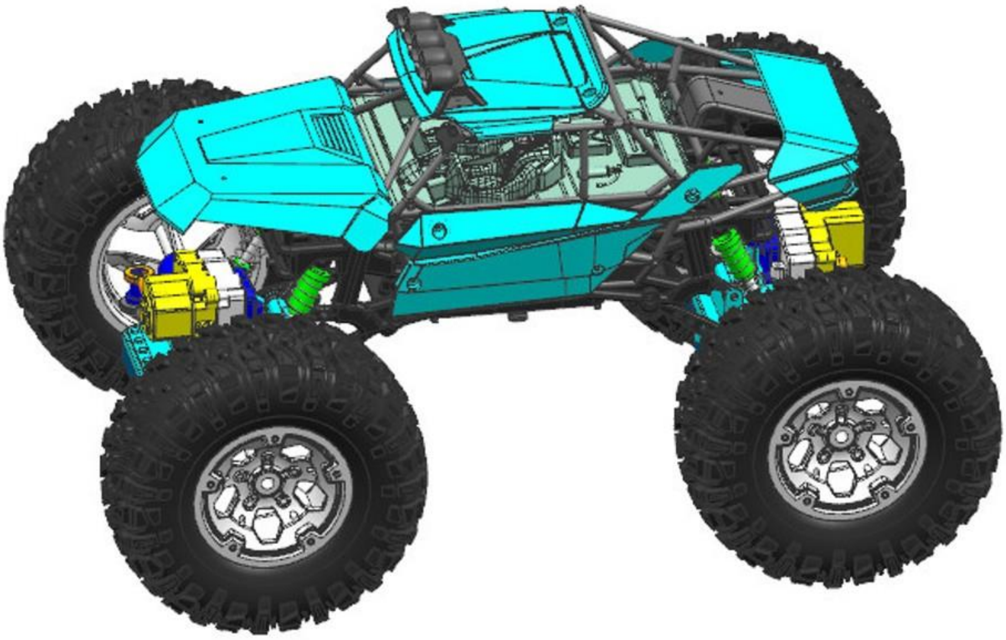


Figure 33: Product image 1

Figure 34: Product image 2

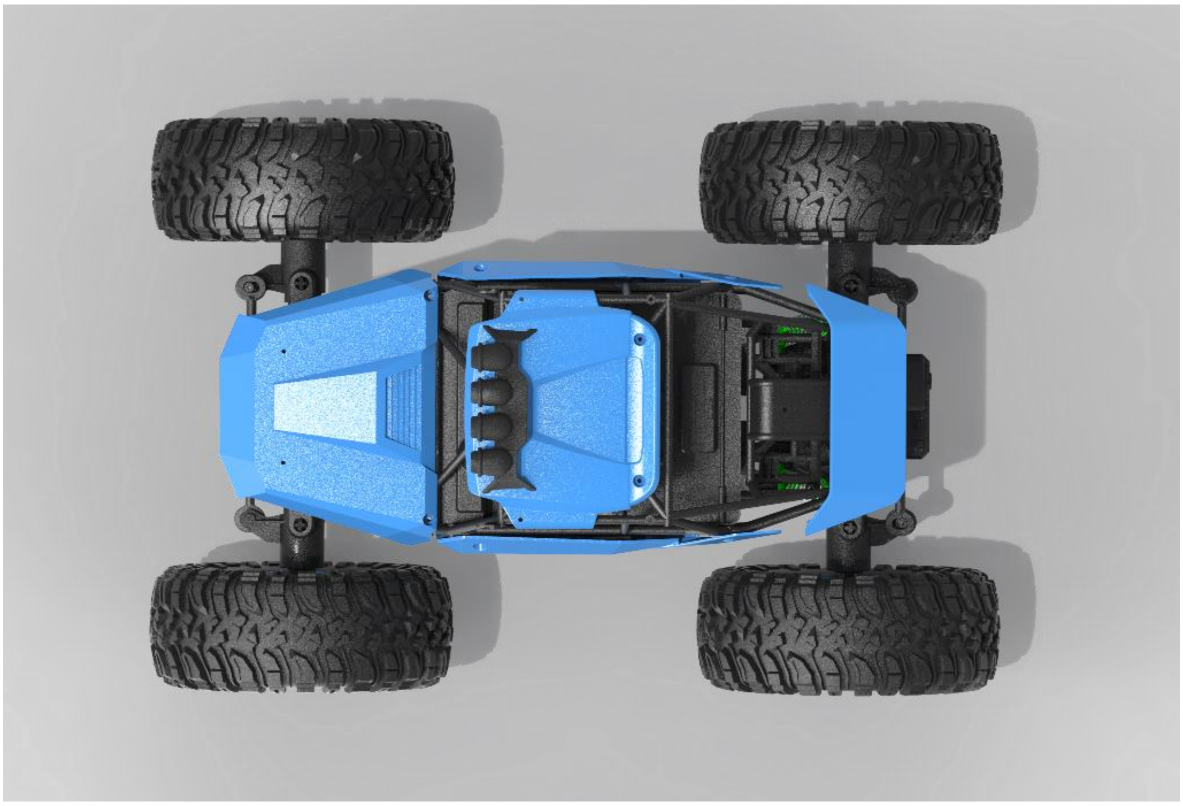


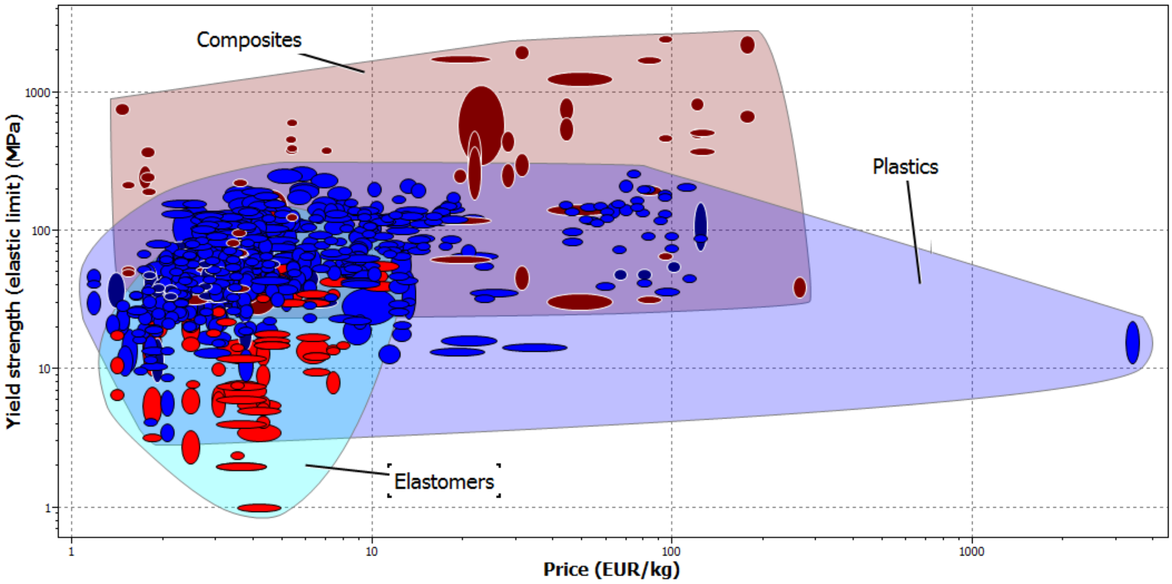
Figure 35: Product image 3

Figure 36: Product image 4

Figure 37: Product image 5

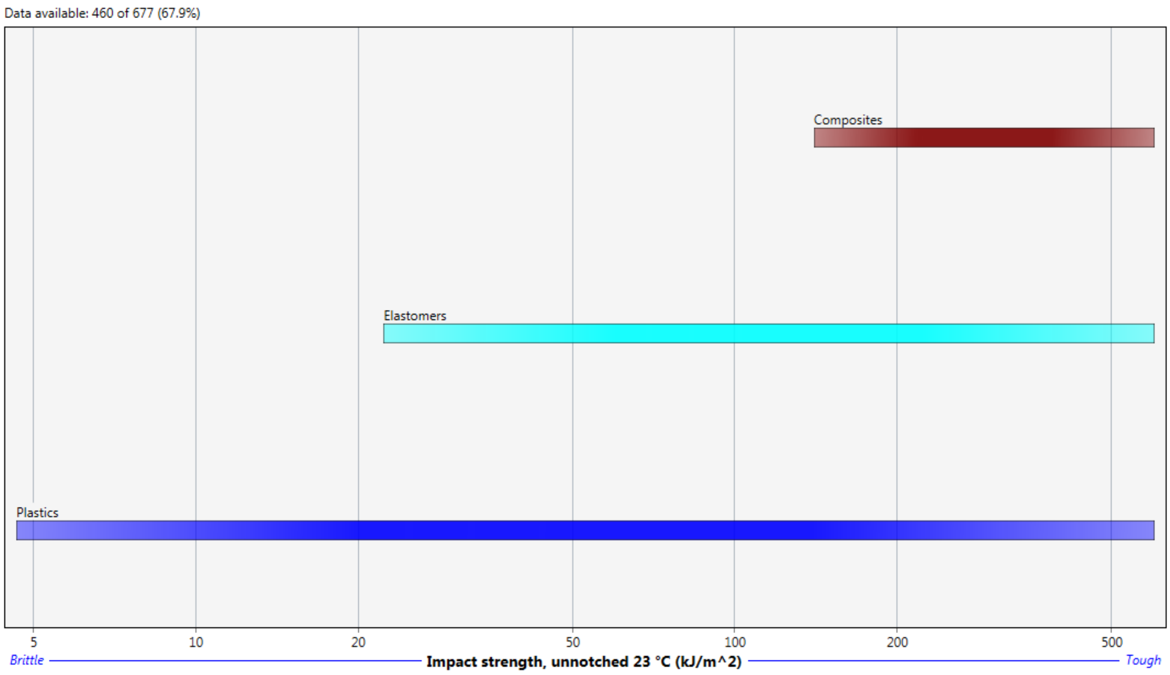
Appendix II

Using CES Edupack software, a material analysis will be done for the product. First of all, only elastomers plastic materials will be taken in account because the company use injection molding process to manufacture the majority of components. The software has 676 elastomers plastic materials. In the next steps, some restrictions will be applied to reduce this list of materials.



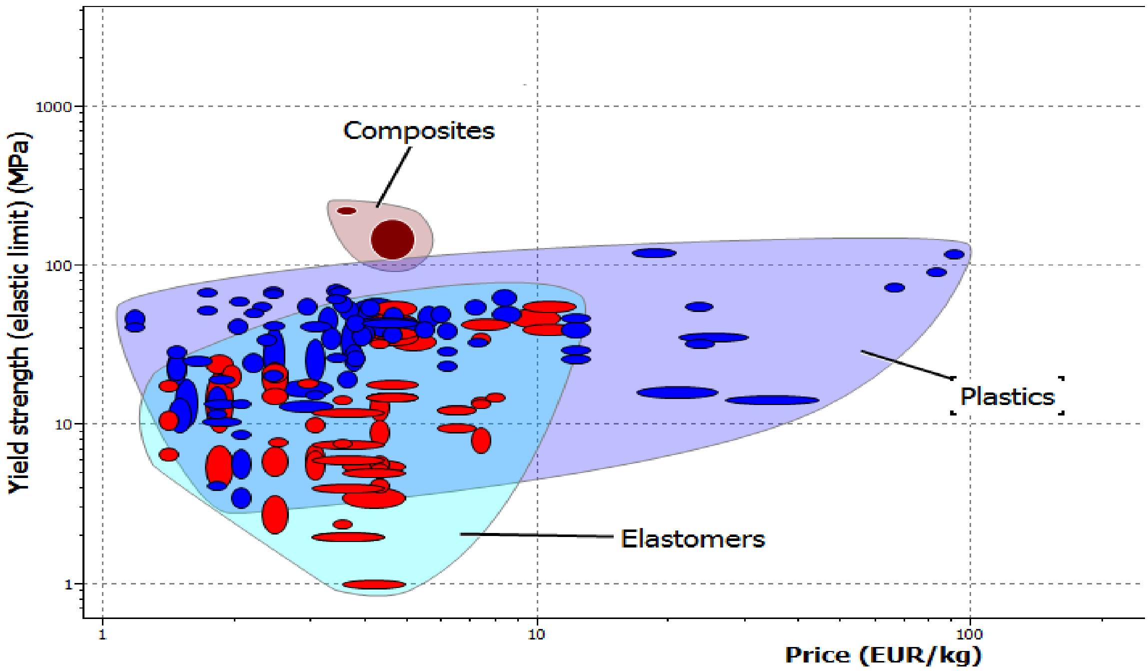
Graphic 8: Material analysis 1

One of the customer requirements is the product resistance against impacts. In this figure, different types of materials are shown their impact strength. First restriction is that the material must have a minimum impact strength of 300 KJ/m^2.



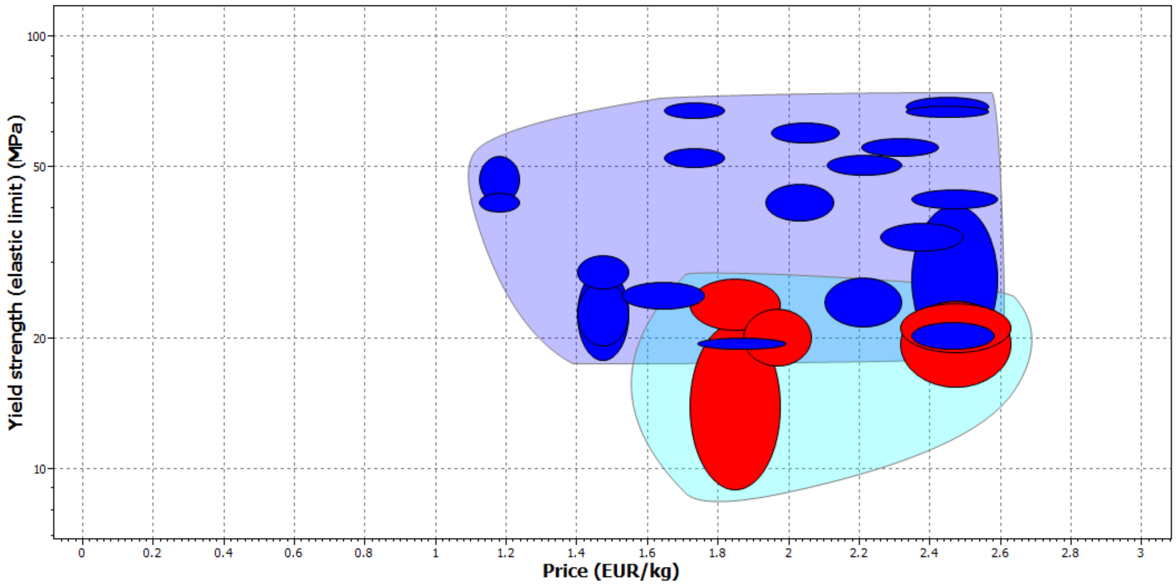
Graphic 9: Material analysis 2

Also, the material must have an excellent water resistance, in salty and fresh water. In this way, the toy can be used even if it has rained.



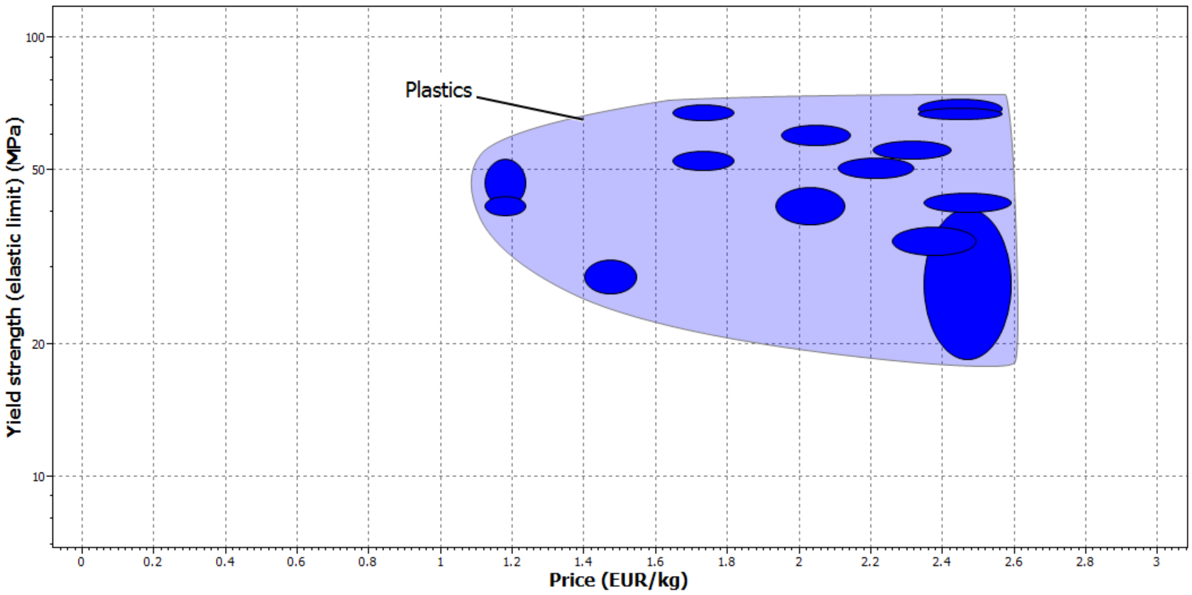
Graphic 10: Material analysis 3

Applying these restrictions, material list has reduced to 142. To reduce more materials, the material price must be less than 2.5 EUR/kg and the Yield strength more than 20 MPa because the company want a cheaper product and resistant materials.



Graphic 11: Material analysis 4

Now, the list has 25 materials such as ABS, PP, POM, PE and PVC. Increasing Yield strength to 30 MPa, the material list is reduced to 14.

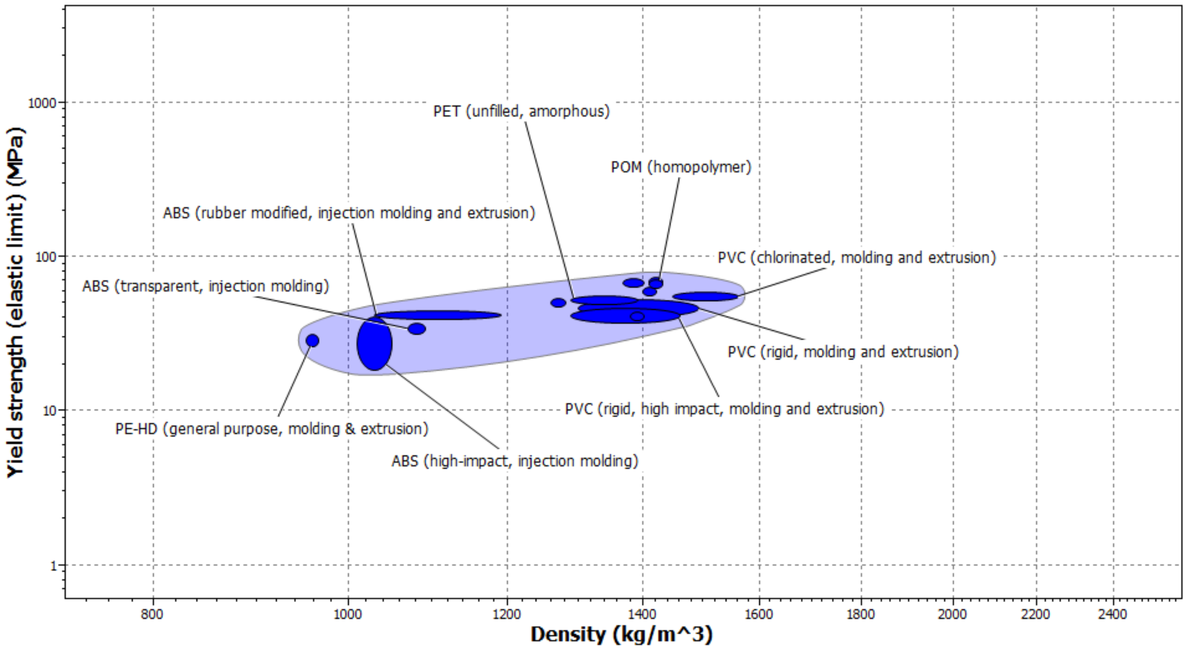


Graphic 12: Material analysis 5

- ABS (high-impact, injection molding)
- ABS (rubber modified, injection molding and extrusion)
- ABS (transparent, injection molding)
- PE-HD (general purpose, molding & extrusion)
- PET (unfilled, amorphous)
- PET (unfilled, semi-crystalline)
- PETG (unfilled)
- POM (homopolymer)
- POM (homopolymer, UV stabilized)
- POM (terpolymer, extrusion and blow-molding)
- PVC (chlorinated, molding and extrusion)
- PVC (rigid, high impact, molding and extrusion)
- PVC (rigid, lead stabilized)
- PVC (rigid, molding and extrusion)

Table 16: Material list 1

Other customer requirement is lightweight. The product should be light so the material must have low density. Comparing density vs. yield strength, two different groups can be identified. ABS and PE-HD have low density and PET, POM and PVC have higher density.

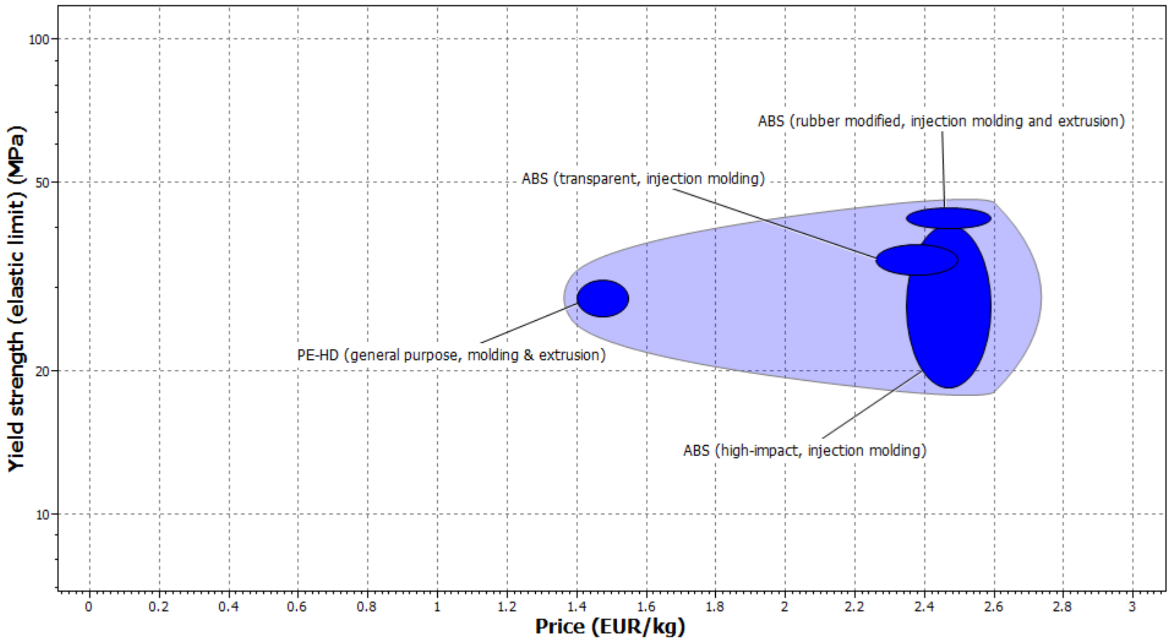


Graphic 13: Material analysis 6

Chosen low density materials, the material list is reduced to the next four materials:

- ABS (high-impact, injection molding)
- ABS (rubber modified, injection molding and extrusion)
- ABS (transparent, injection molding)
- PE-HD (general purpose, molding & extrusion)

Table 17: Material list 2



Graphic 14: Material analysis 7

Appendix III

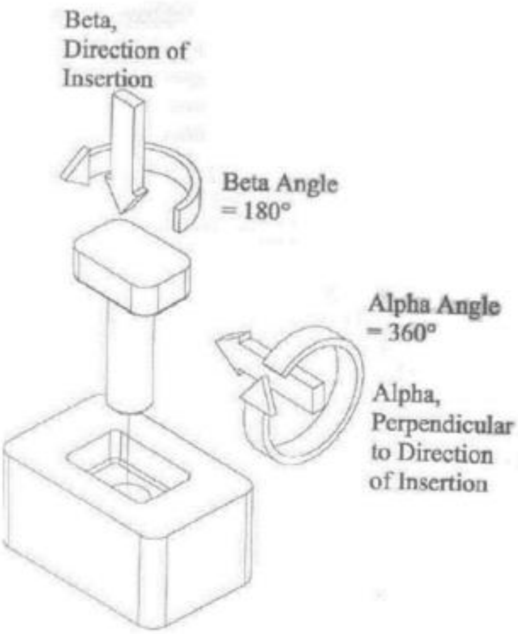


Figure 38: Alfa and beta angles

- Handling & Alignment:
  - Part fetch time: 0.5s / 0.5m distance (0.5s minimum)
  - Symmetry: add (α + β) / 360 seconds
  - Part size: small (*L* < *2 cm*) add 0.5s,
    large (*L* > *20 cm*) add 0.3s
  - Each handling difficulty (sharp, tangle, flexible, etc.) add 0.4s
  - Aspect ratio > 20 add 0.1s, aspect ratio > 40 add 0.3s

- Insert & Secure:
  - General placement: 0.5s
  - Align to small hole (<2mm) add 0.7s, align to a medium hole (2 < hole < 4mm) add 0.3s,
  - Align to pin (opposite of a "hole"), small (<2mm) add 0.4s, medium (2 < pin diameter < 4mm) add 0.1s.
  - Requiring a grasping aid (tweezer, special gloves, magnifying glass) add 1.4s.
  - Turning insertion (e.g. starting a nut or screw) add 1s.
  - Snap: add 0.3s, Crimp: add 0.8s
  - Final screw tightening: add 2s (for one sided, e.g. screw) or 7s (for two sided, e.g. nut on a bolt)
  - For each insertion difficulty (view, force, spring, hold (i.e. needs 2 hands), tight tolerance etc.) add 0.4s
  - Rotate base (i.e. turning the assembly over): 1.8s

Figure 39: Assembly time method