CONCEPT DESIGN OF AN ONLINE TOOL TO IMPROVE GREEN PUBLIC PROCUREMENT AND DESIGN OF A PIECE OF URBAN FURNITURE WITH THE ENVIRONMENTAL CRITERIA USED IN THE TOOL

Bachelor's Thesis

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REPORT

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1. Aim and Reason

This project aims to develop the concept and graphic design of the GUF Tool (Green Urban Furniture Tool); online software aimed to encourage green public procurement (GPP), and to design an element of sustainable urban furniture taking into consideration the selection criteria used in the tool.

The GUF tool is born as part of the European LIFE Future Project, whose main goal is to develop said tool in a collaborative effort from various entities: AIJU, AIMPLAS, Inndea Valencia, City of Koprivnica, ACR+ and UJI. Therefore the project is born in this frame of work and part of it is developed in direct collaboration with these entities, this project will follow the concept design and the graphic image development of LIFE Future and of the GUF Tool.

Encouragement and promotion of GPP in Europe is the main purpose of the LIFE Future Project and thereby of the GUF Tool, prompting public authorities throughout Europe to think about the environmental aspects of the public furniture and inciting them to make a conscious effort to buy greener products. The GUF tool will be a means to bring public authorities closer to the complicated topic of Life Cycle Assessment (LCA), the analysis of the environmental impacts derived from a product, considering all the stages of its life. The tool intends to facilitate the comprehension of complicated environmental facts and provide understandable and accountable results with which to make informed purchase decisions.

The implementation and widespread of the GUF tool throughout the European Union is the goal for LIFE Future authorities and promoters. Once this is achieved, using the GUF Tool will be a common step in public procurement and it is expected it will tempt manufacturers to produce more Eco designed products, ultimately resulting in a significant shift towards sustainability.

As it can be seen, the end user of the tool (a public authority, such as a town hall worker) has a low level of expertise and little interest in LCA, therefore a large objective of the GUF Tool is to be comprehensible to non-experts as well as compelling and enjoyable to use, so to encourage its frequent use and reach. The project shows the need for a good and clear graphic design in improving usability and refining the user experience.

Public authorities and Urban Furniture (UF) manufacturers are the main focus in the project, considered the main stakeholders. However, other users can benefit from the tool: designers. As this project will attempt to demonstrate, an independent designer can take advantage of the GUF Tool to create better, more sustainable and more competitive furniture. Designers - and the public in general - will be able to access the environmental criteria proposed and used in the tool and thereby have specific environmental requirements to use in their designs. In this project an element of urban furniture will be designed using the criteria set by the tool (by the project partners) and then will be compared to a standard item of the same product category to see if impact performance is improved.

1.1. UF ELEMENT JUSTIFICATION: WHY A SWING?

The LIFE Future Project stated that two elements of urban furniture from different product categories would be selected to serve as a baseline or as a reference with which to test the GUF Tool, these elements were chosen to be a bench and a playground. Choosing one of them as the element to design has been considered since the reference item can be easily used to compare the environmental performance, since the required information will be readily available.

Subsequently the decision came in choosing between a bench and a playground. For this purpose a number of factors were considered. In first place, with a quick background research it is easily evidenced that there is far larger variety in benches than in playgrounds, both Eco designed a traditional, therefore one can argue there is more room for innovation in playgrounds, specifically in swing sets where there is less variation.

Secondly, as seen in design trends, specifically in habitat design, playtime and leisure in society have found its way into many products in the past years. This points at the importance of play and time-out in the daily life, not only for children, but for adults too, therefore the idea of a playground is more suitable to be designed in this sociocultural context.

Taking into consideration the factors above and a personal interest in products and safety for children, the decision was made to design a playground element: a **swing set.**

2. Scope

LIFE Future Project is a large European project spanning over 3 years, for the purpose of this project and in relation to the participation in LIFE Future only a few stages of the development will be covered. Throughout the project some information and research that has been developed by other partners of the project will be seen, when so the source will be cited. The team at GID (Grupo de Ingeniería del Diseño) from the UJI has developed the GUF Tool concept design that can be seen in this project.

In first place, this project aims to arrange the logical mechanism of the GUF tool: how it works. This includes a map of the software, the different kinds of data input and output, the consideration of advantages to the different stakeholders and the establishment of environmental criteria, this last step in direct collaboration with other partners.

At the same time, a compelling graphic image concept will be designed for the GUF Tool and the project as a whole to be consistent throughout; the outcome of this graphic design will be in the form of a logo, a promotion poster and several screenshots of the software.

After the concept design of the tool is completed and the environmental criteria are set, an element of urban furniture of choice will be designed using the criteria as design requirements. The scope of the design includes detailed drawing with dimension specifications, justified material selection, basic structural calculations, and LCA comparison with a reference item of the same category[1].

Furthermore, the UF element will serve as a demonstration of the tool's mechanism, used to exemplify its functioning beyond a series of screenshots.

This project will also include a large amount of research and background investigation in a series of different topics that are relevant to the sections project, since some of this research will be done in collaboration with other LIFE Future project partners, the sources will be mentioned when that is the case.

3. Background

In this section the different contexts surrounding the project will be explained along with the state of the art each aspect.

3.1. PROJECT IMAGE

The LIFE Future partners had some preliminary ideas for the image and logo of the project, these were commissioned to an unrelated graphic design firm, Agence 1Terra, these can be seen below. However the project design had not been decided so a new image and logo were to be proposed.

Figure 1 : Designed by Agence 1Terra

Figure 2: Designed by Agence 1Terra

Figure 3: Designed by Agence 1Terra

Figure 4: Designed by Agence 1Terra

Along with the existing logo suggestions the project organization asked that the image should not be the typical "green" logo for environmental or sustainability products and services, they asked to create an innovative or unexpected way to portray the project identity.

3.2. GUF TOOL

In the design of the GUF Tool many aspects have to be considered. In first place the state of the art in LCA software and similar tools is searched and analysed, to learn about how they work and what features are desirable in the tool to develop. Secondly, in relation to the first item, options for product data transfer are explored. Another important characteristic is the graphic design of the tool; therefore a visual background in which media trends are explored is necessary. Finally, the GUF Tool will work following a series of environmental criteria that must be established by the project partners, for the purpose of context and documentation different European environmental criteria are collected and studied.

3.2.1. LCA Software

The GUF Tool will be based in Life Cycle Analysis, a procedure that studies the different environmental impacts for every aspect of the product. A LCA of an object includes, for instance, the carbon dioxide emission derived from the extraction of the materials, the water toxicity resulting from the manufacturing process and the waste generation for the disposal of the product, to name a few.

There are many LCA Software available, each with different characteristics and advantages, this section showcases a summary of the most relevant software and applications and conclusions derived from the research. The most interesting findings will be explained below, but other material is to be found in the LIFE Future project documentation, since this research was made in collaboration with the UJI partners.

Different aspects are taken into account when reviewing the programs:

1. Level of expertise required: level of knowledge of LCA necessary to perform an analysis using the software.
2. Size and reliability of the impact databases.
3. User interface: the usability and convenience of the interface.

Software	User Expertise	Database	User interface
ECO-it	Medium	Limited	Simple, unattractive
BEES	Medium/Expert	Large	Easy to understand, out-dated
OpenLCA	Expert	Custom	Good graphs and charts
Ecodesign PILOT	Medium	Limited	Out-dated, overwhelming
GaBi	Expert	Large	Complicated
SimaPro	Expert	Large	Complicated
Sustainable Minds	Medium	Medium	Attractive, intuitive, user-friendly
LCA Calculator	Medium	Large	Attractive, intuitive, user-friendly

Table 1 LCA Software comparison

SimaPro is probably the most used program to perform LCA analysis by experts and trained investigators, therefore a high level of understanding and knowledge of environmental aspects is necessary to use this software. The GUF Tool aims at a much less prepared user, someone who needs the results but does not know the science. That being the case, the level of complexity of SimaPro and other expert programs surpasses that expected from our user.

On the other side of the spectrum software like Sustainable Minds can be found. These are aimed at a user with a lower lever of expertise but interested in LCA, namely manufacturers, constructors and designers. They have a friendlier interface and usability stands out as can be seen in figures 1 and 2.

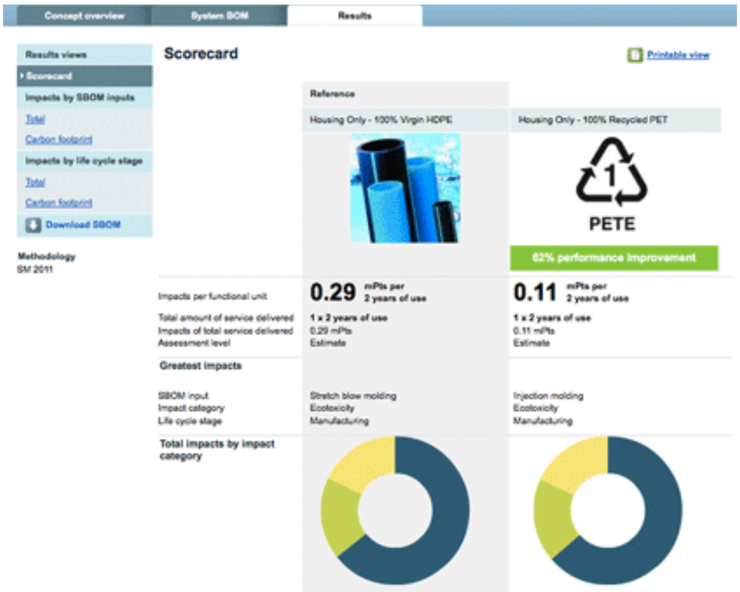

Figure 5 Sustainable Minds screenshot

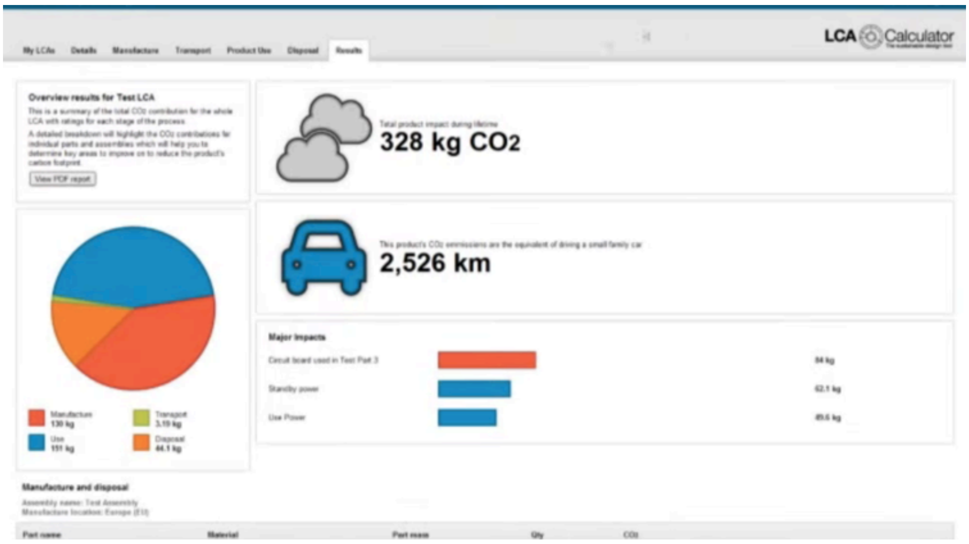

Figure 6 LCA Calculator screenshot

In conclusion, this first step in the design of the tool, both conceptually and graphically, was to look back at all the anterior software available. For the most part, this software is not modern or updated aesthetics-wise, resulting in a bland and unexciting user experience. Some of the most aesthetically pleasing tools found were: Sustainable Minds, which is an online tool that provides comprehensive results; and LCA Calculator, also online and quite easy to use. The level of detail of the databases used by SimaPro and similar programs is useful and interesting to the GUF Tool, but may be too exhaustive for its function. Deriving from this research, it is found that usability and user convenience are imperative and that, since the main users of the tool are going to be public authorities with little to no LCA knowledge, effort must be put into making the tool able to work with as little user input as necessary.

3.2.2. BIM: Building Information Modelling

A very important aspect in the concept development in the tool is to make it very easy to use for the public authority involved, as has been explained before. For this purpose, LIFE Future project organizers suggested looking into BIM, an extended technology that facilitates data transfer and could be of great use for the tool.

3.2.2.1. What is BIM?

"Building Information Modelling" or BIM is a type of digital 3-dimensional representation of objects that contains physical and functional characteristics of the modelled objects. Therefore BIM representation goes beyond the geometry and material of products, it covers spatial relationships, manufacturer's information, environmental information, material properties and quantities, etc. When something is modelled in BIM, it is made from each constructive element separately, like an intelligent object, which has all the physical and logical characteristics of the real components.

As defined by the National BIM Library (RIBA Enterprises, 2012) in the UK, a BIM object is a combination of many things: (The library of manufacturing)

- "Information content that defines the product"
- "Model geometry representing the product's physical characteristics"
- "Behavioural data such as detection, maintenance and clearance zones, that enables the BIM object to be positioned in, or function in the same manner as, the product itself"
- "Visualisation data giving the object a recognisable appearance"

With this larger insight, engineers, architects and designers are able to create and build more efficiently and to manage and adapt the construction process. BIM catalogues also include cost information, which is valuable when developing a complex project. Objects in BIM are defined by parameters and relations to other objects, this allows the user to change an object and the ones related to it will also change to accommodate the new version.

A great advantage BIM provides is the option to work collaboratively with people from other disciplines and exchange information within the CAD applications. People work on different aspects of the project at the same time and the files update continuously, when there is a conflict between parts the users are alerted so they can solve it cooperatively.

3.2.2.2. Uses

Engineers and architects in the development of buildings and infrastructure largely use it. The BIM technology is used throughout the whole life cycle of a project, starting in the planning phase and following through construction and maintenance up until deconstruction. During the use of BIM many variables can be consulted and changed along the way to reduce mistakes in real life that would cost a lot of money and resources. The user can change the values of the parameters to find the most suitable solution in each case, having wide information about environmental impacts, economic viability, energy efficiency, etc.

In the present day, many countries have directives and recommendations to use BIM technology in public procurement of building and infrastructure development. In the European Union, Directive 2014/24/EU states: “For public works contracts and design contests, Member States may require the use of specific electronic tools, such as of building information electronic modelling tools or similar.” Inside the EU, Nordic and British countries have taken a leading role in BIM enforcement, starting a process of gradual implementation. In Spain, the Ministry of Development (Ministerio de Fomento , 2015) has started a commission to promote BIM application in the construction business, advice public authorities to require electronic models in public procurement and encourage the use of BIM during the whole cycle of projects.

3.2.2.3. Environmental aspect

Many materials used include information about their environmental properties, since impact analysis and energetic performance have become pivotal in construction in the last years. Manufacturers facilitate relevant information that is then used to analyse a whole building or infrastructure, an example of this information can be seen below in an image from the ITeC in Catalunya.

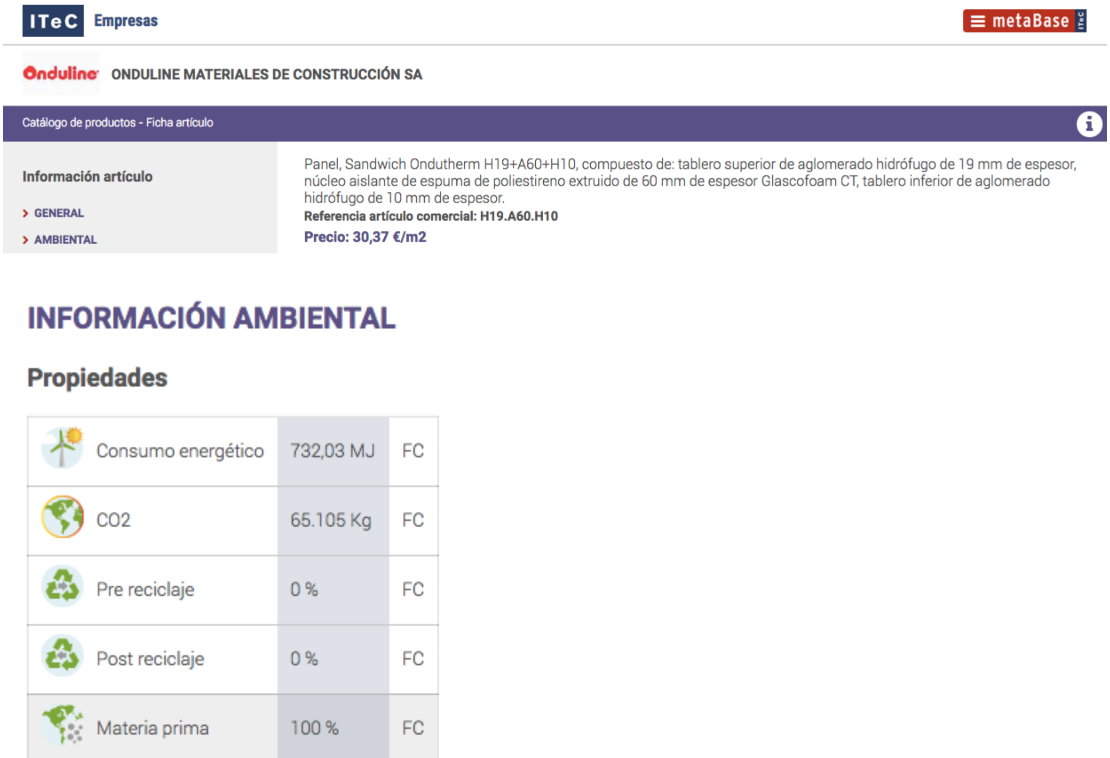

Figure 7 Environmental Information screenshots from the iTeC website

It shows energy consumption in MJ, carbon footprint (CO_2) in kg and percentage of raw material and recycled material (pre and post consuming).

Along with the data that allows to calculate the total impact of a model, working with BIM reduces the errors that produce waste and added costs in manufacture. BIM accommodates design changes in the design stage without increasing cost and use of materials, so waste is being reduced.

3.2.2.4. DATABASES AND CATALOGUES

There are several databases of BIM objects available online, some of them are explained below.

NBS National BIM Library (UK)

Here one can find a vast array of free BIM objects from the leading manufacturers in the UK and the world. It also includes many generic objects such as electrical ones. Experts author all the objects and they comply the NBS Standard

Urban Furniture: There are very few items of urban furniture, mainly tree protectors and grilles, the main focus of this database is construction materials.

BIMCatalogues.net

BIMCATALOGUES.net provides a platform for manufacturers to showcase their products and obtain different formats and types of product presentation to try to become more profitable and expand worldwide. At the same time, architects can use the database by downloading the BIM product files to use on their projects. The information is organised by company catalogues, so finding individual items can be hard.

Urban Furniture: Very few items and very difficult to find.

Polantis

Polantis works similarly to bimcatalogues.net but also has products in other CAD formats and formats compatible with rendering software and Photoshop. Its main asset is that it has objects from leading furniture companies like IKEA, Roca or Baccarat.

Urban Furniture: Over 670 products available from different companies and in a lot of formats.

BIM Archiproducts

This database has many more furniture objects in BIM and CAD formats than other databases along with some construction objects. The files can be downloaded for free after the user is registered in the page. It is very easy to use and aimed at architects and interior designers amongst others.

Urban Furniture: More than 110 products can be found on the website

BIMOBJECT cloud Solution

This catalogue is very widespread and has objects from a vast array of categories. Users can search for objects in the format of the program of choice (AutoCAD, Revit, SketchUp…) and by product type. Urban Furniture: Not many products available.

3.2.2.5. Software

BIM is used in through many tools like Revvit, ArchiCAD, SketchUp, BIMServer, EcoDesigner or BIMx. All of these are made for working on or viewing BIM in different devices. These are professional tools used by architects and engineers and usually are very expensive. However open source software is available for tool developers and users.

There is open software for different stages of BIM, from simply viewing to using BIM from the start. One of the most complete tools is B-processor, although there are other tools in development. Open software can be downloaded and used freely by other applications and tools as the developers can access the code and customize it to fit their needs, therefore developing new open source tools and programs.

3.2.2.6. Application to GUF Tool

BIM could be used in the LIFE FUTURE Project and GUF Tool as a file exchange format with which to obtain product information from the manufacturers. Since many manufacturers already have their products in this format, adding material or environmental information could be relatively easy for them to do facing a public procurement contest. This would hold different advantages:

- Involvement in the promotion of BIM. This would be good for all the stakeholders in construction and public procurement. The government would be supportive since the EU is trying to encourage BIM usage.
- Generalised data transfer. The manufacturers would not need to change to a different format to deliver the product information; they would use the BIM files they are already using.
- Easy for the tool user. All data is uploaded to the tool database and the user only has to choose from it, with no complications or further knowledge of the tool.
- Direct access to specific material/specific impact values in the BIM file.
- Access to already existing catalogues. The catalogues from the existing databases could be used to expand the GUF tool database.

3.2.2.7. BIM Files

A BIM file usually contains a geometric representation of the object, but it may not have one and be only a set of metadata. BIM objects can be component objects (furniture, equipment…) or material objects (flooring, walls, insulation materials…), the main difference being that the latter have no determined size and are applied as a “layer” of material to form the object.

All objects often include a set of metadata that encloses the relevant information for the project development and lifecycle. This metadata includes: product name, type of product, manufacturer, dimensions, weight, materials, amount of materials and relevant links (like pricing or specifications of materials). BIM files can also have information on the product’s complied standards, norms, ecolabels and other similar documentation. In the image below an example of this metadata can be seen for a soft stool, visualized in Autodesk Revit.

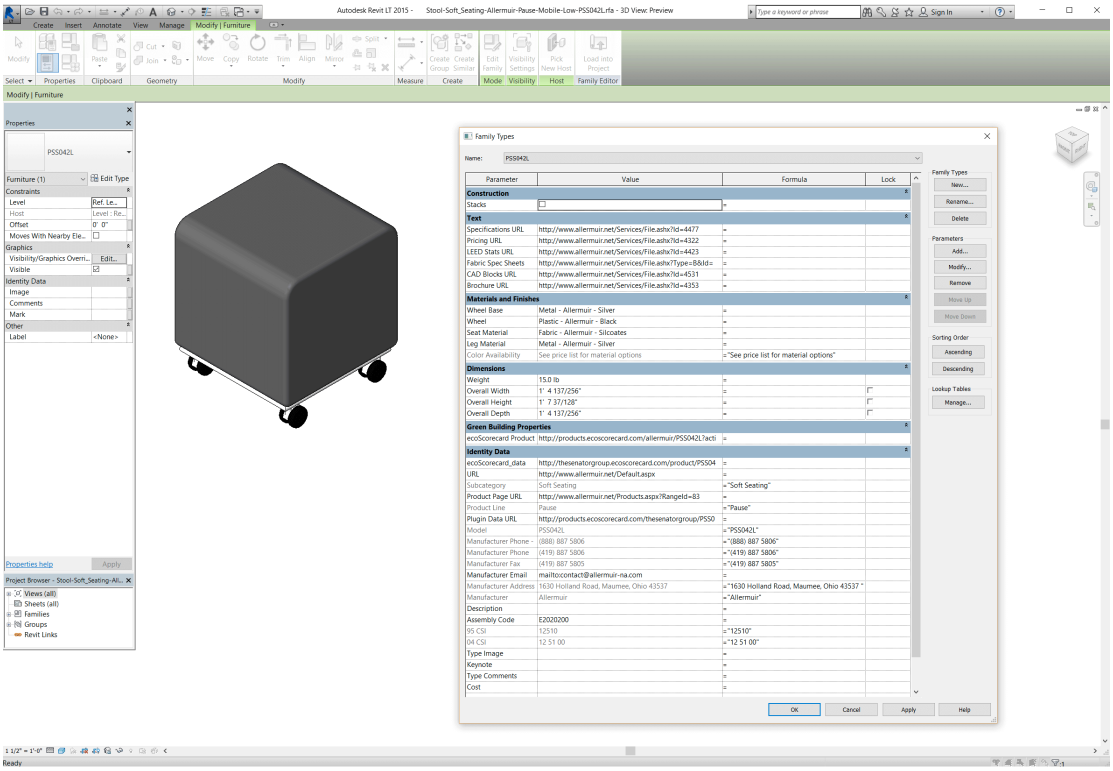

Figure 8: Revit screenshot of a BIM file http://blog.areo.io/bim-objects/

The Chartered Institution of Building Services Engineering (CIBSE) provides product data templates (PDT) to use in BIM as a tool to extract product knowledge, the specific product information can be seen in this template, as shown in the image below.

Parameter Name	Value	Units	Notes
Manufacturer Data			
Manufacturer		Text	
Manufacturer Website		URL	
Product Range		Text	
Product Model Number		Text	Or Code
CE Approval		Text	Number, Yes, No
Product Literature		URL	
Features		Text	Free text to describe product
Construction Data			
Type		Text	This is a COBie field, other fields will be required in final PDTs
Shape		Text	This is a COBie field, other fields will be required in final PDTs
Material		Text	This is a COBie field, other fields will be required in final PDTs
Colour		Text	This is a COBie field, other fields will be required in final PDTs
Finish		Text	This is a COBie field, other fields will be required in final PDTs
Application Data			
Reference Standard		Text	
Power Source (if required)		Text	e.g. Integral battery, System-powered, Other, UserDefined
Dimensional Data			
Overall Length		mm	Or Diameter. Minimum and maximum lengths available
Overall Width		mm	Minimum and maximum widths available
Overall Height		mm	Minimum and maximum heights available
Gross Weight		kg	Equates to Operating Weight
Shipping Weight		kg	Equates to dry weight of unit plus packaging allowance
Access Clearance Top		mm	Access required for maintenance of this item
Access Clearance Bottom		mm	Access required for maintenance of this item
Access Clearance Left		mm	Access required for maintenance of this item
Access Clearance Right		mm	Access required for maintenance of this item
Access Clearance Front		mm	Access required for maintenance of this item
Access Clearance Rear		mm	Access required for maintenance of this item
Performance Data			
Coverage Area		m^2	
Set Point Concentration		ppm	
Electrical Data (if required)			

Figure 9: CIBSE Template http://www.cibse.org/knowledge/bim-building-information-modelling/product-data-templates

As explained before, BIM does not have to me a model or an image; in fact some consider a well-documented Microsoft Excel spreadsheet to be BIM software. An example of this is COBie files: "a spread-sheet containing as much information about a building in as complete and as useful form as possible.” Since the aim of Building Information Modelling is to layer relevant information and digital representation, using spread-sheets for data collection is a valid procedure on its own and specially interesting when used as input for other software applications. In the context of the GUF Tool an Excel template would suffice, but higher levels of BIM could be interesting and valuable to the participants.

3.2.2.8. BIM IMPLEMENTATION IN THE GUF TOOL

Adding BIM technology into the mix allows the GUF tool to improve the user experience. Using BIM or Excel files to compile product data will result in time saving in different stages of the tool use. For instance, as has been commented above, businesses already implementing BIM will be able to post their product offer in less than two minutes and those who don’t use BIM yet could be provided with a spread sheet template that is easy to fill in. By facilitating the steps for the urban furniture manufacturers, data validity and completion is being encouraged, resulting in more realistic analysis and LCA results.

If manufacturers are the stakeholders in charge of submitting their products to the tool, the public authorities are discharged of this task, which can be tedious for un-prepared users. By doing so the user experience is improved since the GUF Tool becomes easy to use by all parts involved.

3.2.3. VISUAL BACKGROUND

The aesthetics and presentation of software have an essential role in how the user perceives and interacts with it, as technology improves and web programmers can do more things, web developers are improving at creating a user experience that is not only enjoyable, but also memorable. The user becomes the centre of the design process and impacting him/her in a positive and durable way turns out to be essential. This is why in the last years web pages have become more enjoyable and easy to use, it is rare that a web page has hard to find information or is cluttered with adds.

The latest trends include responsive designs (designs that adapt to any device), hover actions (interaction by hovering over a button instead of clicking it), flat or material design (using flat icons and buttons and a minimal layout) and long-scroll websites.

While some of these trends may not be applicable to the tool design for this project, it is important to have them in mind. Users learn from and become accustomed to the web pages they use everyday, so using a design that is easy to follow and in some degree similar to what they see often will make it easier on the user and improve the experience.

Some examples of compelling and attractive web designs can be seen in **Error! Reference source not found.** and .

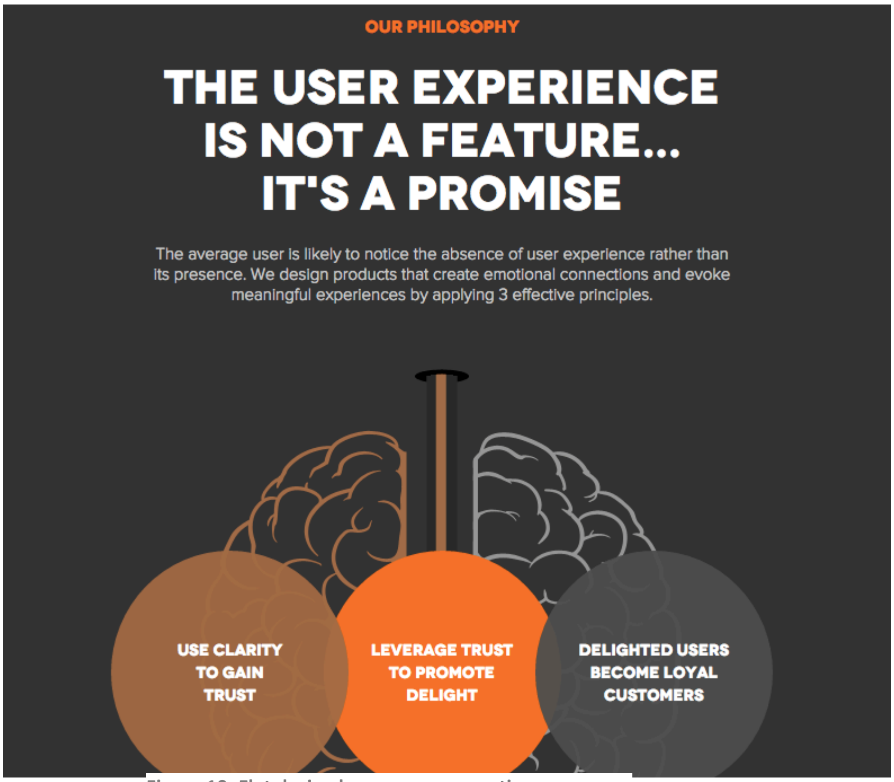

Figure 10: Flat design by www.ponscreative.com

Figure 12: Scroll interaction by www.serioverify.com

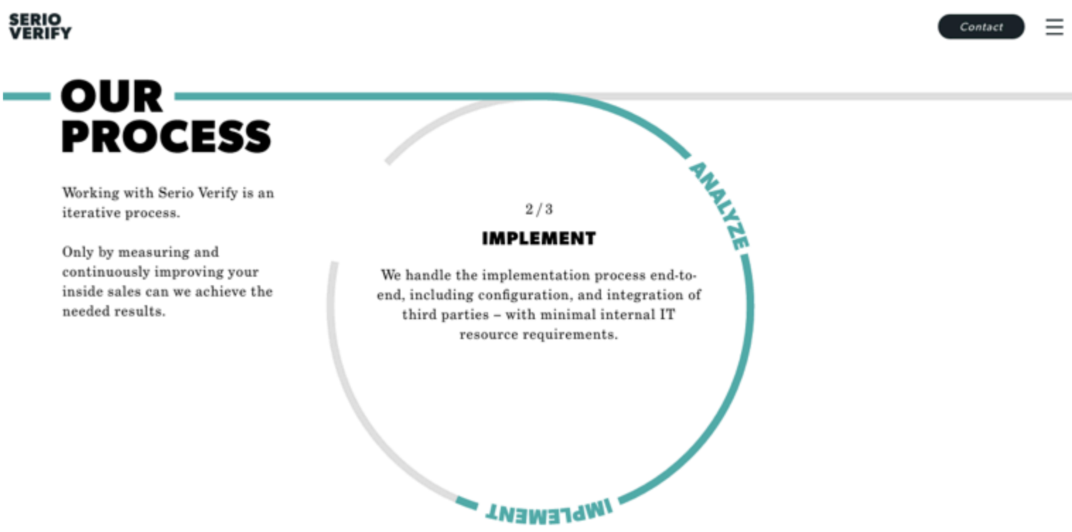

Figure 11: scroll interaction by www.serioverify.com

Mood Board

To summarize the trends and design style a mood board was put together to present preliminary ideas to the project partners and to have an overview of the GUF Tool graphic design. The mood board can be seen in Figure 13.

Figure 13 Mood board

3.2.4. ENVIRONMENTAL CRITERIA

This research section was developed in collaboration with other UJI project partners.

For the concept design of the GUF Tool, relevant environmental criteria must be extracted; in order to do so existing criteria from ecolabels, legislation and other sources is compiled and revised. The environmental criteria will be used as the parameters in the tool to determine whether a product is "green" and to differentiate the most sustainable items. The information that is gathered here is then analysed to decide which criteria to use. For this purpose 3 main sources are analysed: European GPP Tool Kit, Nordic Swan (Ecolabel) Criteria and general ecodesign criteria extracted from the Eco-design guide of the Basque Government and the LiDS eco-design wheel.

3.2.4.1. EUROPEAN GPP TOOL KIT

The following criteria are extracted from the European Commission Green Public Procurement (GPP) Training Toolkit - Module 3: Purchasing Recommendations and European Union Commission Decision of 30 November 2009. The main GGP criteria in the toolkit are:

- Procure timber from legal and sustainably managed forests
- Use materials made partly or totally from recycled materials and/or renewable materials (such as wood)
- Limit the organic solvent content and VOC emissions in products, adhesives and surface treatment substances
- Avoid certain hazardous substances in materials production and surface treatment
- Ensure recyclability and separability of packaging materials and furniture parts and the use of packaging materials based on renewable raw materials
- Procure durable, fit for use, ergonomic, easy to disassemble, repairable and recyclable furniture

WOOD AND WOOD BASED PRODUCTS

- Check for Origin (FSC, other labels): This guarantees that the wood comes from a legally sourced timber, to ensure that the forest biodiversity, productivity and ecology are preserved.
- Use of hazardous substances in wood-based products: Must not contain creosote, halogenated organic binding agents, azidirin, polyaziridins as well as pigments and additives based on heavy metals such as lead, cadmium, chrome and mercury. This can be checked with the Security Data Sheet for each adhesive used in the manufacturing.
- Formaldehyde emissions: Formaldehyde is highly toxic, a powerful irritant and carcinogenic, it is used in preparations and adhesives and its content cannot surpass 0.3% and 0.5%, respectively.

SURFACE TREATMENTS AND ADHESIVES

- Preservatives: The active substances in preservatives must not be based on arsenic, chrome or organic tin compounds. And those elements classified with a durability class of 1 or 2 according to EN 350-2 or equivalent must not have been treated with preservatives. Bidders must present the durability classification of the timber products together with a list of the preservation substances used for each material present in the furniture and their Safety Data Sheet
- Limitation of VOCs and certain aromatic solvents in the content of surface treatment agents: Volatile Organic Compounds are implicated in the depletion of the ozone layer and cause many detrimental effects to human health. VOC content should not exceed 5% in surface treatments and 10% in adhesives.
- Banning the use of surface treatment agents with certain health and environment risk classifications like those which are: carcinogenic, harmful to the reproductive system, mutagenic, toxic, allergenic when inhaled, harmful to the environment, cause heritable genetic damage, danger of serious damage to health by prolonged exposure, possible risks of irreversible effects.
- Banning of hazardous substances (aziridine and Chromium (VI) compounds.)
- Restricting the gloss of the product (coating).
- Formaldehyde emissions from substances and preparations for surface treatment liberating formaldehyde shall be less than 0,05 ppm.

METALS

Aluminium, iron and Steel (usually stainless), are the most used metals in outdoor furniture. Important impacts:

  - Metal contamination in local water and dust emissions during mining for the metal ores and bauxite.
  - Energy consumption and heavy metal release during manufacturing in metallurgic industries.
  - Emissions of heavy metals during surface treatment and coating, stainless steel is an exemption since it does not need any treatment.

- Since they are a non-renewable source, unlike wood, the recycling and re-purposing of metals needs to be encouraged. This avoids production-related impacts and use of the resources.

PLASTICS

Main impacts related to using plastics:

- Use of additives, which are detrimental to human health and hazardous, such as brominated flame-retardants and plasticisers.
- Release of hazardous substances during production and end of life stages.
- They are non-renewable, like metals, so recycling and using recycled material is advised.
- For recycling proper marking and separation of parts for disassembly is essential. All parts ≥ 50g shall be marked for recycling according to ISO 11469 or equivalent and must not contain additions of other materials that may hinder their recycling.

- Presence of CFCs is banned alongside other additives for the production of plastic.

CONCRETE

Although to a lesser extent than wood, plastics or metals, concrete is also used for urban furniture production (e.g. benches, planters…). In these cases, it is considered as a non-structural mass concrete.

- The most important thing is the recycled aggregates rate. It could be appropriate to include at least 20% of them.

PACKAGING MATERIALS

- It is preferable to use recycled materials and/or materials taken from renewable resources for packaging, or be a multi-use system.
- All packaging materials shall be easily separable by hand into recyclable parts consisting in one material (paper, cardboard, plastic, textile…).
- Finally, it is also important to optimize the packaging design in order to reduce the use of raw materials.

CRITERIA FOR THE FINAL PRODUCT

- Material saving: Durability: according to norms and standardized evaluations.
- Safety: according to norms and standardized evaluations.
- Quality
- Packaging: recyclable, renewable or reusable materials.
- Maintenance: availability of spare parts for at least 5 years after the stop of production.
- Recycling and waste: must be easily recyclable and a description of proper disposal must be made available to the user

3.2.4.2. NORDIC SWAN

The Nordic Swan is the ecolabel used in Scandinavia and applies to a wide range of products and services. In the Nordic Eco-labelling of Outdoor Furniture, Outdoor Fixtures and Playground Equipment we can find detailed environmental criteria for outdoor furniture. The following list collects further and more specific information on different aspects of environmental criteria.

- “At least 50% by weight of aluminium and 20% by weight of other metals in the product must comprise recycled metal. Alternatively, the smelting plant that supplies the metal must utilise at least 50% recycled aluminium and 20% recycled metal (other) in production on an annual basis.”
- “A description must be provided of the types of plastic, fillers and reinforcements in plastic parts. Parts made of plastic and weighing more than 50 g must be visibly labelled in accordance with ISO 11469. “
- “Parts of PVC may not be used (except small parts)”
- “In the case of products composed of more than 10% by weight plastic, at least 50% of the plastic must consist of recycled material.”

3.2.4.3. ECODESIGN STRATEGIES AND LIDS WHEEL

In the unit of final product, the object as a whole is considered; in this section the ecodesign strategy wheel and many of its criteria are relevant. An example of the wheel can be seen in Figure 14 below.

- Material saving: it is entrusted to select products which use as little material as possible.
- Weight: it is advisable to choose products with the lowest weight possible.
- Reduced transport: It is also important to work with suppliers close to the manufacturing site and close to the final destination of the products.
- EPDs: It is strongly recommended to give positive assessment products with Environmental Product Declaration.
- Appropriate materials: special attention is needed to use appropriate materials for each use. A clear example of this is the wood. Not all kinds of woods are right for all uses.
- Use of recyclable materials
- Use of recycled materials
- Use of renewable materials
- Recyclable and Reusable packaging
- Minimum use of consumables
- Modular design of the product
- Parts of the product can be reused
- Innovation: it should be considered as very positive when manufacturers use innovative methods as result of R & D + i projects carried out in the last 3 years.
- Reparability: it is very important to look for manufacturers which offer spare parts during the use phase of the product in order to do this phase longer.

Other strategies and criteria have not been included either because they have already been examined in other points or because they are not applicable to the matter.

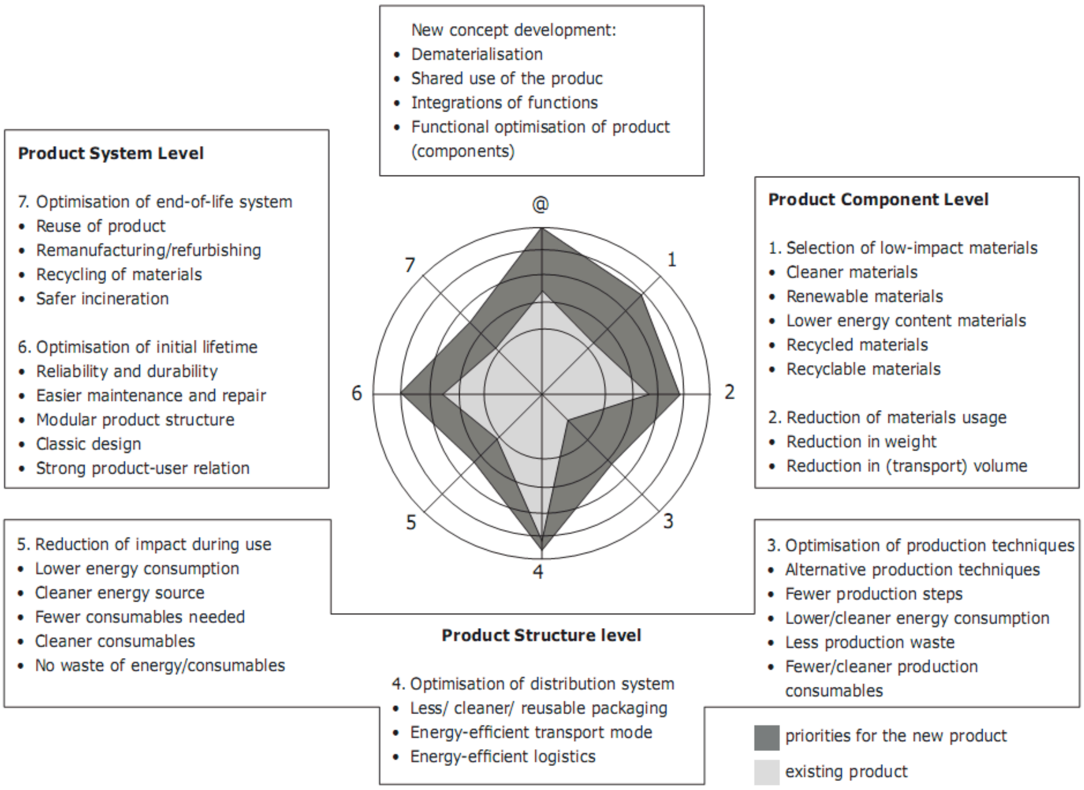

Figure 14: Ecodesign Strategy Wheel (Brezet and van Hemel, 1997)

3.3. SWING SET BACKGROUND

3.3.1. Sustainable Urban Furniture

In this section several items of urban furniture have been collected. They are some of the most relevant examples of sustainable urban elements in Spain and Europe. Some of the objects have been awarded eco-labels and all have been designed using eco-design procedures.

Zebra – Bike Path Separator by Zicla

Made of 100% recycled PVC this bicycle path delimiter is awarded the "Garantía de calidad ambiental" ecolabel distinctive by the Catalan government. It is nowadays found all over the world and is a very good example of ecodesign in urban furniture.

Figure 15: Zebra by zicla http://en.zicla.com/products/65/zebra

Name: Zebra

Designer: Zicla

Description: Made of 100% recycled PVC this bicycle path delimiter is awarded the "Garantía de calidad ambiental" ecolabel distinctive by the Catalan government. It is nowadays found all over the world and is a very good example of ecodesign in urban furniture.

Figure 16: Zimbad by zicla

Name: Zimbad

Designer: Zicla

Description: This bench, also distributed by Zicla, is made entirely of recycled polystyrene and polypropylene. Like the aforementioned path separator, Zimbad benches are ecolabelled with the "Garantía de calidad ambiental". They are a series of benches and stools that can be combined to create different configurations, but the bench itself is presented with a very humble aesthetic, presenting a traditional bench.

Figure 17: Aalb by Grisverd

Name: Aalb Bench

Designer: Grisverd/Nutcreatives

Description: This other bench, although not eco-labelled, has been eco-designed since it has recyclable and recycled materials, needs little to no maintaining, is easily assembled and lightly packaged.

http://grisverd.com/mobles-mobiliari-urba/bancs-aalb/

Figure 18: Forma by Joan Tó

Name: Forma Planter

Designer: Joan Tó

Description: This Flowerpot is made with 100% recycled and recyclable plastic (Syntrewood®), very durable and requires no maintenance.

http://www.urban-equipment.com/es/72585/Mobiliario_urbano_reciclado/__________Jardinera-FORMA.htm

Figure 19: Item by Recollida i reciclatge SL

Name: Wood furniture

Designer: Recollida I Reciclatge S.L.

Description: The Catalan company *Recollida I Reciclatge S.L.* concentrates in creating products with recycled and reclaimed wood, such as planters, bins, benches, fences, and bike parks. Also granted the distinctive by the Catalan government

http://www.recrec.cat/pdfs/Cataleg.pdf

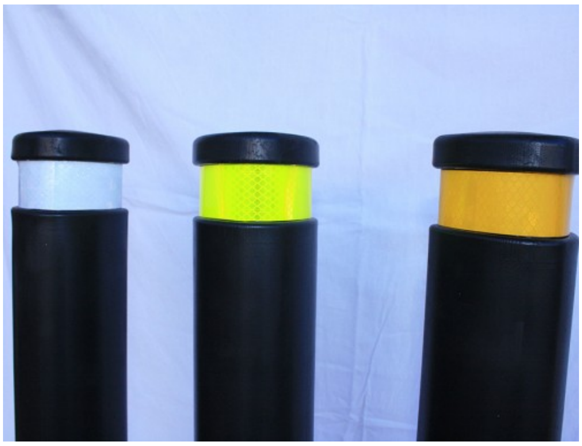

Figure 20: Sweep by Neplas http://www.neplas.com/product/sweep/

Name: Sweep Bollard

Designer: Neplas

Description: This bollard is produced with recycled PVC, and a metal core for structural reinforcement.

www.goo.gl/Iuz4oL

Figure 21: Floor by Neplas
http://www.neplas.com/product/caucho-prensado/

Name: Cushioned Floor

Designer: Neplas

Description: 100% from recycled tyre rubber. Is ideal for park areas or sport courts around the city.

www.goo.gl/Iuz4oL

3.3.2. Modern Swing Sets

Around the world, in the past years more and more innovative playgrounds have arisen. With this tendency designers have innovated in many aspects: interaction and play, materials, shapes, scale, connection to the environment, sustainability, etc. However, in most places the traditional swing remains and is still appreciated and used with joy.

With this in mind, bibliography has been searched to find the most outstanding or relevant playgrounds and swings that serve as inspiration for this project.

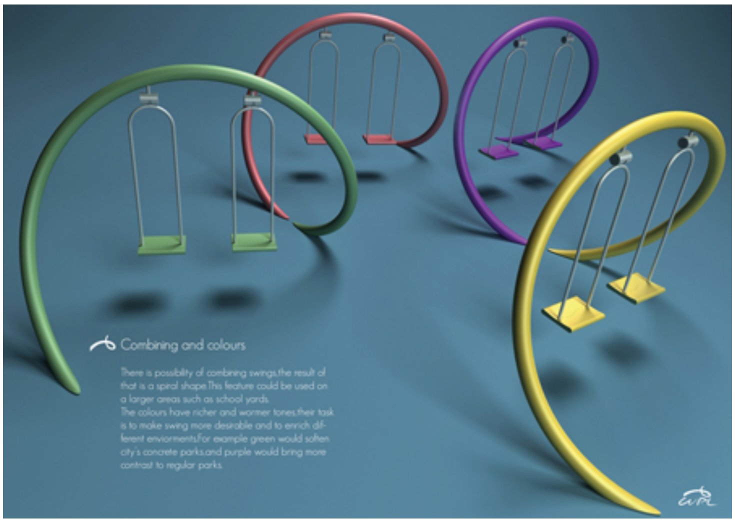

Image 1 Curl by Milos Todorovic

Name: Curl

Designer: Milos Todorovic

Description: This swing set has a very dynamic and interesting **shape**. It attracts children and adults because of the clean line and vivid colours. It has an innovative mechanism for swinging, which is said to improve security and reduce wear. https://www.behance.net/gallery/440153/Curl

Materials: Steel, plastic, rubber


Image 2 Oodle Swing

Name: Oodle swing

Designer: Landscape structures

Description:
This swing is innovative in interaction with the user and in the mechanism.
Many children can use the swing at the same time, all sitting or lying in the wide seat. The equipment can swing back and forth but also from side to side thanks to the mechanic system that connects the swing to the bars. https://goo.gl/JKa7My

Materials: Galvanized steel, polyethylene, rubber

Image 3 Arch Tot Swing

Name: **Arch Tot Swing**
Designer: Landscape structures
Description: This swing is more traditional in its approach and structure. It's very minimal whilst still maintaining a playful aesthetic, through colour and shape. The seats are interchangeable depending on the environment.
Materials: Steel, Aluminium

Image 4 Status Module by HAGS

Name: **Status Module**
Designer: HAGS
Description: This is a very simple swing, the traditional version that can be found in basically all cities and schools, the mechanism is conventional and the materials are common ones. It is a good reference element. http://goo.gl/XPXJH5
Materials: Galvanized steel, polyamides, polyethylene

Image 5 Swing by Roberta Noleggi

Name: Swing
Designer: Roberta Noleggi
Description: This swing is created for both private and public exteriors, and whilst is not totally functional it is innovative in materials; its made entirely using knotted ropes. This swing is only a prototype at the moment. https://goo.gl/q1iKHB
Materials: Rope

Image 6 Irensti swing by Borja Sánchez

Name: Irentsi
Designer: Borja Sánchez
Description: Irentsi is only a concept design but differs from other reviewed products in that it is targeted to an older consumer. It shows a streamlined structure and minimal seating, giving an elegant aesthetic. The use of textile materials is uncommon due to easy vandalising, and this swing has natural fibres in the cover and the seats.
Materials: Aluminium, steel, rope, cotton, jute

From the research, several findings were extracted:

1. The most commonly used materials are: steel (galvanized or coated), rubber (for the seat and bolt covers), a variety of plastics (PA and PE, mainly) and woods (redwood, cedar, pinewood).
2. Eco-designed examples are sparse.

3.3.3. Field Research

With the purpose of discovering what public authorities tend to buy nowadays and to know more about the market a field research is conducted. In this research, different parks in the cities of Castellò and Vila Real are visited and the swing sets there are studied to discover common characteristics, usual problems and good practices. All the swings are analysed and record cards like the one shown in Table 2 are filled with the information.

Number:	Location:
Image:	Functional unit:
	Materials (in order):
	Manufacturer:
	Observations: Grounding: Joints:

Table 2: Record card

<table>
<tr><td>Number: 1</td><td>Location: Vila real plaza in furs de valencia</td></tr>
<tr><td rowspan="4">Image:

</td><td>Functional unit: 2 swings</td></tr>
<tr><td>Materials (in order): metal wood plastic rubber</td></tr>
<tr><td>Manufacturer: mobipark/TUV</td></tr>
<tr><td>Observations:
Rusting, poor maintenance, exposed screws, solid structure, deteriorated plastic

Grounding: metal plates under ground

Joints: soldering, screws</td></tr>
</table>

<table>
<tr><td>Number: 2</td><td>Location: vila real, Mas la vila</td></tr>
<tr><td rowspan="4">Image:

</td><td>Functional unit: 2</td></tr>
<tr><td>Materials (in order): wood metal plastic</td></tr>
<tr><td>Manufacturer: europarques infantiles sl</td></tr>
<tr><td>Observations: rusting, broken plastics,easy extraction of screws, adjustable height,

Grounding: same

Joints: same</td></tr>
</table>

Number: 3	Location: vila real glorieta 20 de febrer
Image:  	Functional unit: 3 Materials (in order): wood metal plastic Manufacturer: unknown Observations: splintered wood, rusted metal, worn out paint, Grounding: concrete foundation Joints: soldered/ screwed

Number:4	Location: Plaça Mestre Tárrega
Image:  	Functional unit: 1 Materials (in order): Steel, rubber, plastic parts Manufacturer: Not shown Observations: New, well kept, rusting on the chains Grounding: Metal fixings Joints: Soldered and screwed.

After studying different swings from different parks, several conclusions were extracted:

1. Most swings are not made of recycled materials; the only common recycled part was the seat.
2. Many swings had rusted metal, chipped paint or splintered wood; maintenance was lacking in many of the studied items.
3. Most swings were anchored to the ground either using large metal parts or concrete, either way they require ground perforation and extra materials and equipment.
4. The metal joints were normally soldered together while wood and plastic parts used pressure joints and metal bolts and screws.
5. In general, the structure of the swings was solid and vandalizing was only an aesthetic issue in most cases.

4. STANDARDS AND REFERENCES

4.1. EUROPEAN AND SPANISH STANDARDS

The following list includes all the relevant European and/or Spanish standards that are applicable to this project and/or have been consulted and referenced throughout.

- General criteria for the drawing-up of the documents which make up a technical project. (UNE 157001:2014)
- Web content accessibility requirements. (UNE 139803:2012)
- Environmental management. Life cycle assessment. Principles and framework (ISO 14040:2006).
- Environmental management. Life cycle assessment. Requirements and guidelines (ISO 14044:2006).
- Environmental management. Environmental communication. Guidelines and examples (ISO 14063:2006).
- Environmental management systems. Guidelines for incorporating ecodesign. (ISO 14006:2011).
- Technical drawings. General principles of presentation. (ISO 128:1996)
- Playground equipment and surfacing. Part 1: General safety requirements and test methods. (UNE-EN 11761-1:2009)
- Playground equipment and surfacing. Part 2: Additional specific safety requirements and test methods for swings. (UNE-EN 1176-2:2009)
- Playground equipment and surfacing. Part 7: Guidance on installation, inspection, maintenance and operation. (UNE-EN 1176-7:2009)
- Playground equipment. Guidelines for the application of UNE-EN 1176-1.
- Precast concrete products. Street furniture and garden products. (UNE-EN 13198:2004)

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- Desarrollo de Catálogos BIM en Bancos de Datos Técnicos (Brochure) – Bimetica, ITeC
- http://itec.es/servicios/bim/
- http://itec.es/servicios/bim/directiva-2014-24-ue/
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4.3. SOFTWARE

The computer software used in the realization of this project was:

Microsoft Excel

CES EduPack 2016

Open LCA

Solid Works 2017

5. Definitions and Abbreviations

AENOR: Asociación Española de Normalización y Certificación.

EU: European Union

GPP: Green Public Procurement

GUF Tool: Green Urban Furniture Tool

HDPE: High Density polyethylene

HSS: High Speed Steel

LCA: Life Cycle Assessment

LDPE: Low Density Polyethylene

PAs: Public Authorities

PE: Polyethylene

PP: Polypropylene

UJI: Universitat Jaume I

UF: Urban Furniture

UFM: Urban Furniture Manufacturer

UNE: Una Norma Española (A Spanish Standard)

6. Design Requirements

Since this project is divided in three different main stages: project image development, GUF Tool concept design and urban furniture design, they are considered separately in this and other topics.

6.1. PROJECT IMAGE REQUIREMENTS

According to the LIFE Future Partners' needs and considering the designer's intentions a short list of objectives and requirements was put together:

1. The design must communicate the values of LIFE Future
2. It must not fall under the typical image for sustainable products ("eco", "green", leaves, recycling triangle, etc.)
3. It is desired that the logo is innovative
4. Must communicate good and positive feelings
5. Liked by project partners

Designer's objectives:

6. Must be aesthetically pleasing
7. Possible to adapt to various formats
8. Bright and clean look is desired

The objectives are then separated into restrictions and specifications

1.The design must communicate the values of LIFE Future - R

2. It must not fall under the typical image for sustainable products ("eco", "green", leaves, recycling triangle, etc.) - R

3. It is desired that the logo is innovative - R

4. Must communicate good and positive feelings- R

5. Liked by project partners - S

    Variable: feedback from project partners

    Criteria: the best possible

    Scale: number (1-5) ordinal scale

6. Must be aesthetically pleasing - R

7. Possible to adapt to various formats- R

8. Bright and clean look are desired- R

The final decision comes from the partner's feedback, becoming the only selection criteria, therefore it is the only specification.

6.2. GUF TOOL REQUIREMENTS

With the information detailed in section 3.2 GUF Tool Background, information from the project organization and partners, the designer's criteria and other considerations the following design objectives for the graphic development are defined and organised. They go from higher level, general objectives to lower, more specific objectives. The specific objectives support the general ones.

Organisation and Partners:

1. Support and encourage GPP
2. Reach as many European public authorities as possible
3. Create a new LCA software
4. Have a good quality GUF Tool
5. Have a modern and attractive tool
6. The tool must adapt to the specific needs of the project
7. Liked by project partners

Design considerations:

8. Must follow the LIFE Future project style and graphics
9. Must be aesthetically pleasing
10. Must be modern in form and in interaction
11. The layout must be clear and not cluttered with information.

GUF Tool Programmers:

12. It must be possible to code the tool

GUF Tool Users:

13. The user experience is positive and encouraging
14. Easy to use by non-expert users
15. Easy to read
16. Easy to understand
17. The information is easy to find
18. It is desirable to have a good looking interface
19. May be used by as many people as possible (with different capabilities)
20. Compatible with text reading apps, for inclusive purposes

The objectives fit into the following categories: aesthetics, usability, viability and Organization's goals. Inside each category they are organised to form a tree of objectives.

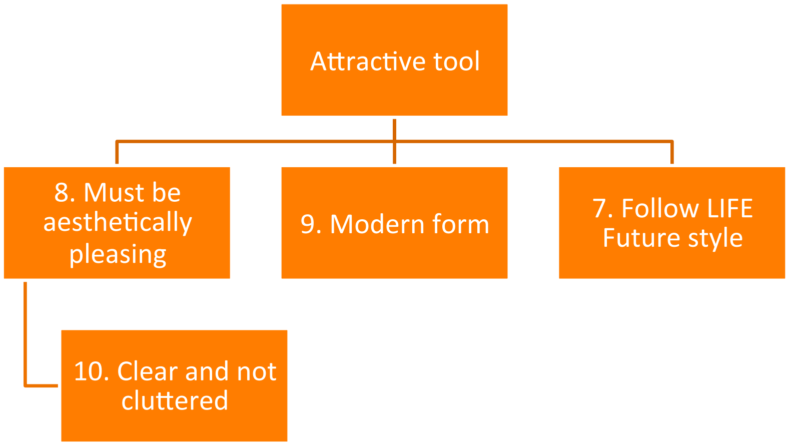
Organization's goals:

1. Support and encourage GPP
2. Reach as many European public authorities as possible
3. Create a new LCA software
4. Have a good quality GUF Tool

Tree 1

Aesthetics:

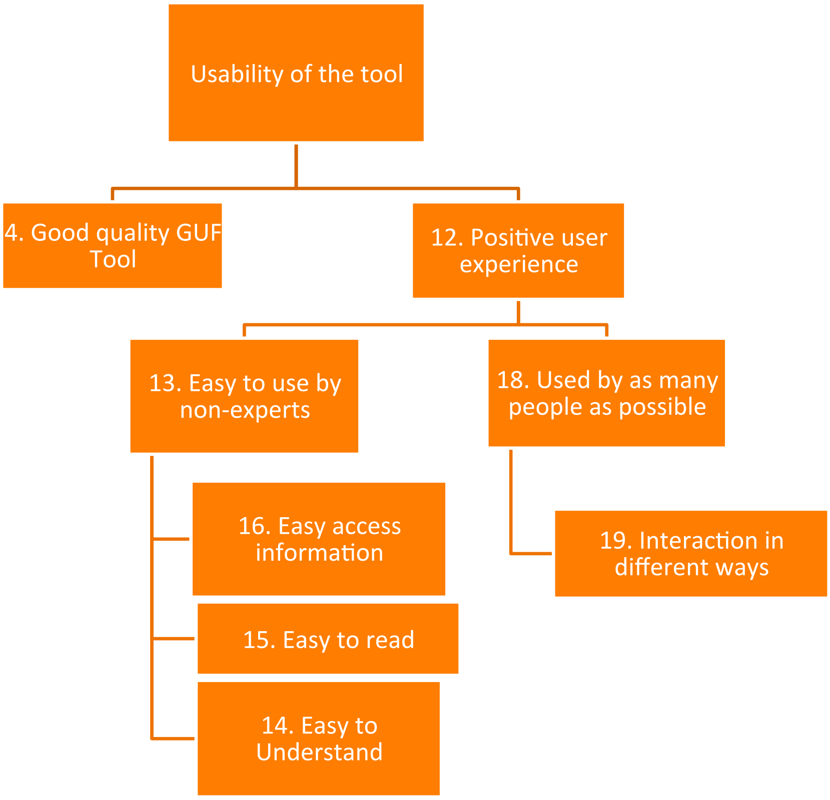
7. Must follow the LIFE Future project style and graphics
8. Must be aesthetically pleasing
9. Must be modern in form and in interaction
10. The layout must clear and not cluttered with information.
5. Have a modern and attractive tool
17. It is desirable to have a good-looking interface



Tree 2

Usability:

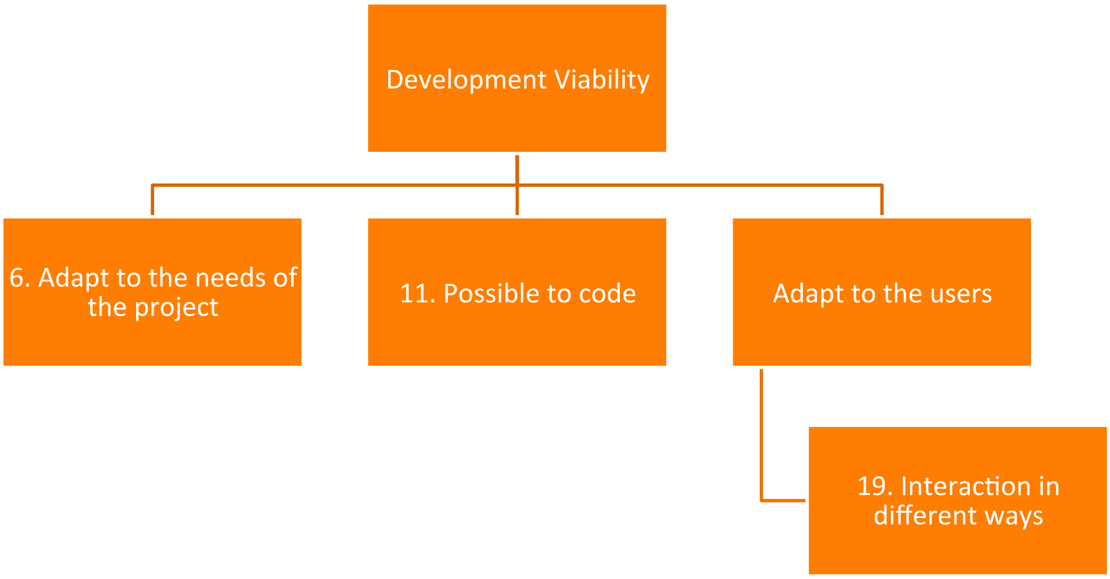
4. Have a good quality GUF Tool
9. Must be modern in form and in interaction
10. The layout must clear and not cluttered with information.
12. The user experience is positive and encouraging
13. Easy to use by non-expert users
14. Easy to read
15. Easy to understand
16. The information is easy to find
18. May be used by as many people as possible (with different capabilities)
19. Compatible with text reading apps, for inclusive purposes
19. Possibility to interact in different ways (through text, sound, images, screen readers)


Usability of the tool
4. Good quality GUF Tool
12. Positive user experience
13. Easy to use by non-experts
18. Used by as many people as possible
16. Easy access information
19. Interaction in different ways
15. Easy to read
14. Easy to Understand

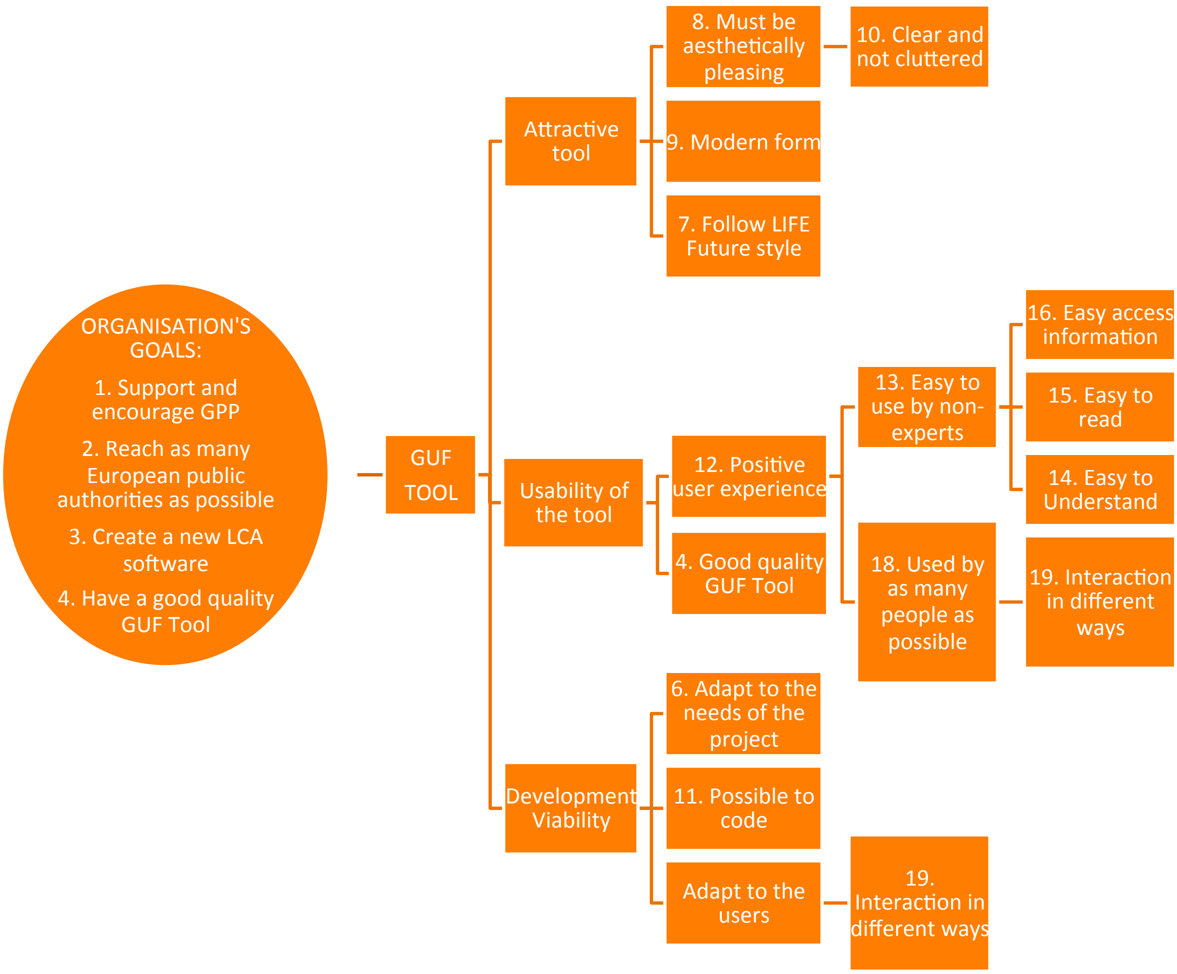
Tree 3

Viability:

6. The tool must adapt to the specific needs of the project
11. It must be possible to code the tool
19. Compatible with text reading apps, for inclusive purposes
19. Possibility to interact in different ways (through text, sound, images, screen readers)



Tree 4



Tree 5. GUF Tool Design Objectives

The objectives are then separated into restictions and specifications:

1. Support and encourage GPP -R
2. Reach as many European public authorities as possible-R
3. Create a new LCA software-R
4. Have a good quality GUF Tool -R
5. Have a modern and attractive tool-R
6. The tool must adapt to the specific needs of the project-R
7. Liked by project partners –S
   Variable: feedback from project partners
   Criteria: the best possible
   Scale: number (1-5) ordinal scale

8. Must follow the LIFE Future project style and graphics-R
9. Must be aesthetically pleasing-R
10. Must be modern in form and in interaction-R
11. The layout must be clear and not cluttered with information. -R
12. It must be possible to code the tool-R
13. The user experience is positive and encouraging -R
14. Easy to use by non-expert users-R
15. Easy to read -R
16. Easy to understand-R
17. The information is easy to find-R
18. It is desirable to have a good looking interface-R
19. May be used by as many people as possible (with different capabilities) -R
20. Compatible with text reading apps, for inclusive purposes-R

Once again, since the only objective that will become an effective selection criteria is number 7, it is the only specification on the list, all other objectives are to remain as restrictions and be checked at the end.

6.3. SWING DESIGN REQUIREMENTS

The development of this urban furniture element is not contracted by any company or organization and is developed only to test the GUF Tool. However, to recreate realistic conditions, the point of view of a designer working in a UF manufacturing company is taken. Said company wishes to create a sustainable swing set that will be well praised in the GUF Tool and be competitive in the market. The company has a sustainable and innovative vision for its products and wants to create unusual designs that will be interesting and fun to use. Europe is the area of operation of this company, which will be based in the eastern coast of Spain, in the Valencian Community. The production volume expected for this swing set is of 1000 units.

As in section 6.2 GUF Tool Design Requirements, in this section a wide range of requirements and objectives are considered and collected in relation to the different stakeholders including: organization, designer, users, installation and maintenance personnel and environmental considerations.

Organization:

1. To compete in European UF markets
2. To improve the sustainability of their products
3. To increase sales
4. To become well-known
5. Develop a new swing with low production cost
6. The swing must have a competitive price point

Designer:

7. Aesthetically interesting design
8. Suitable for different exterior environments
9. Sustainable design
10. Mechanically stable
11. Safe to use
12. If possible, innovative design

Users:

13. Have a comfortable ride
14. Have fun using the swing
15. Safe to use
16. Not easily broken
17. Aesthetically pleasing

Maintenance workers:

18. Difficult to vandalize
19. Simple maintenance procedure
20. Easy to handle and install

Public Procurers (clients):

21. As inexpensive as possible
22. Easy maintenance
23. Sustainable
24. Difficult to vandalize
25. Aesthetically pleasing

Environmental considerations:

26. Sustainable
27. Reduce amount of material
28. Recycled materials
29. Recyclable materials
30. Use certified wood/ sustainably sourced materials
31. Reduce Ozone depletion potential impact
32. Reduce Human toxicity impact
33. Reduce depletion of resources impact
34. Reduce climate change impact

In the next step, the objectives are analysed and organised in categories, each category is formed by a higher-level objective and detailed with smaller objectives.

Organisation's Goals:

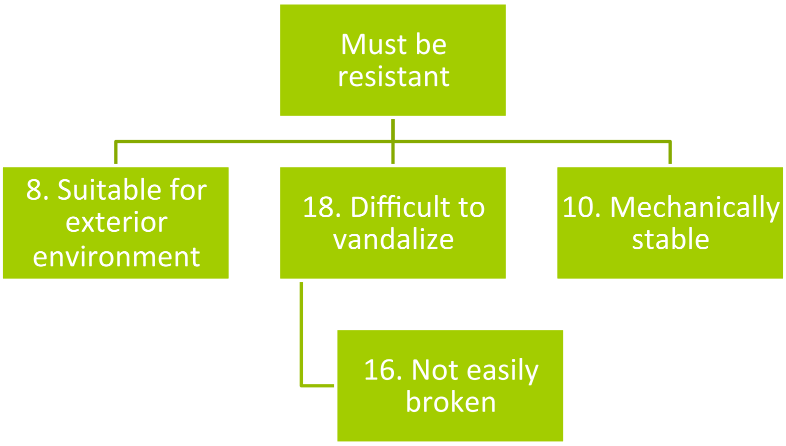
1. To compete in European UF markets
2. To improve the sustainability of their products and the world
3. To increase sales
4. To become well-known

•

Tree 6

Resistance:

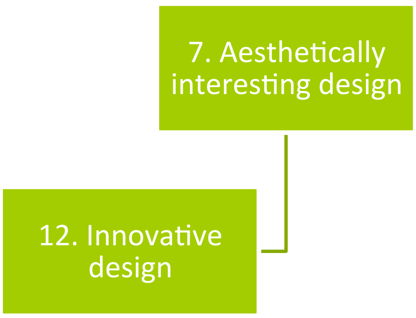
8. Suitable for different exterior environments
10. Mechanically stable
16. Not easily broken
18. Difficult to vandalize
24. ~~Difficult to vandalize:~~ same as 18.



Tree 7

Aesthetics:

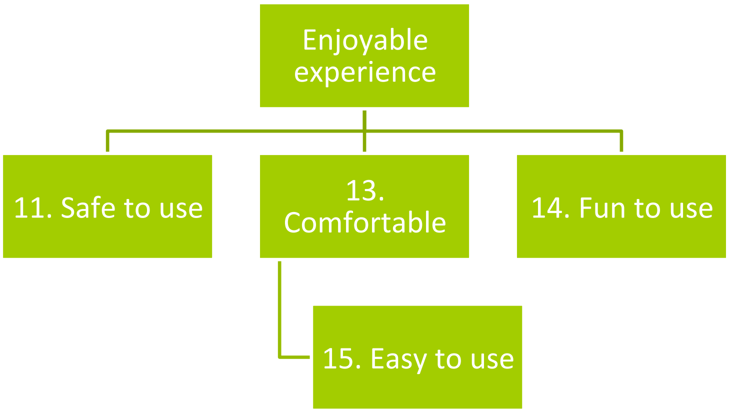
7. Aesthetically interesting design
12. Innovative Design
19. Aesthetically pleasing
28. ~~Aesthetically pleasing~~: same as 19



Tree 8

Use:

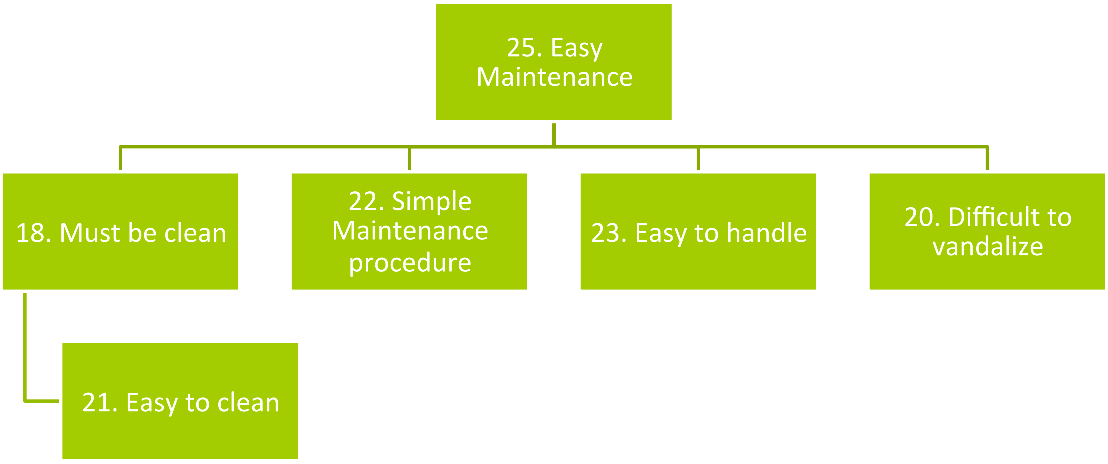
11. Safe to use
13. Have a comfortable ride
14. Have fun using the swing
15. Easy to use
16. Safe to use: same as 11



Tree 9

Maintainance:

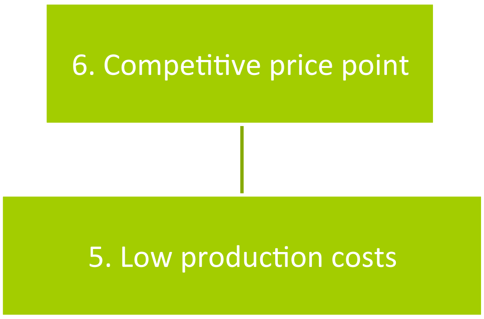
18. Must be clean
20. Difficult to vandalize
21. Easy to clean
22. Simple maintenance procedure
23. Easy to handle and install
25. Easy maintenance
27. Difficult to vandalize: same as 20



Tree 10

Costs:

5. Develop a new swing with low production cost
6. The swing must have a competitive price point
24. As inexpensive as possible: similar to 5, but less specific



Tree 11

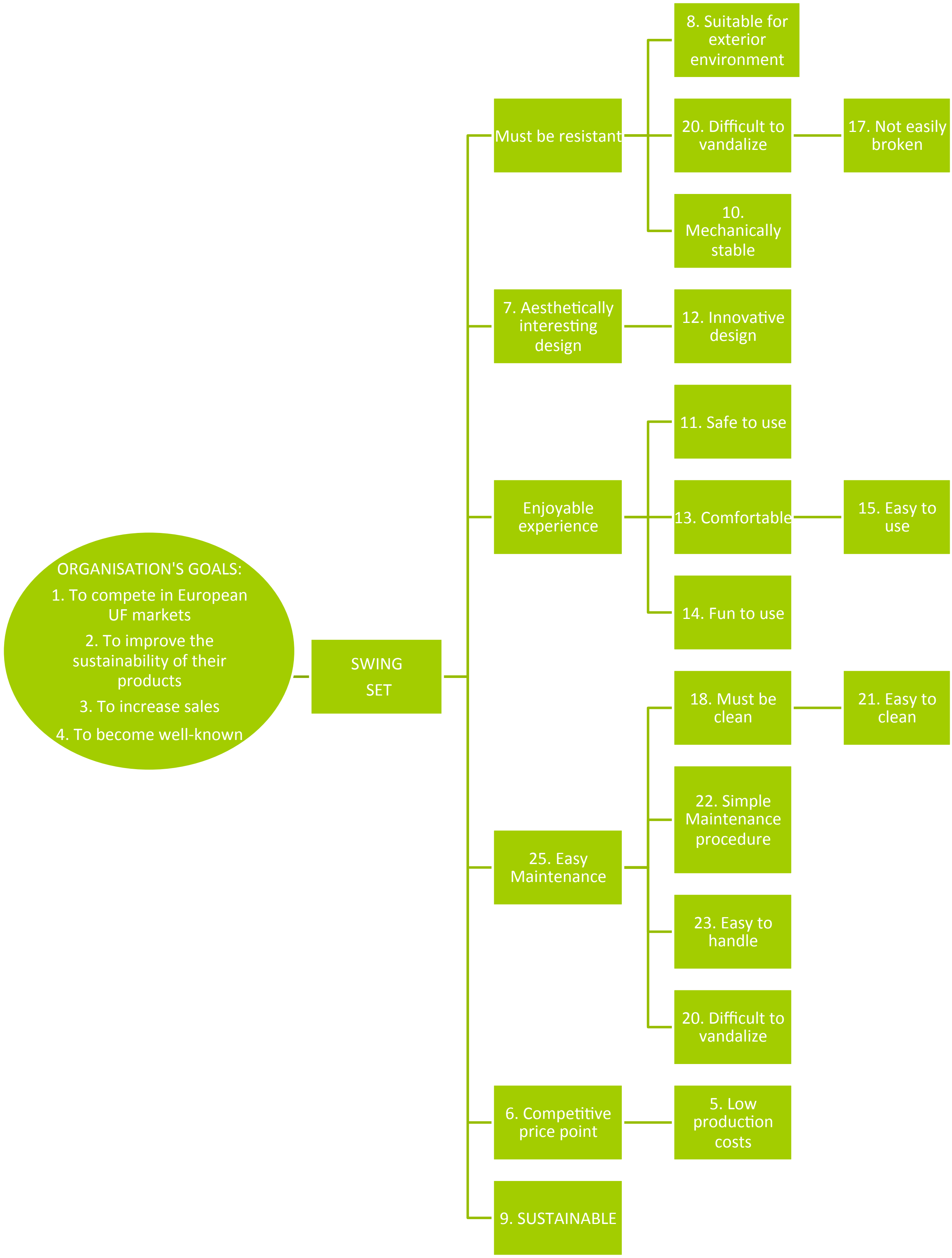
26. Sustainability:

This is the main focus of the project and is present in the objectives of different stakeholders, so it's the most important objective.

As has been seen in section 3.2.4 Environmental Criteria, there are several conditions and principles for designing for sustainability. Some of this principles will be used in the GUF Tool as will be seen in section 0 GUF Tool Final Solution, while others are eco-design criteria that focus in the design process.

To reach environmental sustainability as an objective some other lower-level objectives must be established and for that purpose the aforementioned environmental criteria are put to use. The lower-level objectives can be seen below.

27. Reduce amount of material
28. Recycled materials
29. Recyclable materials
30. Use certified wood/ sustainably sourced materials
31. Reduce Ozone depletion potential impact
32. Reduce Human toxicity impact
33. Reduce depletion of resources impact
34. Reduce climate change impact



Tree 12 Swing Set Design Objectives

6.3.1. Swing Design Specifications and Restrictions

When the design objectives are established, the next step is to set the limits within the solution must be created. To do so the objectives are sorted into restrictions and specifications, and the latter are broken down to the measured variables and scales.

8. Suitable for different exterior environments – R (restriction)
10. Mechanically stable – R
17. Not easily broken – R
20. Difficult to vandalize – R
7. Aesthetically interesting design
12. Innovative Design
11. Safe to use – R
13. Have a comfortable ride – R
14. Have fun using the swing
19. Aesthetically pleasing –S
    - Variable: positive aesthetic impression on people
    - Criteria: the best possible
    - Scale: number 1-5 (ordinal)
22. Simple maintenance procedure – S
    - Variable: amount of maintenance operations
    - Criteria: the minimum possible
    - Scale: number (proportional)
23. Easy to handle and install – R
30. Reduce amount of material – S
    - Variable: amount of material
    - Criteria: the minimum possible
    - Scale: kg of material (proportional)
31. Recycled materials - S
    - Variable: content of recycled material
    - Criteria: the maximum possible
    - Scale: % over total material content
32. Recyclable materials – S
    - Variable: content of recyclable material
    - Criteria: the maximum possible
    - Scale: % over total material content
33. Use certified wood/ sustainably sourced materials – R
31. Reduce Ozone depletion potential impact-S
    - Variable: value of impact
    - Criteria: the minimum possible
    - Scale: units in kg CFC-11 eq.
32. Reduce Human toxicity impact - S
    - Variable: value of impact
    - Criteria: the minimum possible
    - Scale: units in kg DCB eq.

33. Reduce depletion of resources impact -S

Variable: value of impact

Criteria: the minimum possible

Scale: units in kg antinomy eq.

34.Reduce climate change impact -S

Variable: value of impact

Criteria: the minimum possible

Scale: units in kg CO_2 eq.

7. Alternatives Analysis

7.1. PROJECT IMAGE

7.1.1. Logotype

With the objectives in mind and taking advantage of the previous logotypes, several creativity techniques – brainstorming and mind maps – were used to come up with the following designs.

7.1.1.1. Idea 1

The existing logotypes used the initials "L" and "F" to create various forms and designs. Further exploration of the idea gave rise to "Idea 1", as seen in **Error! Reference source not found.** and in Figure 23 In this case the colours used in original logo 4 (were used, since they seemed the most appealing to the designer and to the project partners.

This logo was presented in two forms; Figure 22 shows a square type logo where in Figure 23 can be seen a more rectangular version.

Figure 22: Idea 1 version1

Figure 23: Idea 1 version 2

7.1.1.2. Idea 2

Idea 2 has the same colours and font as idea 1, but the initials have been used to draw a figure. The "L" and "F" take the same shape but in different colours and the centre-bar in the "F" is displaced so that it is enclosed in the middle space. By doing so, a pictogram resembling an eye is created; it represents vision and so, the future. The pictogram can also be seen as a leaf that is reminiscent of nature and the environment, whose protection is LIFE Future's ultimate goal.

Figure 24: Idea 2

7.1.1.3. IDEA 3

This alternative shows a variation in the colours to more traditional “nature-related” ones in figure 29 and brighter colours in figure 28.

Square shapes are aligned at the side to give graphic content and structure; it is somehow reminiscent of building blocks and of learning and knowledge.

Figure 26: Idea 3 version 1

Figure 25: Idea 3 version 2

7.1.1.4. IDEA 4

The last idea is very different from the others since it has a very distinctive graphical content, and the project name is given a secondary role. The image and colours reflect the urban character of the project and the green colour reflects a park, related with leisure and positive feelings as well as nature.

Figure 27: Idea 4 version 1

7.1.1.5. SELECTION

The project partners made the final decision, to do so the different alternatives were shown and each partner voted for the favourite one. At last, idea 2 was chosen as the most representative and suitable.

7.1.2. Project Notice Posters

The chosen logo was Idea 2, as is explained in section7.1.1. With this LIFE Future project image a communication poster was to be made. Other project partners already chose the information for the poster, so the notice posters had to be adapted in turn.

7.1.2.1. Poster 1

Figure 28 LIFE Future Poster Design 1

The poster in Figure 28 features different sections: summary, objectives, results and contact information, with a clear emphasis in "objectives". It has a dark background with light text and white boxes for different sections. The colours used are the three colours of the chosen logo.

7.1.2.2. Poster 2

Figure 29 LIFE Future Poster Design 2

Poster 2 is more colourful and has a different layout, favouring photography over illustrations and incorporating a grid-like layout. It also uses the aforementioned colours and has all the necessary information, but presented in a different way. The photographs are owned by LIFE Future project, as well as the "*Sustainable Urban FUrniTUre"* illustration in the top right-hand-corner.

7.1.2.3. Selection

The chosen poster was the second one since it was the preferred one by most of the partners.

7.2. GUF TOOL ALTERNATIVES

Since the LIFE Future Project is on going - and constantly changing and adjusting as new aspects arise - the design of the GUF Tool has undertaken many re-designs along the way. However, from the begging a few aspects were considered and a mood-board was put together to have a reference of ideas, interesting aspects and general atmosphere, it can be seen in Figure 13 in section 3.2 GUF Tool Background. With these clear ideas in mind, several designs were developed. Below the most interesting designs are discussed.

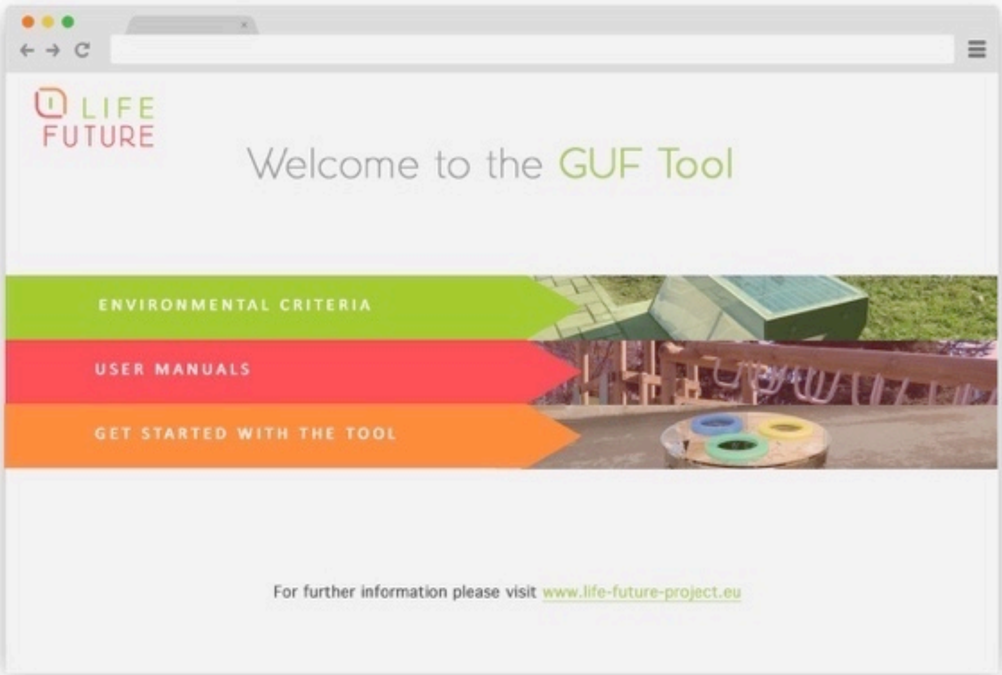


Figure 30 GUF Tool design 1

7.2.1.1. Design 1

The first design is bright, dainty and colourful. The different options are distinguished through colour and accompanied by an image of urban furniture vaguely related to the option topic. The buttons and interactions are all two-dimensional reflecting the flat design trend, which gives it a modern feel. As it can be seen the project colours are all present and respected in this home page.

The overall design feels light and balanced, this is achieved by concentrating heavy objects (block colours and images) in the option buttons and keeping a lot of blank and vacant space in a neutral and soothing colour.

Regarding the readability aspect of the design, different traits must be commented: the fonts are all sans serif, in order to improve readability; the size of the fonts is adequate, and even bigger that required; and the colours of the texts are not optimal in contrast, this can be challenging for users with reduced visual capacity.

This design allows for easy finding of information, and clearly distinguishes the tree options available as well as the option to visit the project's web site.

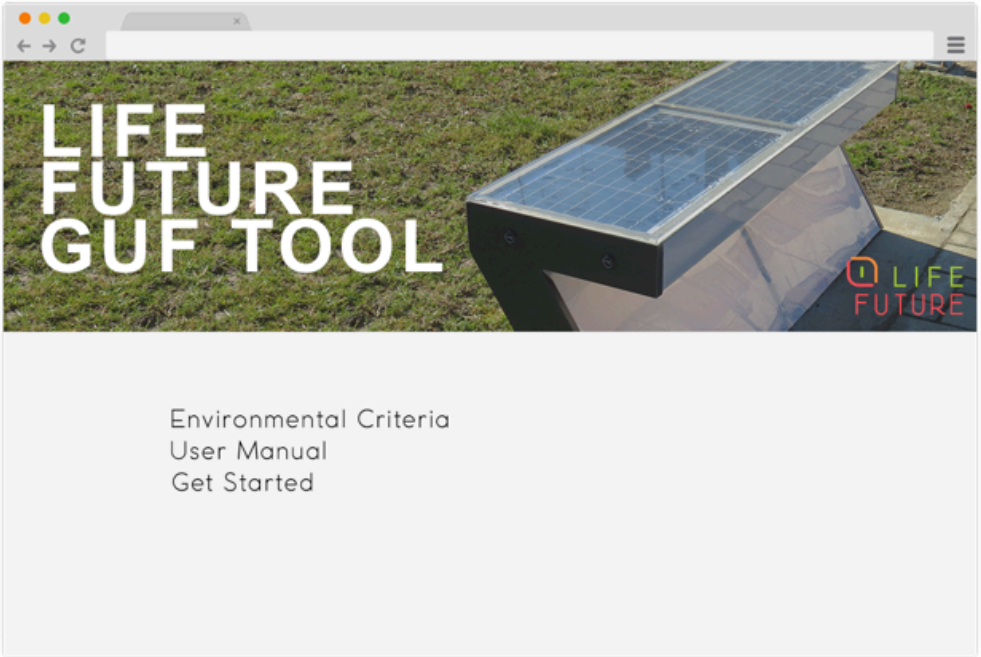


Figure 31 GUF Tool design 2

7.2.1.2. Design 2

The aesthetic of this design is minimal, simplistic and more conventional than the first design. The LIFE Future style is discreet in this design, being the image of a bench the centre-point and main feature. There is a lot of empty space in the bottom section but as one can see in Figure 32, when the user hovers over one of the options an explanation is revealed in the right.

In this design the text is very contrasted to its background, the font is sans serif and the texts sizes are adequate for reading. Whilst the information is easy to find, the links in the options work as the mouse hovers over, so initially they just look like text, this can be confusing to some users and make if difficult to use.

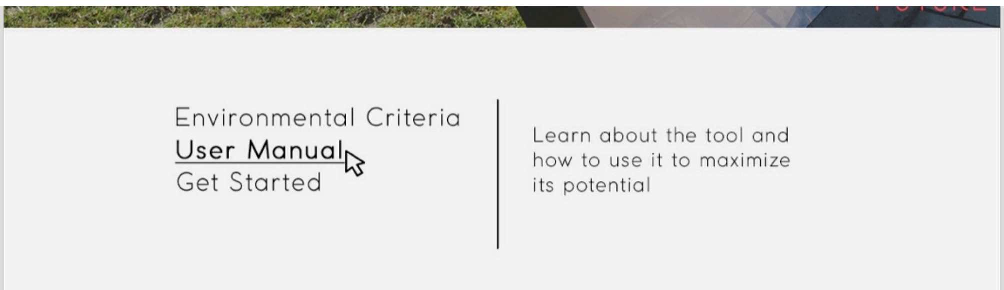


Figure 32 Hover action design 2

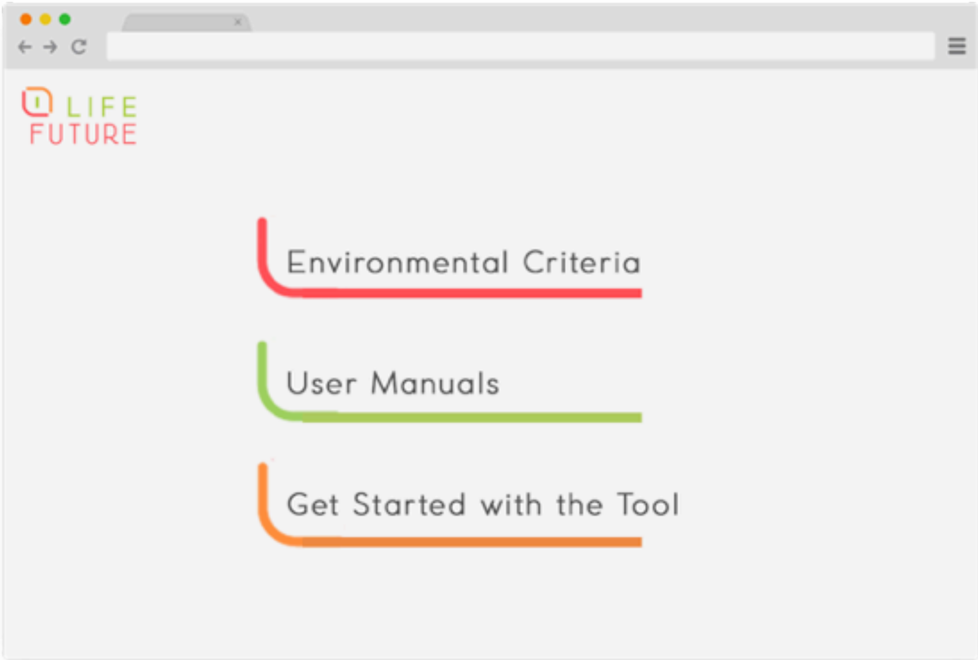


Figure 33 GUF Tool design 3

7.2.1.3. Design 3

Simple, colourful and clear. Design 3 has a very refreshing and calm look, using shapes and colours that capture the LIFE Future style in a simple and elegant way.

The font is the same as in design 2 (Figure 31) so readability is good for a large number of users. The options are clearly differentiated and the shapes help the user understand that they are clickable buttons.

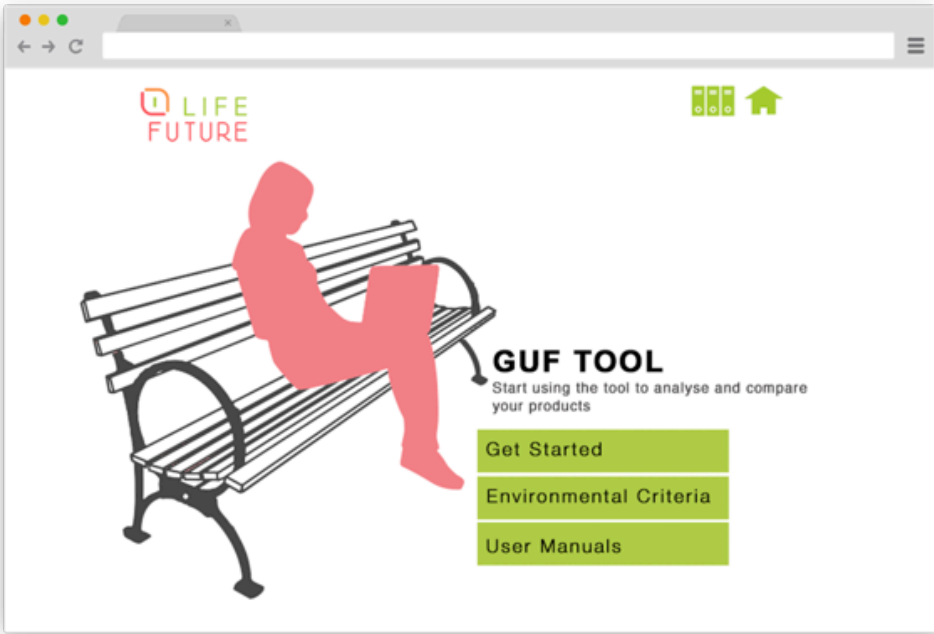


Figure 34 GUF Tool design 4

7.2.1.4. Design 4

The last design is vivid, modern and colourful. As can be seen in Figure 34, the project colours play an important role in the design, being part of the imagery as well as the written information and buttons. This design as an asymmetric layout and different elements competing in attention, therefore it can be considered more jumbled than the prior designs.

The layout is easy to read and the buttons are close together in a menu, making it look familiar and easy to find and understand. The colour contrast overall is very good, making it easy for everyone to read the information and to see the illustration. The font size is also large and easy to see.

7.2.1.5. Selection

Consulting with the project partners and with the GID team in particular, in was decided that the preferred graphic concept for the GUF Tool was Design 4. The different designs were voted and it came up as the favourite alternative.

7.3. SWING ALTERNATIVES

7.3.1. Alternative 1: Wave

When studying different swings in the city and online there was a recurring factor that resulted in extra material use: grounding the equipment for stability. For the swings to be safe they are many times anchored to the ground using large quantities of cement or lots of metal parts and bolts. Seeing this feature was common, the following alternative aims to avoid the need for anchoring, reducing the materials needed and also minimizing the difficulty in the installation process.

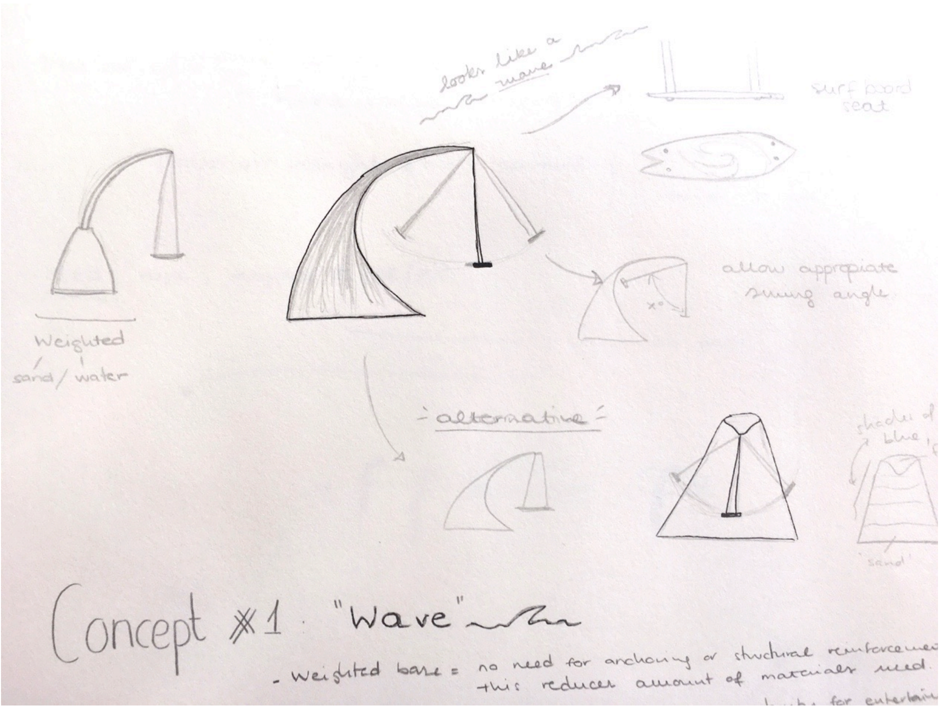


Figure 35 Alternative 1

This design incorporates a weighted base, which will serve as the stabilizing component of the swing. With a base several times heavier than the combined weight of the swing and the user, the forces and moments produced during the use are thwarted. The base has a pyramid shape to avoid tipping over in adverse conditions and under unusual forces.

In development the design acquires an organic shape resembling a wave, this characteristic is enhanced by the use of colour and marine elements. This is done partly to support children's imagination in the playground and also to play with the aesthetic impression.

The design feels bulky and solid, but the material used must be minimum to achieve the environmental goals and the body will be filled with sand or re-purposed concrete, which adds very little impact. If possible, recycled plastic will be used for the outer structure and wood or recycled steel may be used for re-enforcement and in the horizontal part.

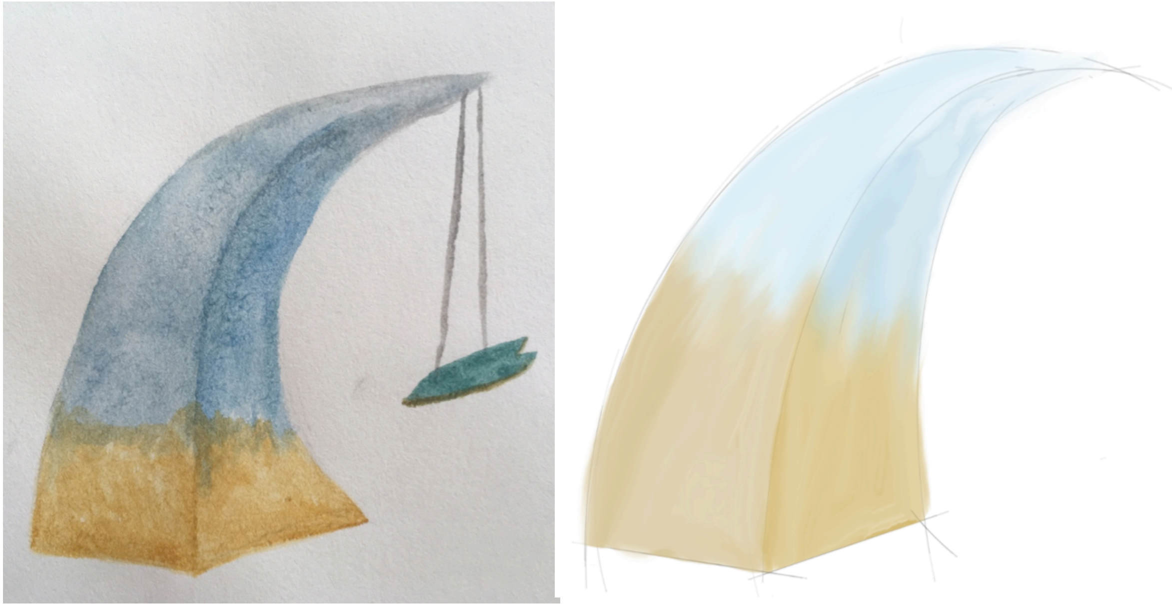
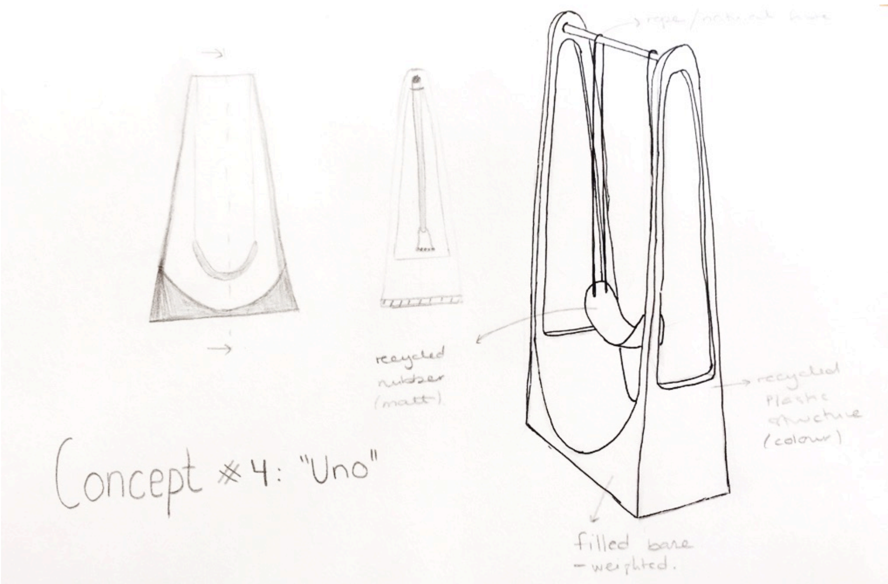


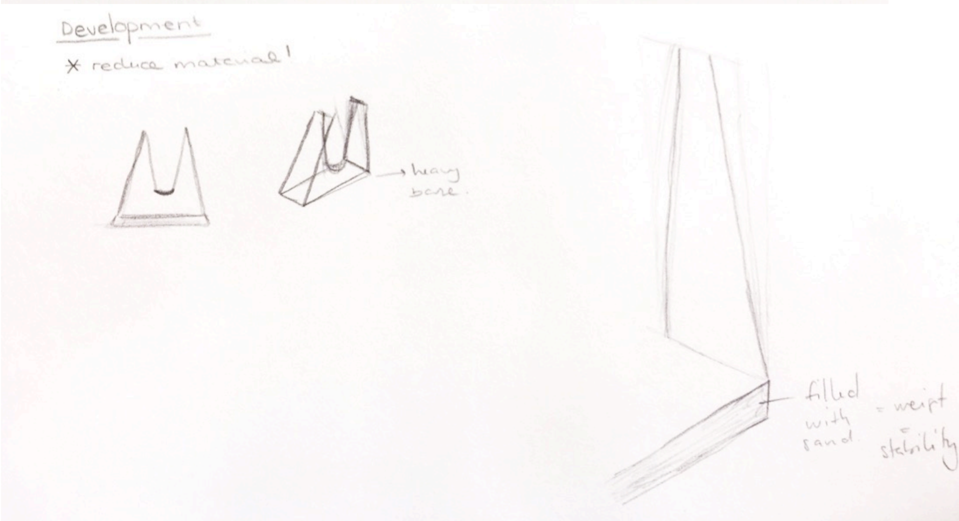
Figure 36: Alternative 1 "Wave"

7.3.2. Alternative 2: UNO

This individual swing can be combined with other units in a row to form a set or can be installed on its own. As with the first alternative, the base is weighted to improve the stability and reduce material and installation costs, although the frame is more traditional.

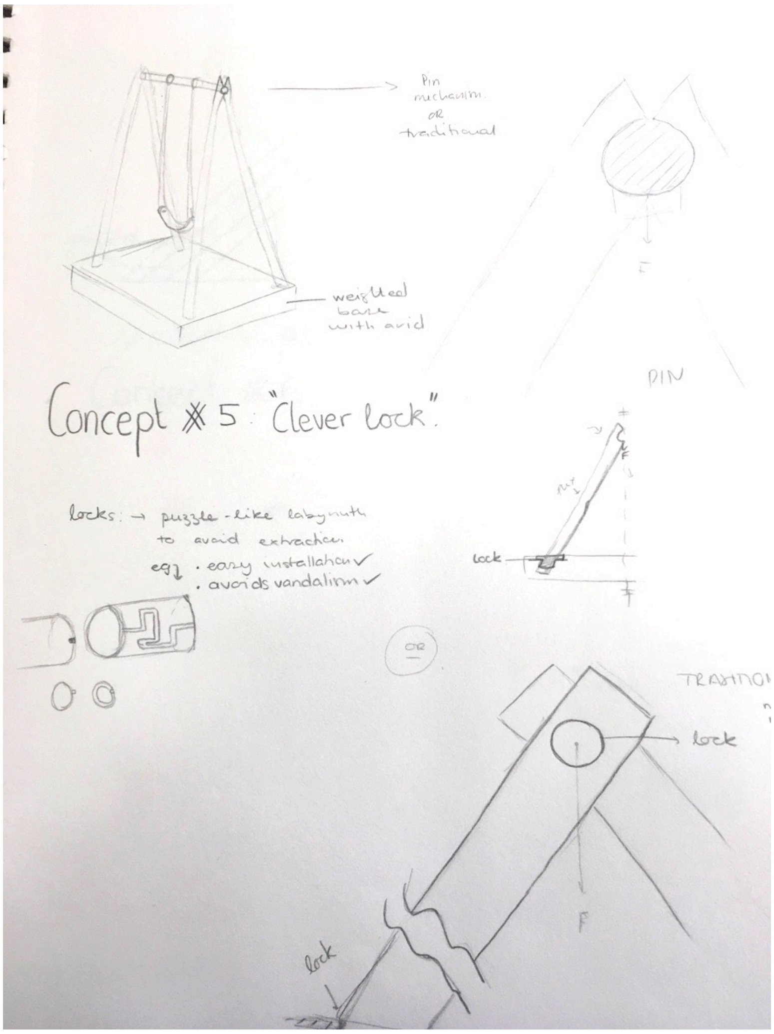
The material selected will depend on the final design and fabrication requirements, but the first idea is to have the structure made by entirely recycled plastic, built with no metal screws (only fitted together), have the rope made of renewable natural fibres (such as hemp, bamboo, etc.) and have the seat made with recycled tyre rubber or similar material to allow some flexibility. Therefore the rope and seat would be neutral in colour and the frame could be coloured or could remain neutral to blend in the environment.





7.3.3. Alternative 3: Clever Lock

This alternative attempts to reduce material not only by incorporating a weighted base, but also by forgoing the need of screws and other metal parts in favour of pressured joints and an interesting anti-vandalism mechanism.

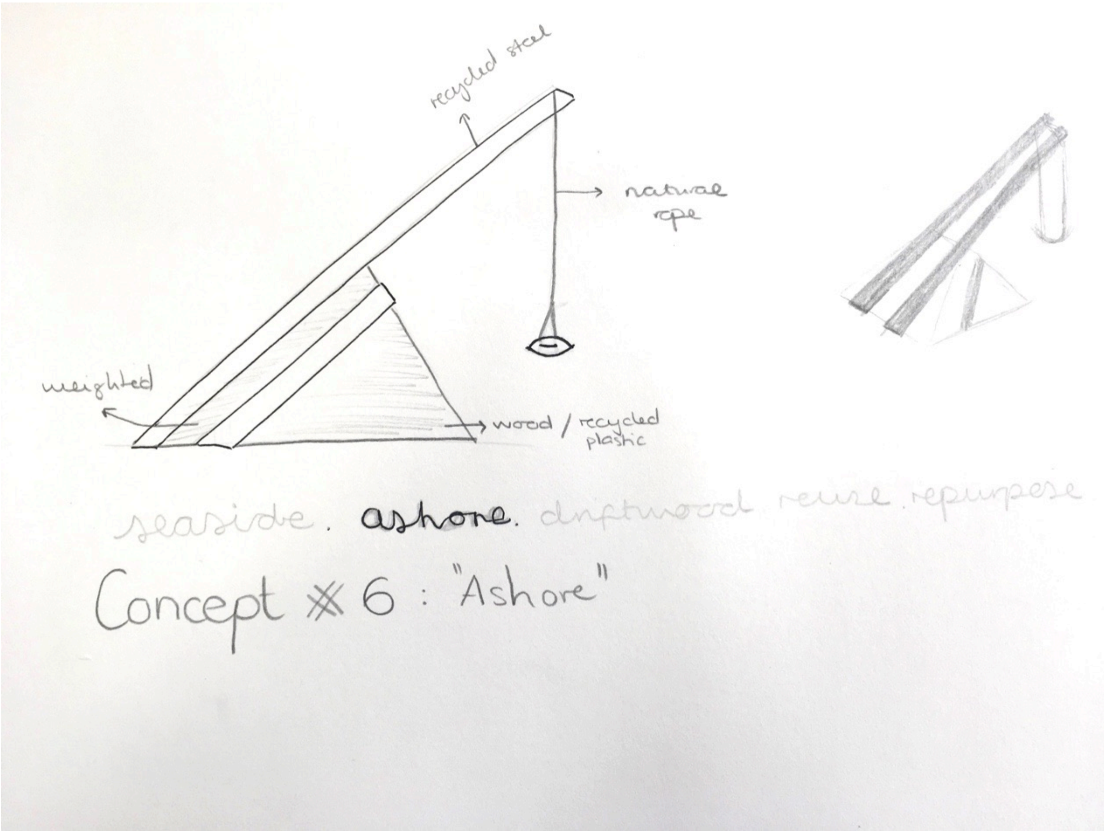


In this design all parts are made of the same material, ideally that would be recycled plastic or reclaimed wood with a matt finish and a dark colour. The base is a rectangular box where the arid (either sand, recycled concrete, ceramic, …) is contained, in this base the four posts that make the main structure are secured. Between the posts a beam is secured in place and from it the swing is hung.

The cilindrical parts that go inside other parts or pass through them are all provided with a puzzle like mechanism for insertion and extraction. This ensures that only authorised people are able to instal and take apart the swing, avoiding vandalism. This mechanism is necessary since the use of screws and metal parts has been sacrificed in favor of parts reduction and material sustainability.

7.3.4. Alternative 4: Ashore

The seaside and materials we associate with the beach and the ocean inspire this last alternative. The main material is wood, more specifically reclaimed wood that looks like driftwood (wood that has been in the water and washed ashore), this material is accompanied by the sand used in the weighted base and recycled straps of steel, used in the "arm". The wooden part may also be made from recycled plastic and given a texture and colour to look like wood.



7.3.5. Selection Criteria

7.3.5.1. Quantitative evaluation: LCA Comparison

As can be seen, the environmental criteria are essential to the definition of the solution, therefore a small Life Cycle Analysis of the alternatives and a sample swing is made in order to establish a quantitative comparison between alternatives and of the alternatives in relation to a usual swing.

First, the sample swing is analysed. The chosen swing and its technical specifications have been given by AIJU, one of the LIFE Future project partners that is specialised in toys and play areas. The swing set is *Groupswing Stratus* single module by the company HAGS (ref: 8000751) shown in Figure 37, its specifications can be seen in Figure 38.

Figure 37: Groupswing Stratus

LOS MATERIALES

Material	kg	%
Zink (electro-galvanised)	0.028	0.02
Polyamide (PA)	0.24	0.21
Polyethylene (PE)	0.487	0.32
Stainless steel	0.8236	0.54
Zink (hot-galvanised)	2.9375	1.92
Untreated Steel	148.273	96.89
Glasfiberarm polyester	0.4	0.26
Cast iron	0.08	0.05
	153.3 kg	100%

Figure 38: Material Information

All the information about materials and processes is entered into a program called OpenLCA, which helps calculate the total impacts of a product. To enter the appropriate data into the program different calculations are made. For the designed swing set alternatives - since they have been developed up to the first stages of design - all of the quantities and fabrication processes are approximate and therefore the results are only to be used as a guideline, when the final design is selected and detailed an additional LCA will be done to show more exhaustive result.

A breakdown and explanation of the LCA process can be seen in the annexes, where the method is explained in detail and captions of the OpenLCA can be seen.

CONCLUSIONS

The most sustainable solution will be the one with the minimum impact overall. The impacts being considered are wide and general: ozone depletion, climate change, resource depletion and human toxicity. Additionally, and only to use as a guideline, the total impact in points has been included, but is not conclusive to the analysis.

Table 3: LCA Results

Design	Ozone depletion (kg CFC-11 eq.)	Climate Change (kg CO2 eq.)	Depletion of resources (kg antimony eq.)	Human toxicity (kg DCB eq.)	Total impact (points)
HAGS Groupswing Stratus	$1{,}49 \cdot 10^{-5}$	355,06	2,679	238,34	32,68
A1: Wave	$2{,}268 \cdot 10^{-5}$	86,74	0,843	105,468	8,99
A2: UNO	$9{,}23 \cdot 10^{-6}$	140,54	1,547	54,84	15,75
A3: Clever Lock	$1{,}26 \cdot 10^{-5}$	45,27	0,4606	18,82	4,78
A4a: Ashore (Polyethylene)	$1{,}27 \cdot 10^{-5}$	56,027	0,504	42,548	5,56
A4b: Ashore (Wood)	$7{,}77 \cdot 10^{-6}$	88,43	0,548	154,343	75,88

Table 3 above shows the results of the Life Cycle Analysis. Overall, the most sustainable alternative is A3: Clever Lock, followed closely by A4a: Ashore (polyethylene) and in third place A1: Wave. All three reduce massively the impacts derived from the HAGS design and would be suitable solutions.

7.3.5.2. QUALITATIVE EVALUATION: AESTHETIC IMPRESSIONS

A very important objective now is the aesthetic aspect. This decision has been made taking into account the product consumer: the public authorities. They will be more inclined to buy a sustainable product if it is interesting or beautiful, and the final purpose is to reach the public authorities and stimulate green public procurement, therefore the aesthetic aspect must be evaluated and considered as much as the sustainable aspect.

With this in mind, to evaluate the objective 19 "Aesthetically Pleasing" a small sample of 50 people is interviewed to determine which design is the most praised by its appearance. To do so, the following questions are asked regarding alternatives 1,3 and 4 using Google Forms, a polling application by Google.

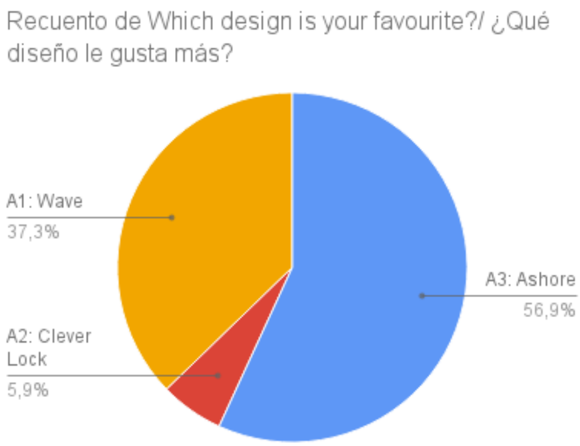
1. Rate the design from 1 to 5 (A1)
2. Rate the design from 1 to 5 (A3)
3. Rate the design from 1 to 5 (A4)
4. Please choose the order of preference between the designs.

A detailed explanation of the poll and the results can be seen in Annex 1, the conclusions extracted from it can be seen below:

Average score:

- A1: Wave **3,49**
- A2: Clever Lock **2,78**
- A3: Ashore **3,96**

And the preferred alternative was determined:



With the results shown in X it is clear that the best liked design is A4 "ashore" and the least liked one is A3 "Clever Lock".

7.3.5.3. TOPSIS METHOD

With the results for the LCA and the aesthetics poll a mathematical method for alternative selection is used to decide what is the most suitable alternative. The TOPSIS method is based around a selection matrix in which different alternatives are evaluated in regard to pondered objectives. The outcome of this method is given as the distance where each alternative lies in relation to the ideal solution. The method used was researched and directly extracted from a thesis by Mª del Socorro Cascales titled "Métodos para la comparación de alternativas mediante un Sistema de Ayuda a la Decisión (S.A.D.) y "Soft Computing" (Cascales, 2009).

The first step involves the creation of a solution matrix:

$$\begin{matrix} . & C1 & C2 \\ A1 & x_{11} & x_{12} \\ A3 & x_{12} & x_{22} \end{matrix}$$

Where C1 is the sustainability criteria and C2 the aesthetic criteria, A1 is Clever Lock and A2 is Ashore and the results for C1 are given in LCA results in points and those for C2 are the poll average evaluation.

The next step is the normalization of the values, to do so the next formula is applied:

$$n_{ij} = {x_{ij}}\Big/{\sqrt{\Sigma(x_{ij})^2}}$$

And then those values are multiplied by the pondering coefficients to obtain a pondered matrix; here both coefficients equal 0,5. The next step is to obtain the most ideal values for the most positive solution out of the pondered values, in this case the larger number for C2 and the smaller for C1.

Then the mean distances of each alternative to the extreme solution are extracted using the following formulas:

$$d_i^+ = (\Sigma(v_{ij} - v_j^+)^2)^{\frac{1}{2}}$$

$$d_i^- = (\Sigma(v_{ij} - v_j^-)^2)^{\frac{1}{2}}$$

And finally the distance to the ideal solution is calculated using the formula below, the solution most close to 1 is the best solution:

$$R_i = \frac{d_i^-}{d_i^+ + d_i^-}$$

Table 4: TOPSIS Method

	W1=0,5	**W2=0,5**			
	C1	**C2**		**Pondered matrix**	
A1	4,78	2,78		0,326	0,287
A2	5,56	3,96		0,379	0,409
Normalization	7,33	4,83	**V+**	0,326	0,409
			V-	0,379	0,287
	d+A1=	0,099	**d-A1=**	0,053	**RA1= 0,348**
	d+A2=	0,053	**d-A2=**	0,099	**RA2= 0,651**

Therefore, as can be seen in Table 4 where all the values for this TOPSIS method are represented, alternative 2 "Ashore" is the most suitable alternative, since its distance R is most proximate to 1.

8. FINAL SOLUTION

8.1. FINAL IMAGE

Since the logotype would define the graphic image of the whole project (posters, information panels, presentations, official documents, etc.) it was essential that the project partners decided on the logo to use. For this purpose, the four ideas were consulted with the project organisation and each partner voted for an alternative and explained the reasoning behind the decision (this was key in case any other possible solutions and combinations of features were necessary).

As a result, idea 2 was largely chosen as the preferred one and so became the project logotype and its colours became the base of further designs.

Figure 39 LIFE Future Logo

In the following page different scenarios for the logotype are captured. It can be transformed to grey scale and to black and white format without losing content to be reproduced and printed in all occasions. It is also shown in small dimension to verify that its quality remains clear. Finally, the colour references are indicated in order to be used in other communication and dissemination aspects.

	C	M	Y	K	R	G	B	HEXADECIMAL
	0	80	56	0	232	83	88	#E85358
	39	0	84	0	177	203	70	#B1CB46
	0	54	76	0	240	142	70	#F08E46

8.1.1. Requirement Check

In this section the objectives are checked to make sure that the final design is aligned with the restrictions and desires established in the objectives.

Objective	YES/NO/NA
The design must communicate the values of LIFE Future - R	YES
2. It must not fall under the typical image for sustainable products (“eco”, “green”, leaves, recycling triangle, etc.) - R	YES
3. It is desired that the logo is innovative - R	YES
4. Must communicate good and positive feelings- R	YES
5. Liked by project partners - S	YES
6. Must be aesthetically pleasing - R	YES
7. Possible to adapt to various formats- R	YES
8. Bright and clean look are desired- R	YES

8.2. GUF TOOL FINAL SOLUTION

In this section the final and complete design of the online GUF Tool is explained and shown in detail. In the context of the LIFE Future project every page had to be designed to fit a purpose, this is why the design varies from page to page but the same elements and colours are maintained.

Home Page

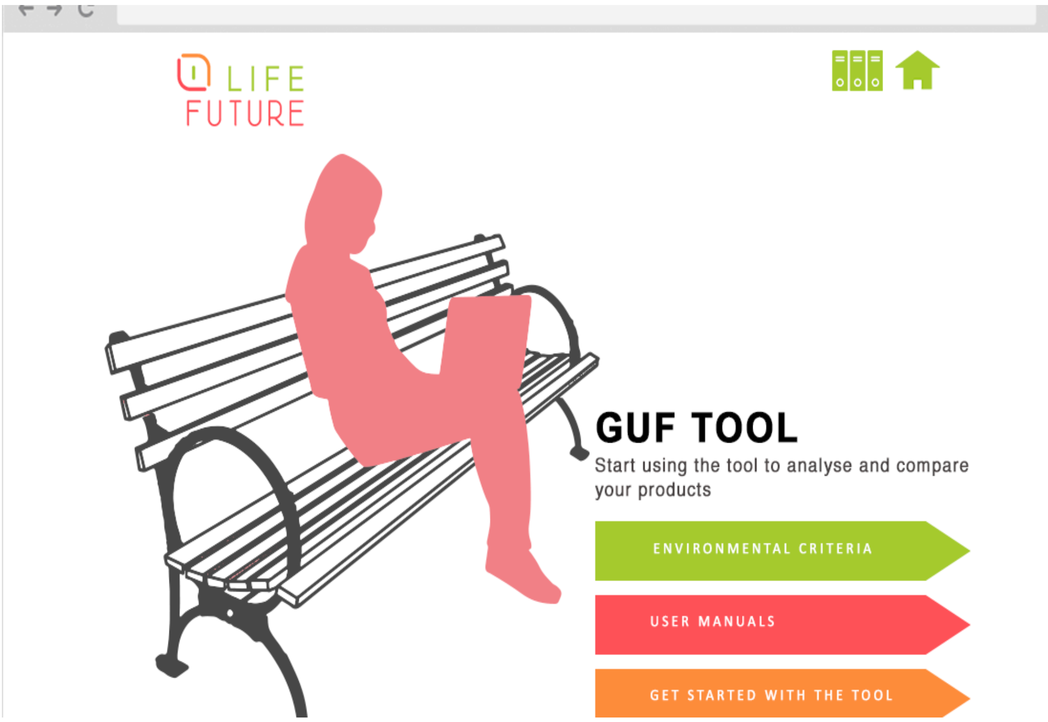


Figure 40 Home Page

The main page is the first seen by the user; it sets the chromatic style and the overall mood of the GUF Tool.

From this main page the user can go to “Environmental Criteria”, “User Manuals” and “Get started with the tool. The user manuals are to be directly downloaded in a PDF file upon clicking the link. “Get started…” leads the user to the “Log in” page, seen below.

Log In

This is the page where the user identifies as a public authority or an uban furniture manufacturer. To do so they must first contact the project organisation and obtain a user name and password to register in the GUF Tool.

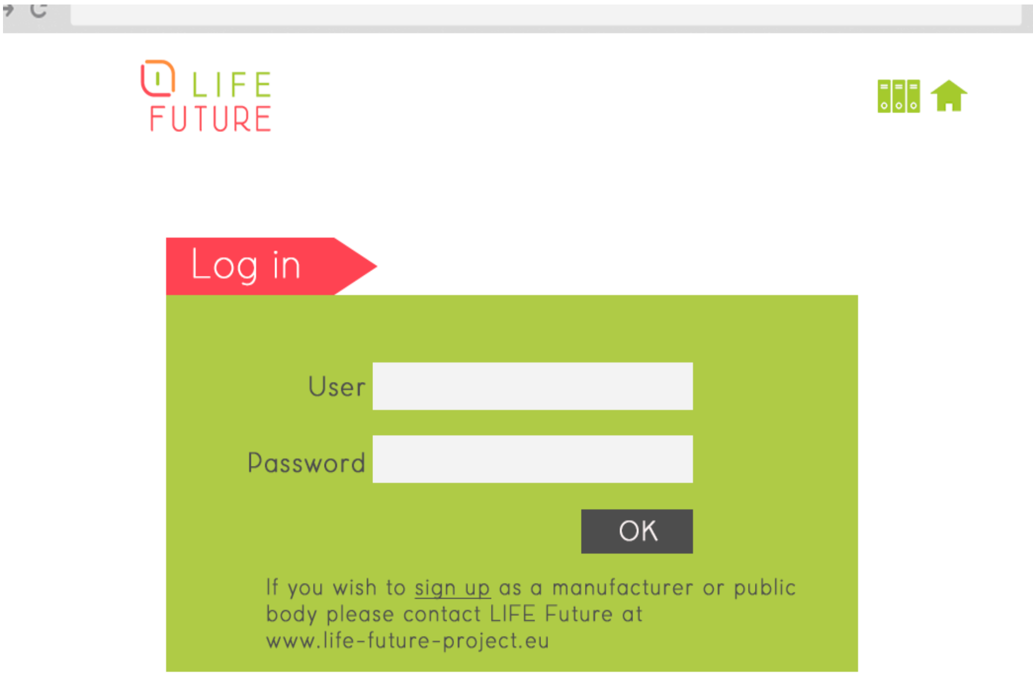


Figure 41 Log In

Offers

Figure 42 Offer menu

This page derives in three paths:

1. Search by location: searches tenders in an area.
2. Search by product: searches tenders by product category.
3. Post new offer: for public authorities, to open a new tender.

Search by product

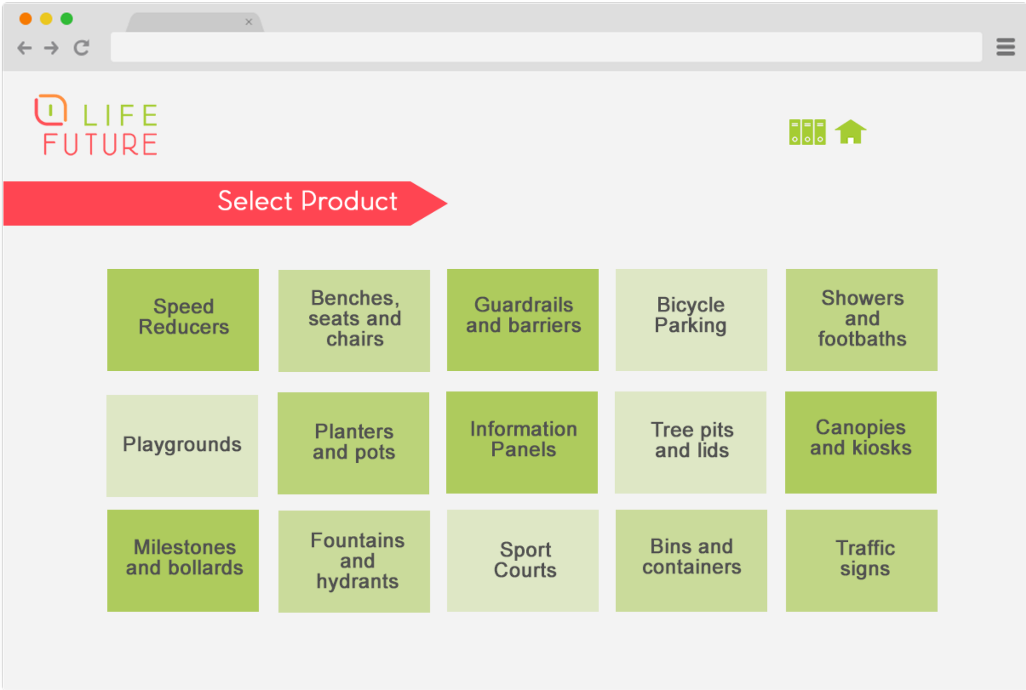


Figure 43 Search by product

This page lists all of the categories defines in the project and presents them in the form of a grid. This way the user can rapidly pinpoint the product of interest and view all the current public procurement offers in that product category. This is especially interesting since many manufacturers specialize in one or few types of furniture.

View Offer

The following image shows how an offer is viewed when the user selects it. General information is shown in the title of the tender: Number, city, product and quantity. Proposals made by different manufacturers can be seen in the box beneath the title and at the bottom there is a link to make a life cycle analysis comparison of the current proposals. To the right, the user can find the different ways to make a proposal: “Upload BIM file” or “Enter data manually”

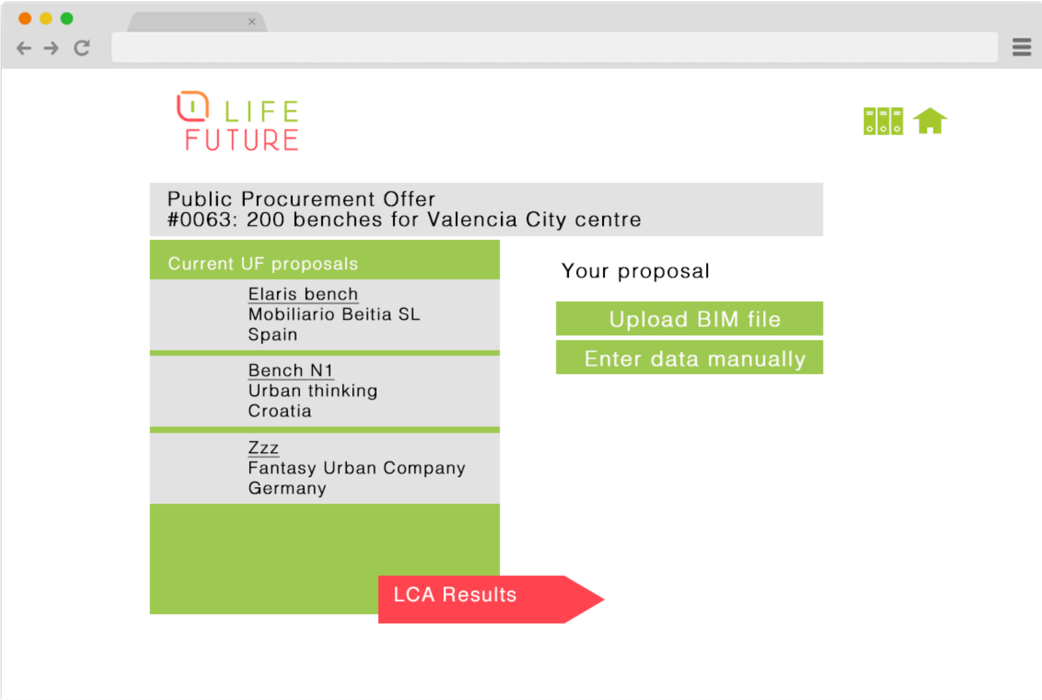


Figure 44 View Offer

Upload BIM

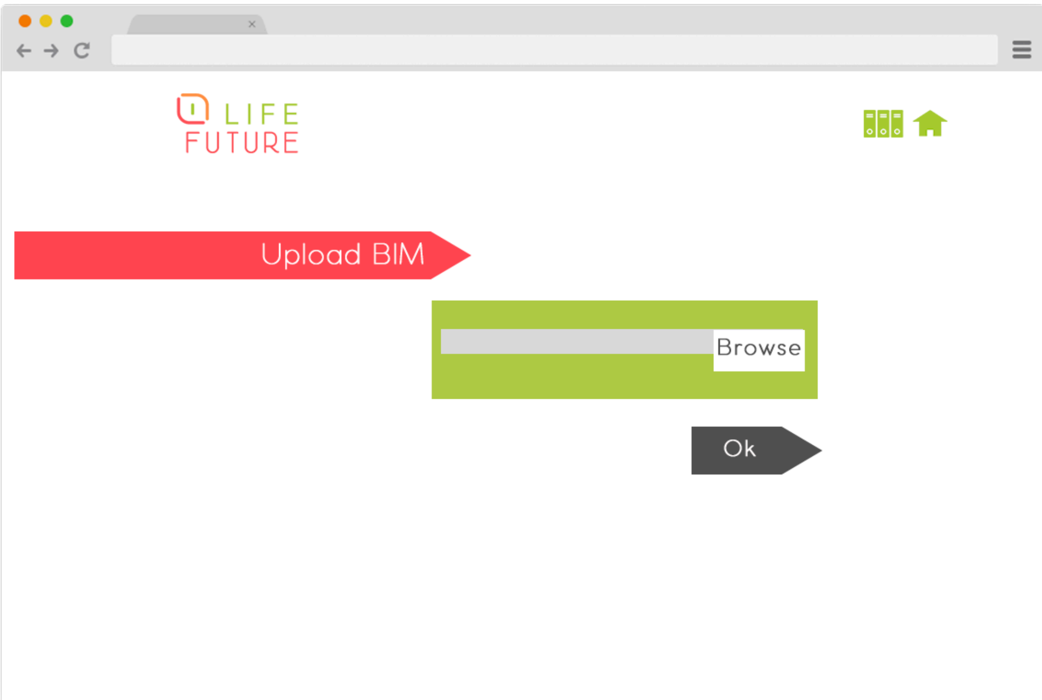


Figure 45 Upload BIM

This page has a browse button that aids the user in finding the desired BIM file to upload as a proposal. The file will contain all the information and fields detailed in the manual for the GUF tool to work with it correctly.

Enter data Manually

Being more tedious of a task than uploading a BIM file, this process entails four different pages. This is so that the information requirements are broken down for the user in a more palatable manner. The first three pages ask general information about the product: page 1 asks about product manufacturer and basic characteristics; page 2 about life cycle details like maintenance and packaging; page 3 allows the users to enter any environmental impacts they may know; finally, page 4 requires the users to enter all the known material information.

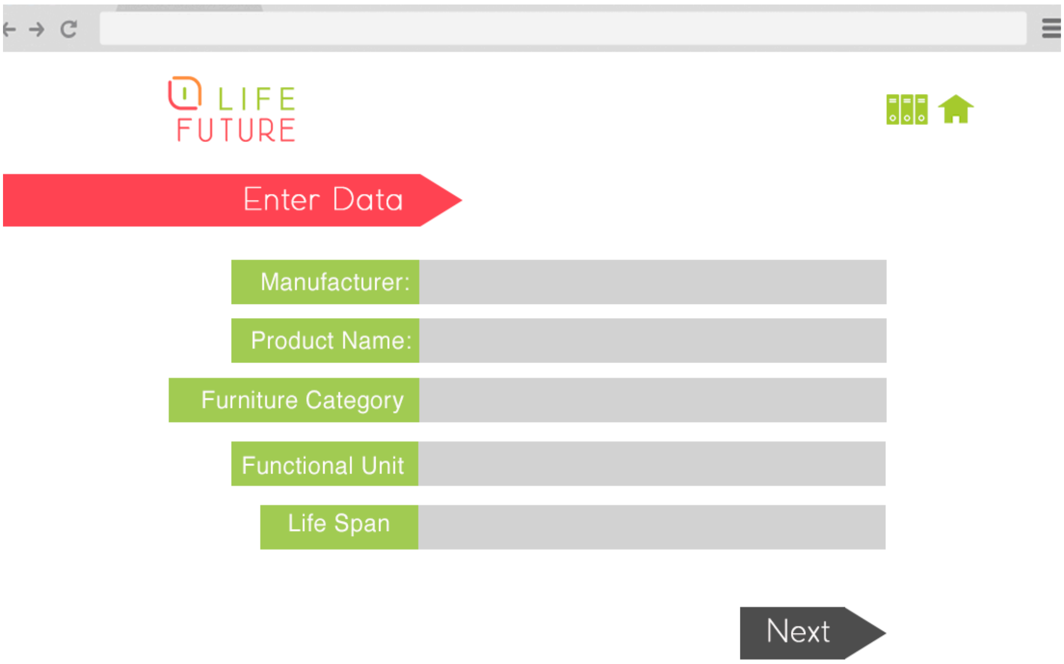


Figure 46 Enter data page 1

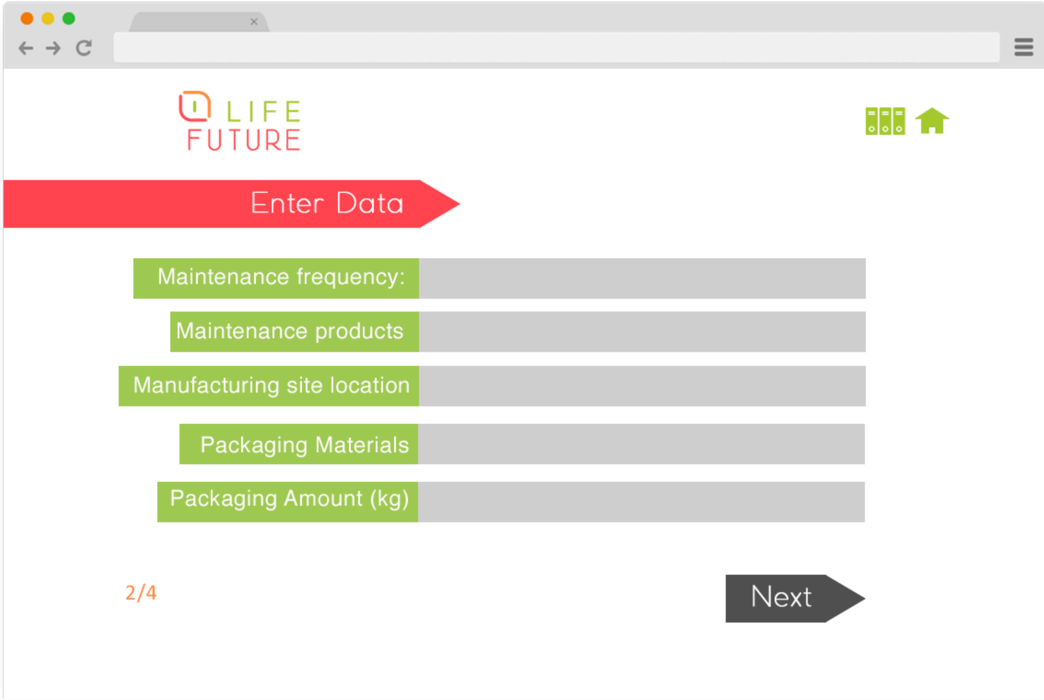


Figure 47 Enter data page 2

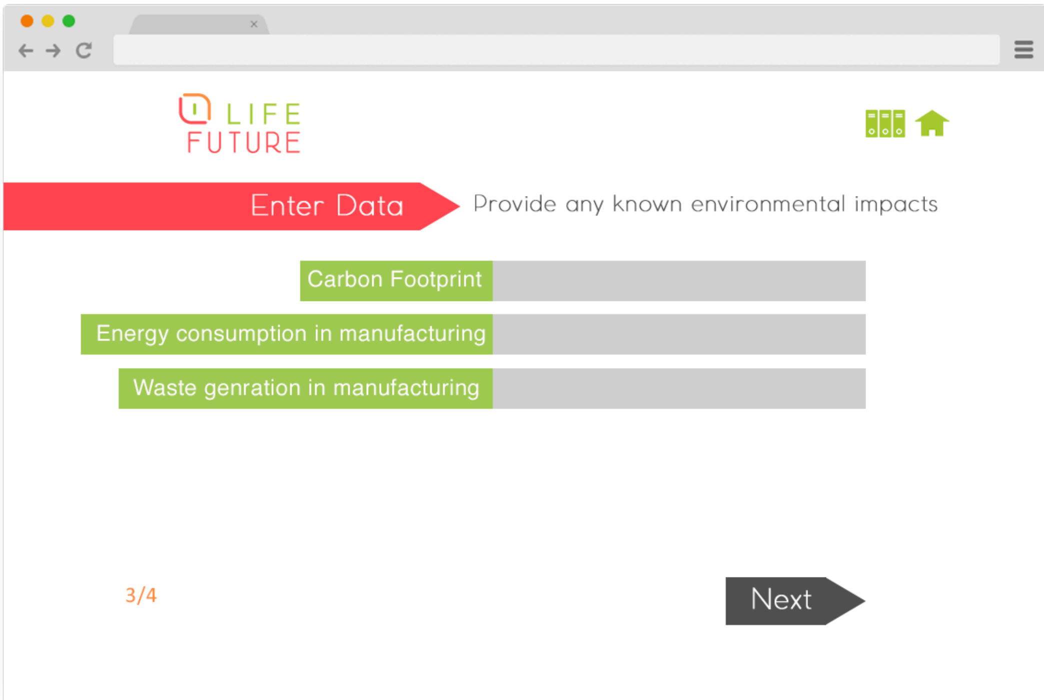


Figure 48 Enter data page 3

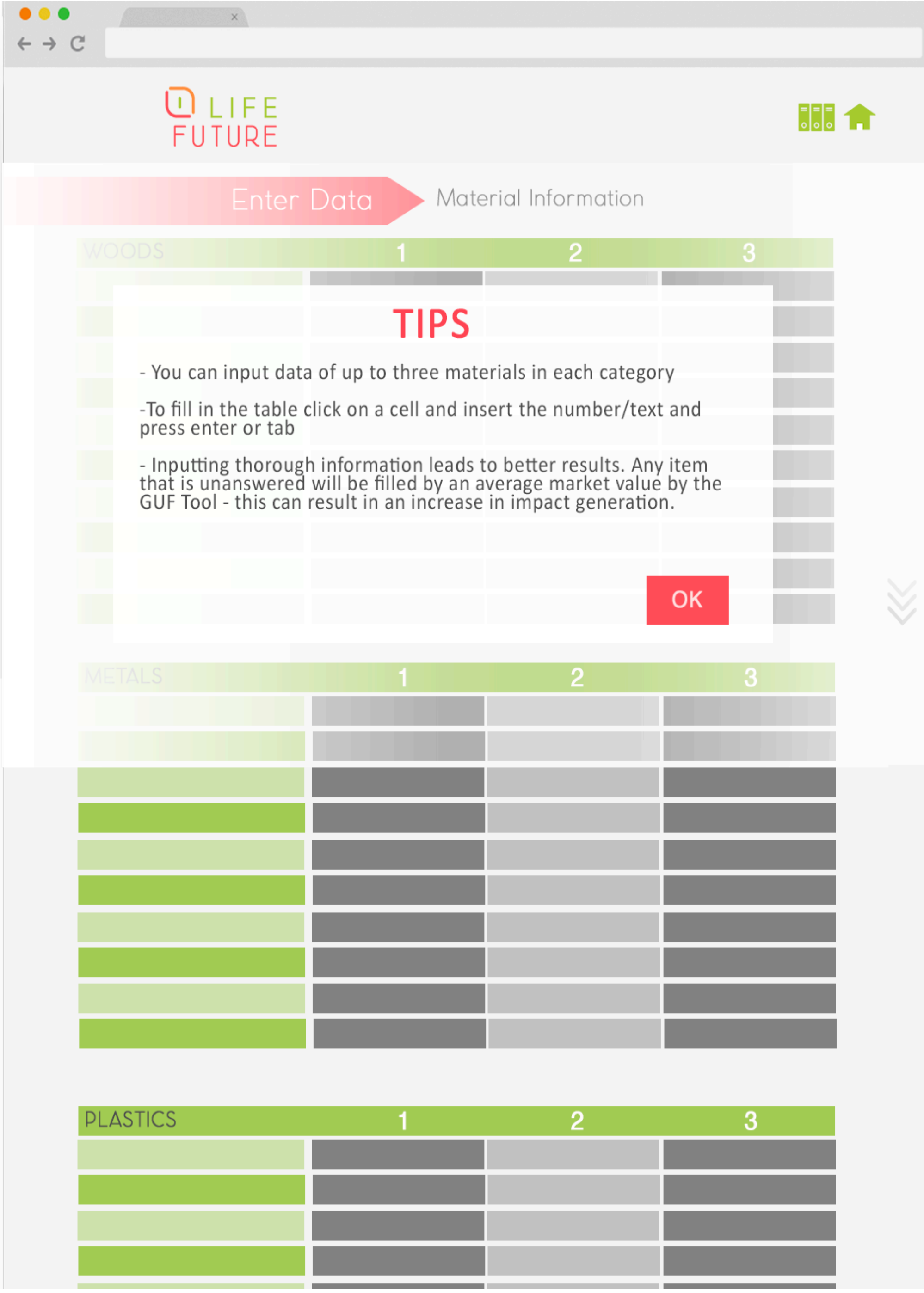


Figure 49 Enter data page 4

Page four is different from all the others because it comes in a long display format that is intended for the user to scroll through. The reason behind this is that there is a lot of information to enter and a tabular format makes it easy for the user to figure out what information belongs in each cell. If working from a technical sheet or an EPD the user can add information in the order they find most comfortable and can jump from a material to another with no information loss, since everything is saved as you go.

Checklist and additional information

After BIM upload or manual data entry, the users are directed to this page in which they must upload content for verification of the specifications and award criteria, used to ensure quality of the analysis and further improve a product's environmental performance score. The files to upload include EPDs, Security Data Sheets, detail drawings, ecolabels, any kind of certification, etc.

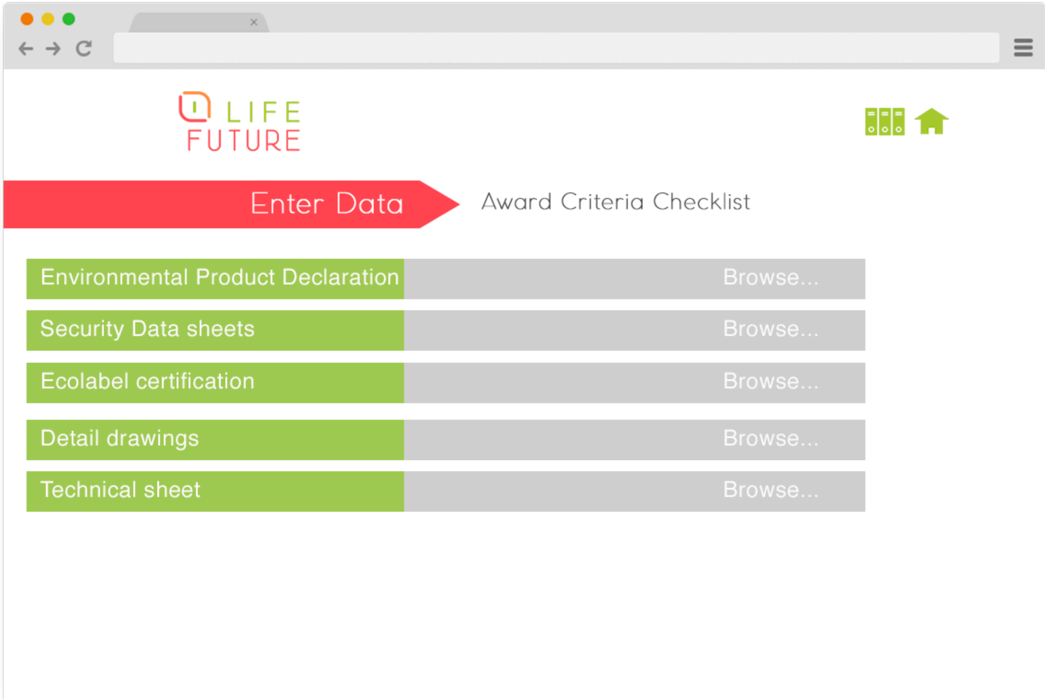


Figure 50 File upload

Post new offer

Public authorities will be able to post their own offers and tenders using the link provided in Figure 42 Offer menu, named “Post offer”. They will be directed to the page shown below.

Figure 51 New offer page 1

Figure 52 New Offer page 2

Once completed the offer is saved and published for proposals to come in.

User Menus

Each user can access their own personal menu by clicking the folder icon, visible in all pages. By doing so they are directed to their personalized page where they can see their current products and/or offers as can be seen in the following images.

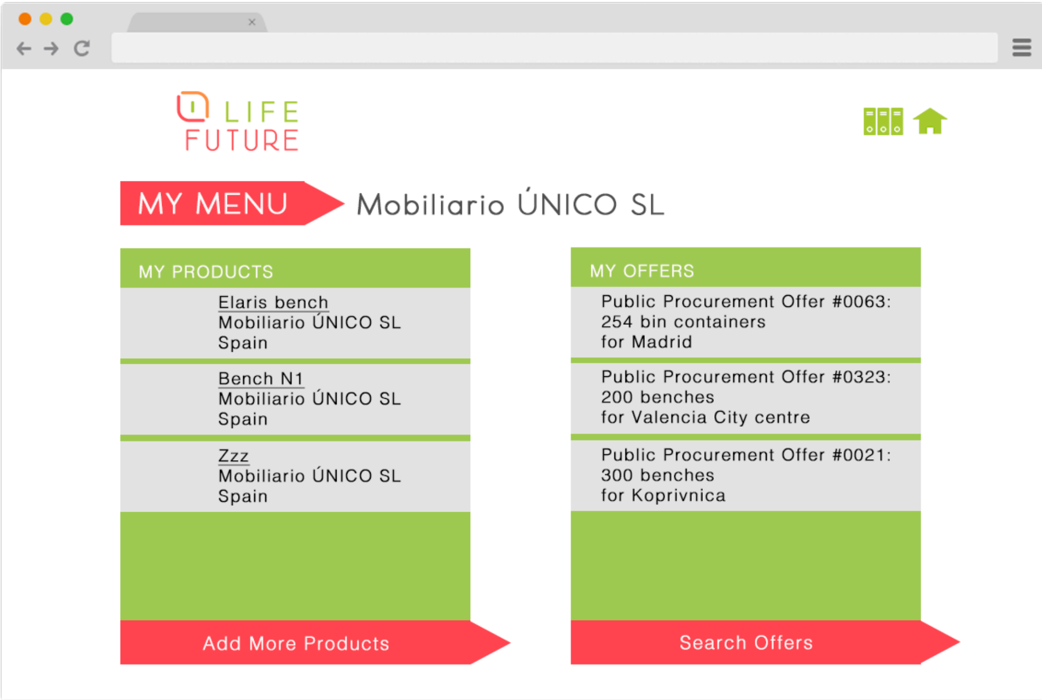


Figure 53 Mock up of a User menu for a UF manufacturer

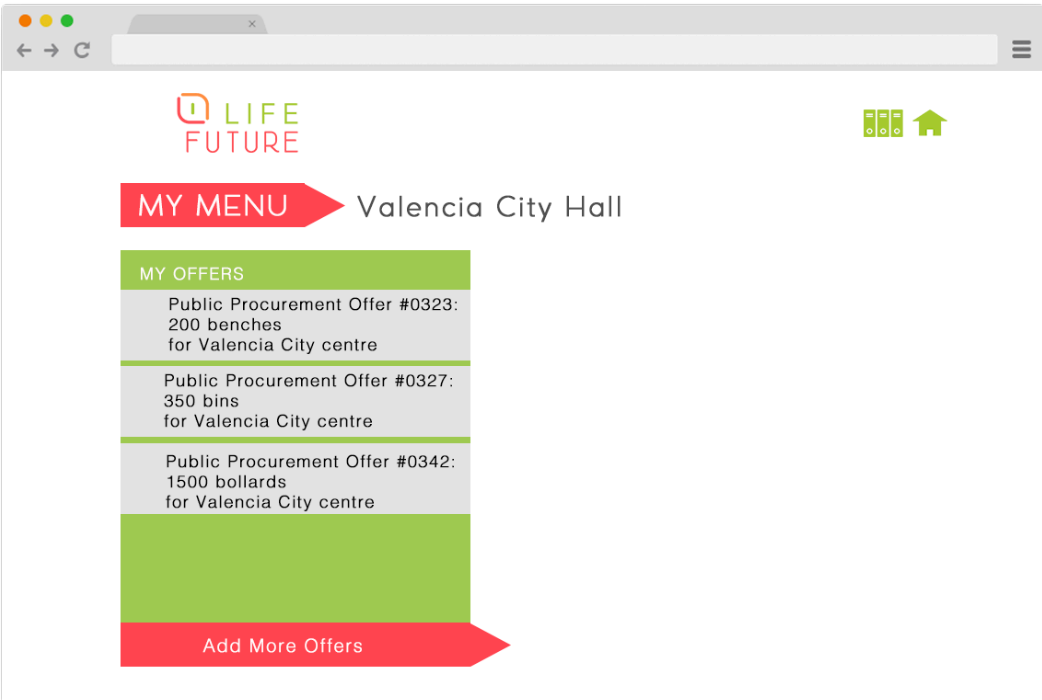


Figure 54 Mock up of a User menu for a public authority

Results

The result section is intended to be easy to understand whilst still providing enough information. This way, users with different levels of LCA expertise can use the tool up to their capacities. Figure 55 shows the first page of the results, here an overview and comparison of different products can be seen (5 are shown, benches A-E), each colour block belongs to one contributing environmental impact which is added to the others to produce the final result as a % of the least sustainable product.

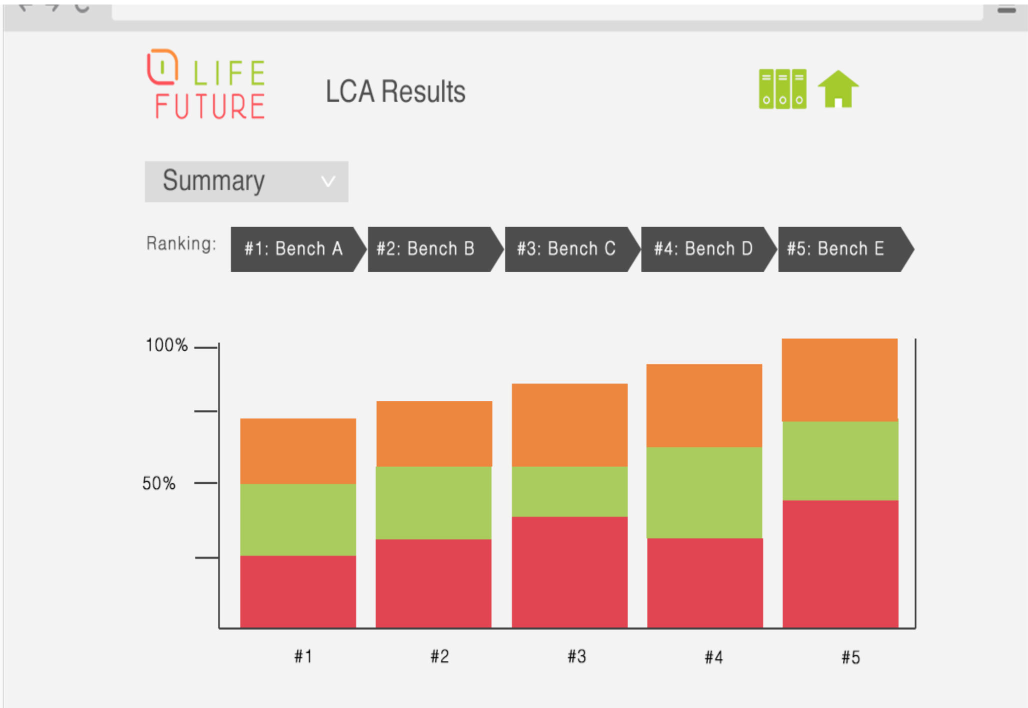


Figure 55 Results Summary

By clicking on the left top drop-down list, the users can select a specific impact category, for instance carbon footprint. When doing so Figure 56 will appear, in this page the users will be able to see the contribution each stage of the life cycle has on the impact category and pinpoint the most harmful stages and areas for sustainability improvement.

It must be noted that, for confidentiality purposes, when a UF manufacturer views the results he/she will only be able to see the name of his/her product; the other products will remain anonymous with letters for names.

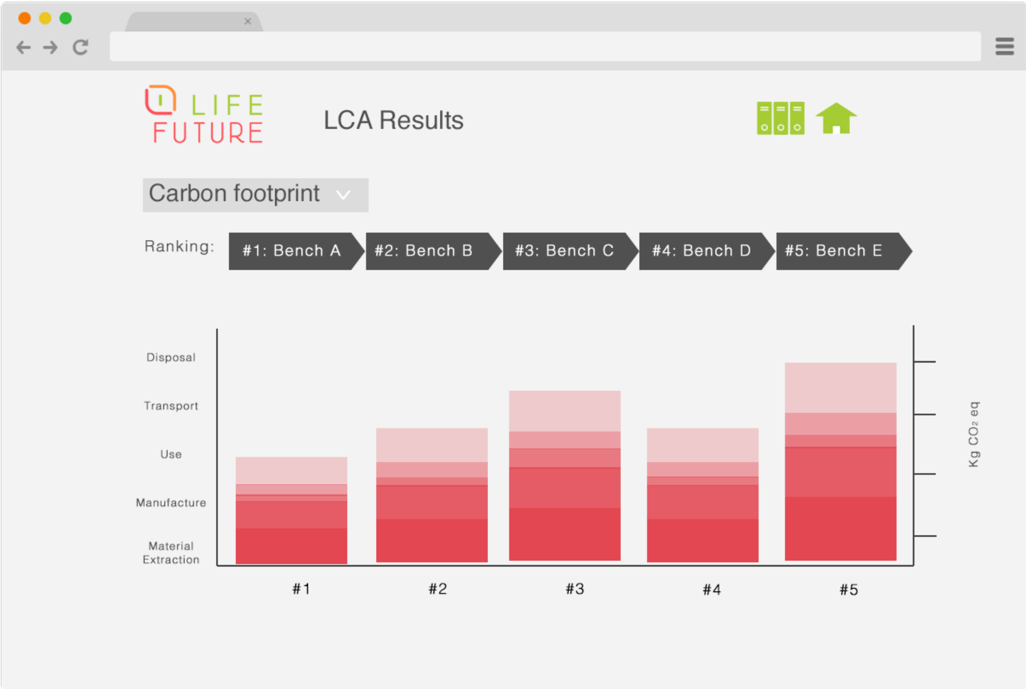


Figure 56 Carbon footprint results

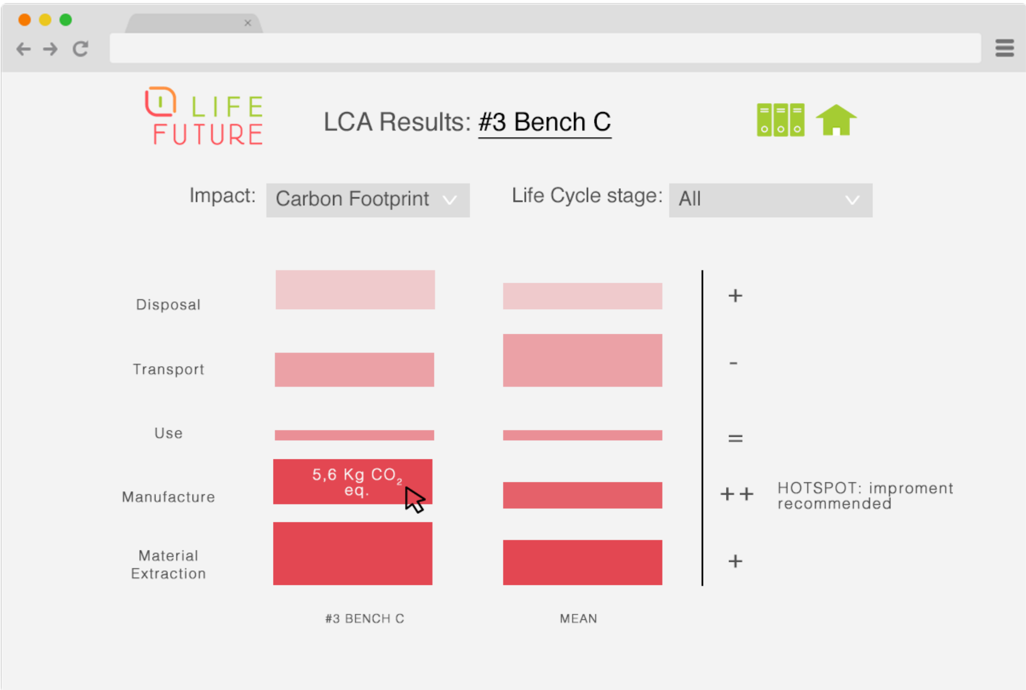


Figure 57 Individual results

Furthermore, the users will be able to access the individual LCA results for each product as can be seen in Figure 57. In this page one can select the impact category and the life cycle stage, whatever the selection, the page shows the individual results for the product compared to the mean of all the products. Additionally, the GUF tool provides insight on what are the hotspots and recommends improvements if appropriate.

8.2.1. REQUIREMENT CHECK

In order to ensure that all the objectives are met by the design, the list of requirements is checked to see whether they are attained. The check can be seen in where the checklist has been completed using YES/NO or NA, the latter meaning that the information is Not Available.

Objective	YES/NO/NA
1. Support and encourage GPP -R	YES
2. Reach as many European public authorities as possible-R	NA
3. Create a new LCA software-R	YES
4. Have a good quality GUF Tool -R	YES
5. Have a modern and attractive tool-R	YES
6. The tool must adapt to the specific needs of the project-R	YES
7. Liked by project partners –S	YES
8. Must follow the LIFE Future project style and graphics-R	YES
9. Must be aesthetically pleasing-R	YES
10. Must be modern in form and in interaction-R	YES
11. The layout must be clear and not cluttered with information. -R	YES
12. It must be possible to code the tool-R	YES
13. The user experience is positive and encouraging -R	YES
14. Easy to use by non-expert users-R	NA
15. Easy to read -R	YES
16. Easy to understand-R	YES
17. The information is easy to find-R	YES
18. It is desirable to have a good looking interface-R	YES
19. May be used by as many people as possible (with different capabilities) -R	NA
20. Compatible with text reading apps, for inclusive purposes-R	YES

8.3. SWING SET FINAL SOLUTION

The name of the swing is changed to LIFE swing set, to match the identity of the LIFE Future project in which it is based and inspired.

In the following sections all the aspects of the swing are detailed, including the material specifications, but in this section the desired textures and colours will be explained.

The most prominent component is the base of the swing, which gives colour and by so helps define the character and emotions linked to the design. Vivid, light and vibrant colours are preferred in this part. Since it's so visually heavy and attractive for the eyes, the colourful aspect is essential. For this reasons, the LIFE Future project colours are tested:

All colours are vivid and cheerful but each communicates a different set of values and emotions, compelling to different types of people and different environments. Since this is the case, it is decided that the clients will be able to choose the colour that best suits their needs from the following colours:

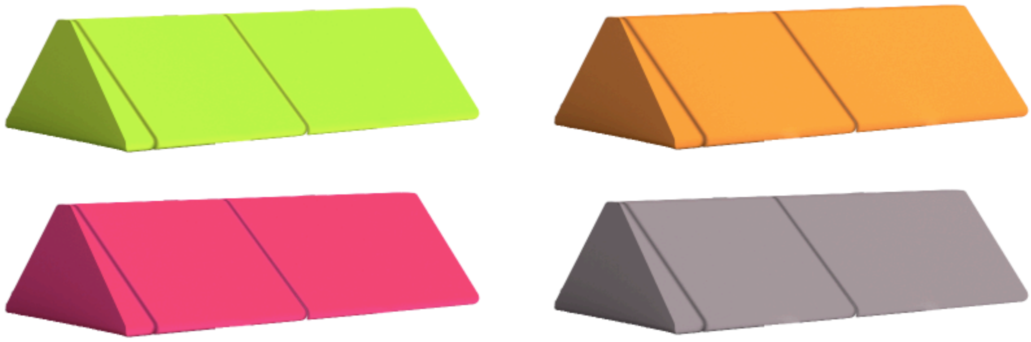


Figure 58: Base colour options

As for the beams and other metallic parts, two options are considered, a polished metallic look or a sleek paint colour to match the base, finally deciding in favour of the metallic look since metal structures transmit a greater sense of stability and in this case it will keep the design clean streamlined. Additionally, galvanising or anodising will protect the metal and increase its surface hardness more than paint will.

The desired texture of the rope is of a thick lined texture, that feels secure to the touch but that is not damaging for the skin. The best suitable colours for this component are neutrals like black, brown or light beige.

8.3.1. Renders

Figure 59: LIFE swing in a park

Figure 60: Several LIFE swing in a park

8.3.2. Detailed Design

8.3.2.1. Materials

To determine the appropriate materials to use different aspects must be considered: the physical properties of the material, the mechanical demands of the design, the cost of material, the recyclability and the availability of recycled material in the area amongst others.

The first step in the determination of the materials is separating the swing in its different parts and deciding the different demands these entail.

- Base block: store sand, stand weight, contact with “beams”, endure environmental conditions.
- Beams: bear weight and endure environmental conditions.
- Sand/Weight: Counteract forces in the swing.
- Ropes/Chains: stand weight and swing
- Seat: Support user, be comfortable and flexible, and be sustainable.

BASE

The requirements for this material are: in first place, it must be as sustainable as possible; in second place, it must endure the environmental conditions and additionally the cost is desired to be as low as possible.

Further research shows that the most recycled plastic in the UK and in Spain from citizen’s waste is polyethylene

Through a thorough search of companies that produce recycled materials and products for urban furniture there is a company and material that stand out: *Syntrewood* by *Lasentiu* is a material made of 70% recycled polyethylene and polypropylene and 30% made of other recycled materials and virgin polyethylene. This material presents many opportunities for design. It is easily transformed into parts of different thicknesses and maintains good mechanical and chemical properties, however there are many similar products in the market with just as good properties.

Finally, a mix of recycled and virgin polyethylene is chosen in the ratio 7:3. This ratio maintains good material properties while being most sustainable.

BEAMS

To determine the best possible material for these parts the Ashby Methodology is followed, Table 5 illustrates the analysis of the problem. With this information the computer software CES EduPack is used to determine which materials are excluded by undertaking a first sift in which any material with a low stiffness or a high cost / density is disqualified.

Table 5: Material design analysis

Function:	Withstand a force
Aim:	Minimize volume and weight Minimize cost
Restrictions:	Avoid material failure (resistance, stiffness) Endure environmental conditions (rain, saltwater,) Must be recyclable and recycled (>50%)
Free Variables:	Section Area Material type

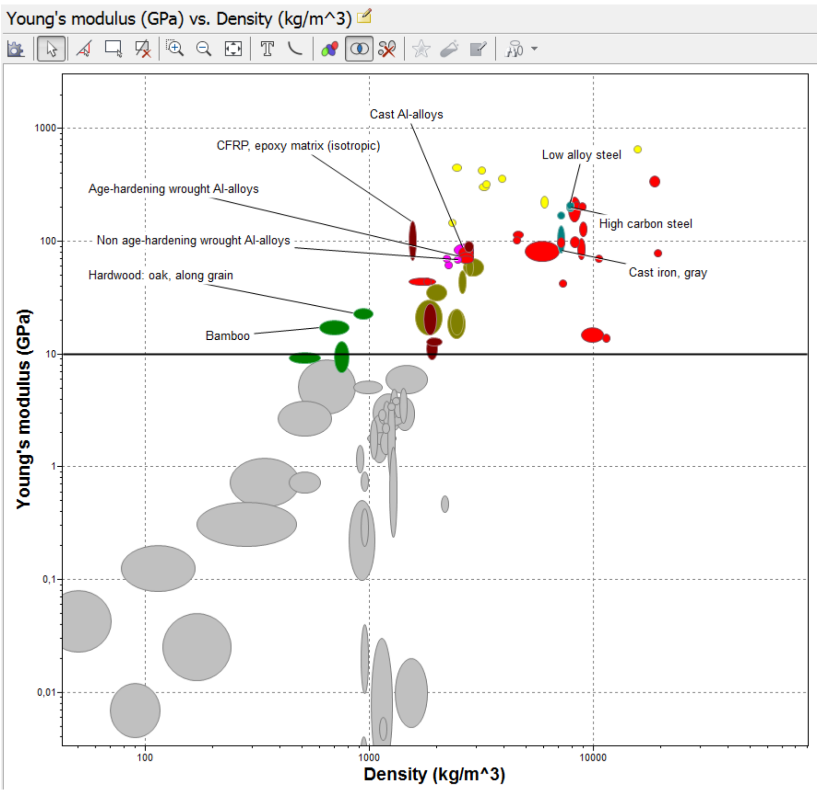


Figure 61: Young's Modulus/ Density Material graph

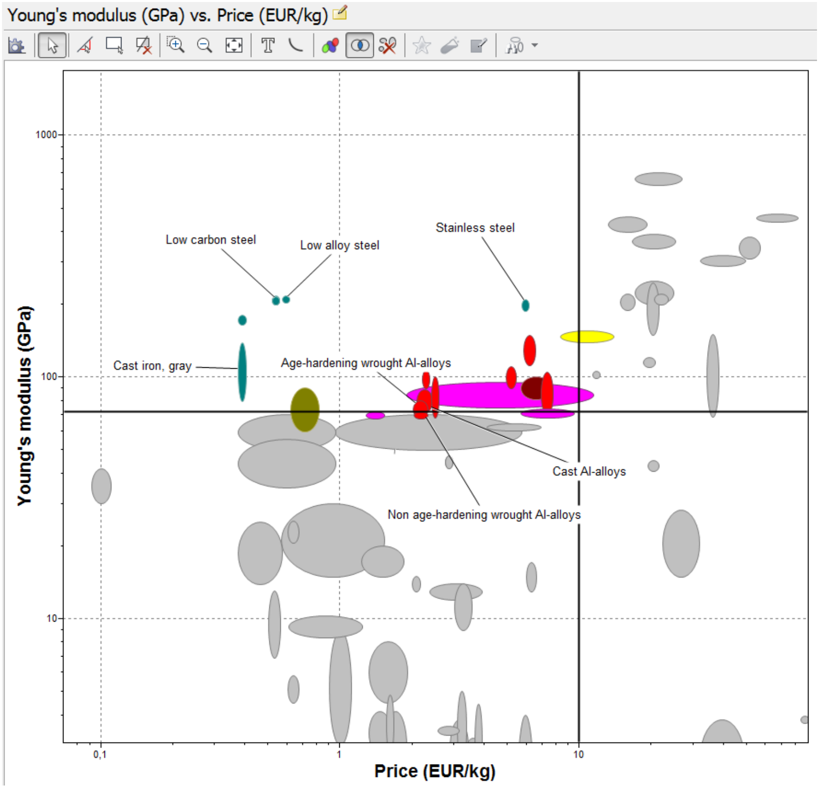


Figure 62: Young's Modulus / Price per kg material graph

Once the first sift is done, the best possible material is selected from the remaining. To do so, it is necessary to determine a material index derived from the equation of material behaviour (where the behaviour P is determined by: F, functional requirements; G, geometric requirements; and M, material properties.):

$$P = f(F, G, M)$$

Each of the parameters can be separated since maximising one of them maximises all and the behaviour parameter, thus the performance index $f_3(M)$ is isolated. Since the aim is to have a minimum weight in a beam standing flexion without failing, the deriving material index is determined as:

$$M = {E^{1/2}}/{\rho}$$

Where E is the Young's Modulus of the material and ρ is the density and to maximize the performance index (M) E must be maximized and ρ minimized.

Using CES EduPack, the restrictions of stiffness and machinability are introduced, alongside a new restriction of price (<2€/kg) as shown in Figure 63. With the restrictions in order, a logarithmic graph of Young's Modulus against density is made (Figure 64) and using a slope with an index of 2, the most optimum materials are determined.

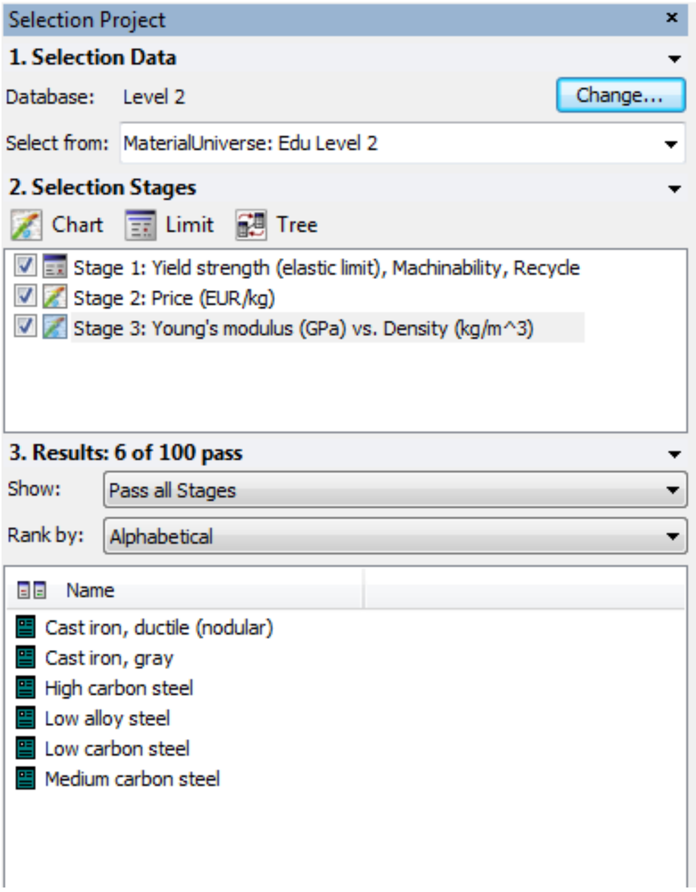


Figure 63: CES EduPack screenshot

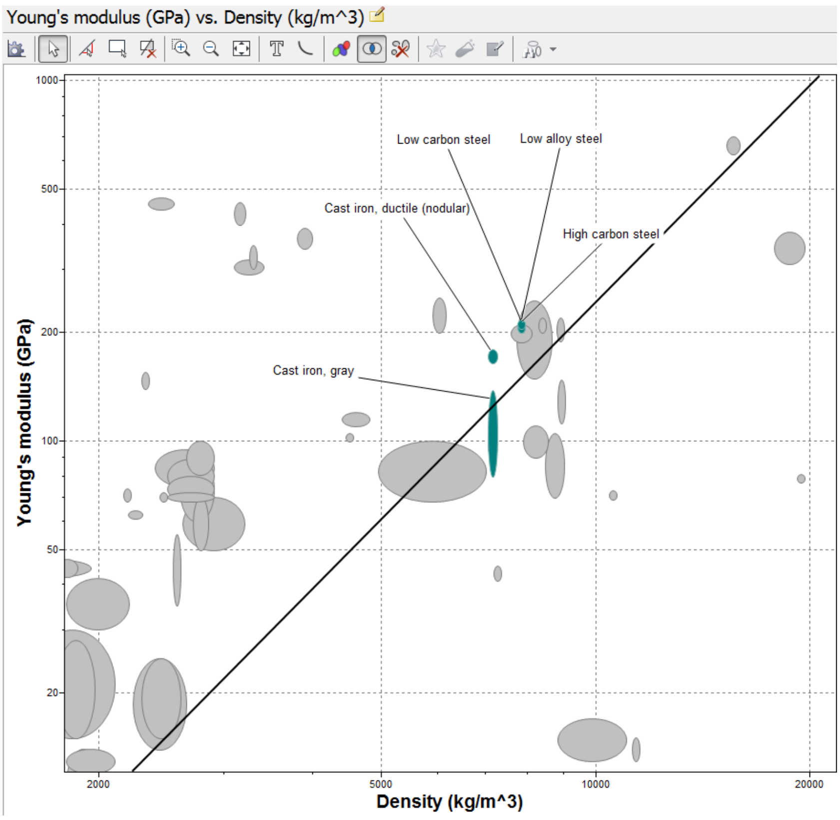


Figure 64: Stage 3, optimum materials

CES EduPack gives a range of appropriate materials (high and low carbon steels, low alloyed steels and cast irons), these are then researched and studied to examine which fits best the rest of the requirements, in this case the recyclability and availability in the area.

After researching the availability in the area it is found that the most suitable steel is a low carbon structural steel used in construction, with a recycled content of 50%. The manufacturer (*Ferros Puig*) provides hot-rolled structural profiles of different quality steels; the selected product is a solid rectangular plane of S275JR* Steel with a layer of hot zinc galvanizing to protect it from the environmental surroundings.

*S indicates its structural steel; 275 refer to its elastic limit in MPa; and JR references the grade, in this case ordinary construction grade steel.

WEIGHT FILLING

The main requirements for this material are the availability in the local area, the highest possible density and the lowest possible price. With this criteria at hand and using CES EduPack, it is determined that an arid should be used, but since in the program one cannot find different types of sands, the national distributors are searched to find the most suitable sand and so it's decided that a white sand from "Comercial Río Aragón" is the best price for an acceptable weight (36,95€ for 1300kg of sand).

ROPES/CHAINS

These parts are essential for the proper use of the swing therefore they must be made of a resistant material that its both sustainable and strong. The usual materials in swing ropes are plastic, textiles or metal chains. Textiles are only used in private use swings, not in public use ones. The plastic ropes can be made from recycled plastics also and are good in exterior conditions. Metal chains are the most typical form of chains as they are very strong and durable, however they are very bulky and tend to easily rust, as was found in the field research.

Plastic ropes seem to be the best alternative in this situation, the best plastic to use in this application was found to be polypropylene and a good amount of recycled content was found to be 30%, without compromising the mechanical properties.

SEAT

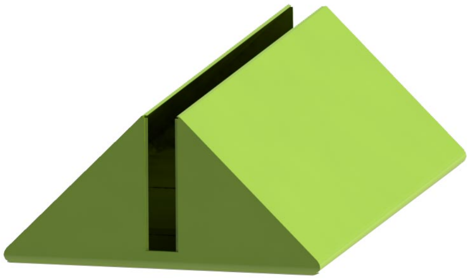
The final piece of the swing set is the seat, which must be comfortable and durable. It is found that a common material is rubber, recycled entirely from other uses – usually vehicle pneumatics.

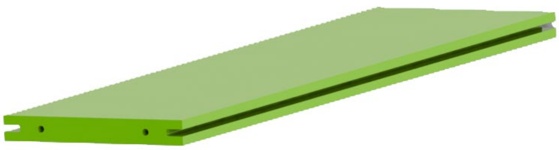
8.3.2.2. Fabrication Processes

Each individual part of the swing set is made of different materials and conformed using different production processes and techniques. Below, all the parts are detailed and the processes explained.

RECYCLED POLYETHYLENE BASE

All the recycled polyethylene (PE) material is cleaned mechanically and chemically and then extruded and made into pellets, which are then used to form the different parts. The parts forming the base are manufactured in different ways: for some of them the pellets are bought from the recycling company and used in rotomoulding; for the others, plastic sheets of the desired thickness are directly bought and then machined to obtain the final geometry.





ROTOMOULDING

This fabrication process is ideal for large hollow pieces manufactured with plastics; it is specially used with high and low-density polyethylene. Although slower, rotomolding has lower mould and machinery costs and is preferable for small productive volumes. When producing by rotomolding its important to consider wall thickness and sufficient edge rounding (since wall thickness decreases in them). Openings are achieved through mould insulation to avoid material build-up in those areas. Tolerances of 0,2 to 1mm are obtained and roughness of up to 1,6 microns.

DEBURRING AND SANDING

This is usually a manual process in which any large imperfections and protuberances are cut out and sharp edges are smoothed down improving aesthetics and safety. Many manufacturing machines already incorporate a deburring station for their pieces, but others don't and has to be done later on. Sanding can also be done mechanically using sandpaper at no more than 10m/s.

MACHINING: CUTTING/SAWING

High Speed Steel (HSS) saws are used in the cutting of plastic, with a low cutting speed and small sawtooth size to avoid increases in temperature that could soften or melt the material. Tolerances of 0,25 up to 3mm are expected, and the cutting speeds vary in relation to the material. For plastics around 0,07m/s is used in computerized saws.

MACHINING: MILLING

The milling of plastics, contrary to metal milling, involves high cutting speeds and small advance speeds. The tools of preference when working with plastics are made of HSS and hard steel. In this specific operation a groove is made on two sides of a panel. The obtainable tolerances range from 0,02 to 0,5 µm. This process is economic for any production quantity.

MACHINING: DRILLING

For the drilling of the holes helical drill bits are used. The bits used for polyethylene have a small tip angle (80º) since thermoplastics are usually softer. The best materials for the drill (Cascales, 2009)bit are high speed steels (HSS). Since plastics start flowing with high temperatures, slow speeds are used as well as small machining forces.

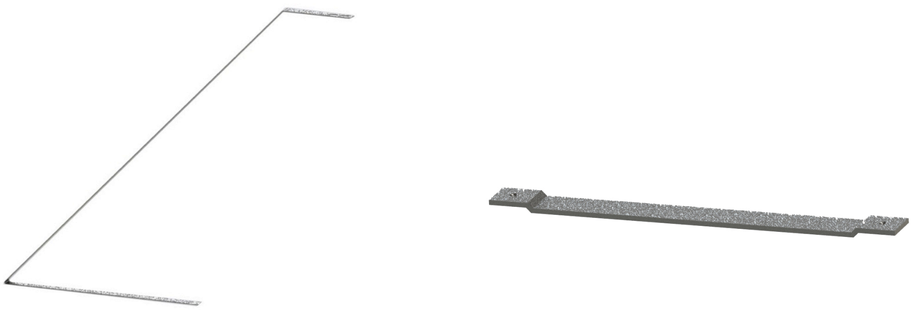
Parts and manufacturing:

BODY OF THE BASE

SLIDING LIDS (Lateral and Top Lids)

STEEL BEAMS

There a two long beams that support the swing and two transversal ones with the same cross section that aid in the rigidity of the structure. They are bought from a manufacturer in 5m lengths of the desired section (60x8mm) ready to be transformed into their final shape.



STEEL SHEET HOT ROLLING

This is the first step in the manufacturing of most steel or metal parts. The slabs or blooms (thick metal sheets) that the metal is found in are operated over its recrystallization temperature. They are passed through pairs of rolls to obtain a smaller and regular thickness. Since the section of the steel beams will have a normalised commercial dimension (solid rectangular 60x8mm) they will be bought already formed from a steelwork manufacturer.

MACHINING: PUNCHING

The next step is to obtain the holes through which the ropes will go. To do this the metal parts are machined using a punching machine. In this process a tool is pressed against the metal sheet until the elastic limit is overcome and two cracks are formed, as the tool continues to press on the sheet the cracks rapidly grow until the material is fractured and the corresponding holes are obtained.

BENDING

In this machining process the metal sheets are given the desired shape by bending using a press with the adequate punch shape and corresponding matrix. During the process the punch is used to impact against the metal sheet, pressing it against the matrix and deforming it through plastic deformation. Since the deformation creates internal forces in the bent corner the piece tends to go back to place, so in many occasions the sheet is bended a larger angle than the angle desired, to account for the unfolding.

GALVANISING

The process of hot zinc galvanising protects the steel from corrosion and environmental conditions for over 30 years. Galvanised steel also improves superficial strength (<10 Vickers). This process is very cost effective and needs little to no maintenance, and incidentally has less environmental impact than other superficial treatments like electroplating. In the case of the swing, cold zinc galvanising will be necessary since its easier to apply and requires no immersion tank or out-sourcing, for this procedure to yield the same benefits as hot galvanising the applied zinc layer must be of at least 75 µm.

STEEL BEAMS

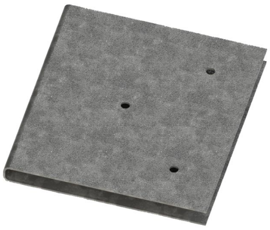
TRANSVERSAL BEAMS/BARS

RUBBER SEAT

There are different components that make up the rubber seat: a rubber sheet, two steel fixing rings, two steel fixing plates and six M2 screws.

FIXING PLATES

The steel fixing plates connect the seat to the ropes, and they are made of galvanised steel. They have three drilled holes through which screws are fastened to secure the rubber sheet in place. Though the sheets will be bought from a steel manufacturer, they are included below.



FIXING RINGS

They are attached to the plates and the ropes of the swing, connecting both.

RUBBER SHEET

The main part of the seat is made of this rubber part, from recycled tire rubber and virgin synthetic EPDM rubber. The manufacture of the rubber sheets is outsourced to a different manufacturer that provides sheets of the desired length, 900mm, that are then cut into 200mm strips and then the oval shape is given. Finally the holes for the rivets are made by a punching machine.

8.3.3. Assembly

The assembly of the finished swing is divided in two parts, one to be done as part of the production and another to be completed in the installation site.

FACTORY ASSEMBLY

Once all the parts have been manufactured the product is assembled and packaged for transport to do so there are the following steps:

1. Pass the Seat Rod (SR) through the Seat Plate (SP), then
2. Slide a side of the Seat Body (SB) through the Seat Plate so the holes on each component fit together.
3. Pass the three rivets through the holes
4. Fix the rivets using the riveting machine
5. Repeat all steps in the other part of SB.
6. Place the Base Screws (BS), the Structure Screws (SS) in a small bag.
7. Place the bag detailed above along with the transversal bars (TB) and the rope (R) inside the Base Body (BB)
8. Slide the Lateral Lids (LL) in place on either side of the base body (BB)
9. Slide the Top Lid (TL) on top of the base body fitting the holes with the holes in the Lateral Lids
10. Place the Base Screws in place and screw them in.
11. Place the foam edge protectors on the sides of the Longitudinal Beams (LB) and the corner protector on the bent corner.

The swing set is now ready for transport.

ON-SITE ASSEMBLY

When arriving at the site the following instructions are followed to assemble the swing set.

1. Unpack all the packaged items
2. Select a levelled and appropriate ground that satisfies safety conditions
3. Screw the Transversal Bars (TB) on to the Longitudinal Beams (LB)
4. Loop the ropes (R) around the holes in the Longitudinal Beams and secure in place.
5. Lift structure to an upright position
6. Place the Base Body (BB) in place on top of the aforementioned structure
7. Fill the base with the sand filling
8. Slide the Lateral Lids (LL) in place on either side of the base body (BB)
9. Slide the Top Lid (TL) on top of the base body fitting the holes with the holes in the Lateral Lids
10. Place the Base Screws in place and screw them in.

The swing is now assembled and ready for use.

8.3.4. Packaging

Following the environmental beliefs of the project, the packaging is considered from a viewpoint of simplicity and material economy.

Taking advantage of the hollow body of the base, it is decided that the smaller and manageable parts (the seat, already assembled, the base and structure screws, the ropes and their fixings and the transversal bars) will be placed inside bio-degradable bags, made from cellulose or potato starch and following the standard UNE 13432: Requirements For Packaging Recoverable Through Composting And Biodegradation. Test Scheme And Evaluation Criteria For The Final Acceptance Of Packaging. Once in the bags those will be thermo-sealed and introduced in the base body. The base will be closed using its lids.

The longitudinal larger beams will be protected at their edges to make sure they are not damaged or damage anything during transport. To do so, the edges and the bent corner will be covered with fitting foam edge protectors, ideally made of starch based-foam.

8.3.5. Mechanical Stability Check

In order to ensure the safety and the mechanical stability of this equipment different calculations are made. In first place, the standard UNE EN 1176-1: Playground Equipment and Surfacing is followed, specifically section B.4 Force calculations on a swing. This section gives a set of equations for vertical, horizontal and resultant forces acting on a moving swing (Figure 65). The standard provides a set of normalised values to use as weight coefficients depending on the different angles.

$$F_h = C_h \times g \times (G_n + G_s)$$

$$F_v = C_v \times g \times (G_n + G_s)$$

$$F_r = C_r \times g \times (G_n + G_s)$$

Figure 65: Forces acting on a moving swing. UNE-EN 1176-1

Here:

F_h= horizontal force

F_v= Vertical Force

F_r= Resultant force

g= acceleration due to gravity

G_s= mass of the moving system, here 3kg approximately

G_n= mass of the users, in this case and following the same standard a user of up to 69,5kg is considered

C_h, C_v and C_r= weight coefficients depending on the angle of the swing, these are normalized and can be seen in Figure 66.

$\alpha_{max} = 80°$			
α	C_r	C_v	C_h
80°	0,174	0,030	0,171
70°	0,679	0,232	0,638
60°	1,153	0,577	0,999
50°	1,581	1,016	1,211
42,6°	1,950	1,494	1,253
30°	2,251	1,949	1,126
20°	2,472	2,323	0,845
10°	2,607	2,567	0,453
0°	2,653	2,653	0,000

Figure 66: Weight distribution coefficients. UNE-EN 1176-1

According to this standard the forces are calculated at α=0º, where the vertical force is maximised, and at α=42,6º, where C_h is maximised.

$$F_h = 0 \times 9{,}81 \times (69{,}5 + 3) = 0N$$

$$F_v = 2{,}653 \times 9{,}81 \times (69{,}5 + 3) = 1886{,}88N$$

$$F_h = 1{,}253 \times 9{,}81 \times (69{,}5 + 3) = 895{,}23N$$

$$F_v = 1{,}494 \times 9{,}81 \times (69{,}5 + 3) = 974{,}806N$$

At the critical point (α=42,6º) the momentum produced is used to calculate the necessary momentum produced by the sand weight for the system to remain stable.

$$\Sigma M = 0 \rightarrow \quad F_h \times d_1 + F_v \times d_2 - W \times d_3 = 0$$

$$W = \frac{F_h \times d_1 + F_v \times d_2}{d_3}$$

$$\boldsymbol{W} = 2765\text{N} = \mathbf{281,89kg}$$

This indicates that a weight of 282kg would be enough for a safe swing motion, however the sand weight will be even more: **400kg**, filling up the whole container.

The next step was to prove that the steel beams would in fact be able to support the weight of a person during use. This was done by simplifying of the structure to a fixed beam undergoing combined flexion forces as shown in the diagram in Figure 67.

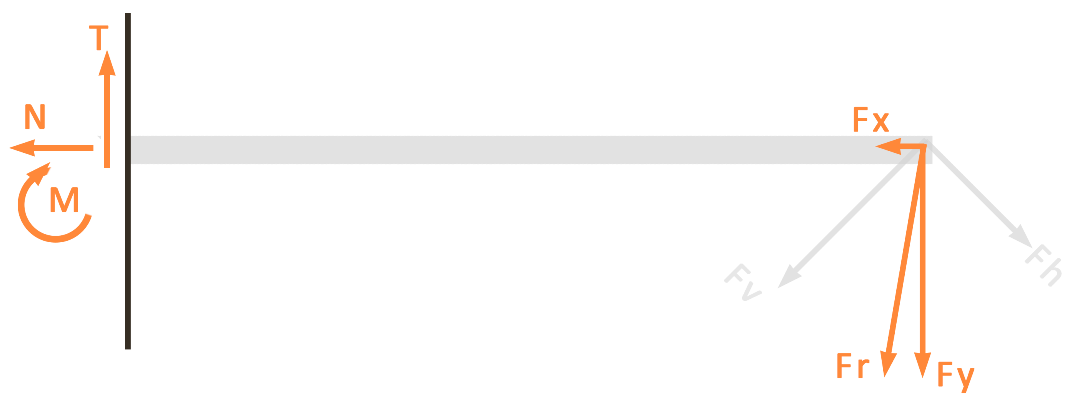


Figure 67 Forces on simplified steel beam

The minimum safe cross section was calculated using the following data and formulas:

N_s = 2 (safety coefficient)

σ_{adm}= 275MPa ; $\sigma_t = \sigma_{adm} \cdot N_s$

Using the equations from the aforementioned standard, Fr is calculated:

$$F_r = 1{,}950 \times 9{,}81 \times (69{,}5 + 3) = 1385N$$

L=2700mm + 450mm = 3150mm

Cross-section: b=60mm; h=? To be determined

$$\Sigma Fx = 0 \;\rightarrow\; N + F_r \sin(2{,}5) = 0 \rightarrow N = -60{,}43\text{N}$$

$$\Sigma Fy = 0 \;\rightarrow\; T - F_r \cos(2{,}5) = 0 \rightarrow T = 1384{,}16\text{N}$$

$$\Sigma M = 0 \rightarrow M + F_r(\cos 2{,}5) \cdot \text{L} = 0 \rightarrow M = -4360{,}09\text{Nm}$$

$$\sigma_t = \left|\frac{N}{A} + \frac{M\,(\pm Yg)}{I_z}\right|$$

$$275 \cdot 2{,}5 = \left|\frac{-60{,}43\text{N}}{60 \cdot \text{h}} + \frac{-4360{,}09\,(\pm 2)}{\frac{1}{12} 60 \cdot \text{h}^3}\right|$$

$$\text{h} = 0{,}79\text{mm}$$

With the working stress and a safety coefficient of 2,5, it is found that the minimum admissible cross section of the steel used must be **0,79mm**. This is the minimum cross section that would withstand the flexion, however this is not near enough to avoid flexion in the movement, and for safety and reasonable purposes the cross section is established to be 10+ times larger, 8mm.

Finally, since the swing set is not anchored to the ground, the forces necessary to slide and turn the set are determined. This is done to make sure the swing doesn't move with normal use and to warn users of the maximum forces that can be applied without damaging the equipment.

The maximum force that can be applied parallel to the ground before the set slides is calculated first with the following data:

W=400kg =3924N

μ=0,6 (static friction coefficient steel-concrete)

R=W·μ

$$F_{max} = W \cdot \mu = 3924 \cdot 0{,}6 = \mathbf{2354{,}4N}$$

Then, the resistance of the swing set to twist if used improperly – and perpendicular forces are applied to the seat – is calculated, as can be seen in Figure 68.

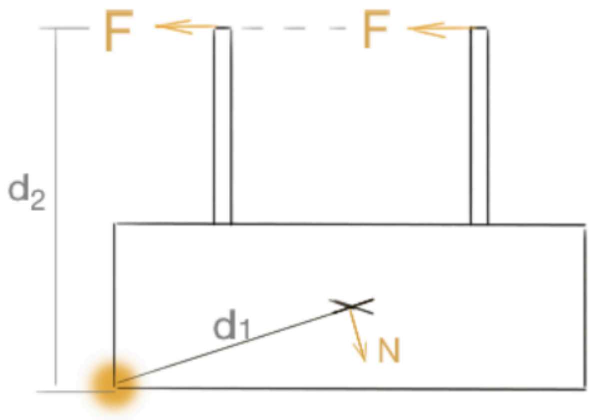


Figure 68 Bottom view with forces

Here:

N=W·µ

D_1=750mm

D_2=2350mm

$$N \cdot d_1 > F \cdot d_2$$

$$F < \frac{400 \cdot 0{,}6 \cdot 750}{2350}$$

$\boldsymbol{F}$ **<76,6kg**

Since the maximum weight of a user considered in the aforementioned standard is of 69,5kg, and is very rarely – if ever – to be applied at a completely horizontal direction, this value can be considered safe.

8.3.6. LCA Comparison

In this section the final design is analysed using the LCA software OpenLCA. It is then compared to the reference swing (Stratus Groupswing by HAGS). The intent in doing so is to determine if designing a new swing has reduced the impact categories and if, in fact, designing with sustainability in mind has lead to a more environmentally-friendly solution.

To carry out the analysis all the materials and known processes for both swings are entered into the program in function of the weight and/or size of each item. The input/output summary for the reference swing (Figure 69) and the designed swing () can be seen below.

Process: HAGS Groupswing Stratus

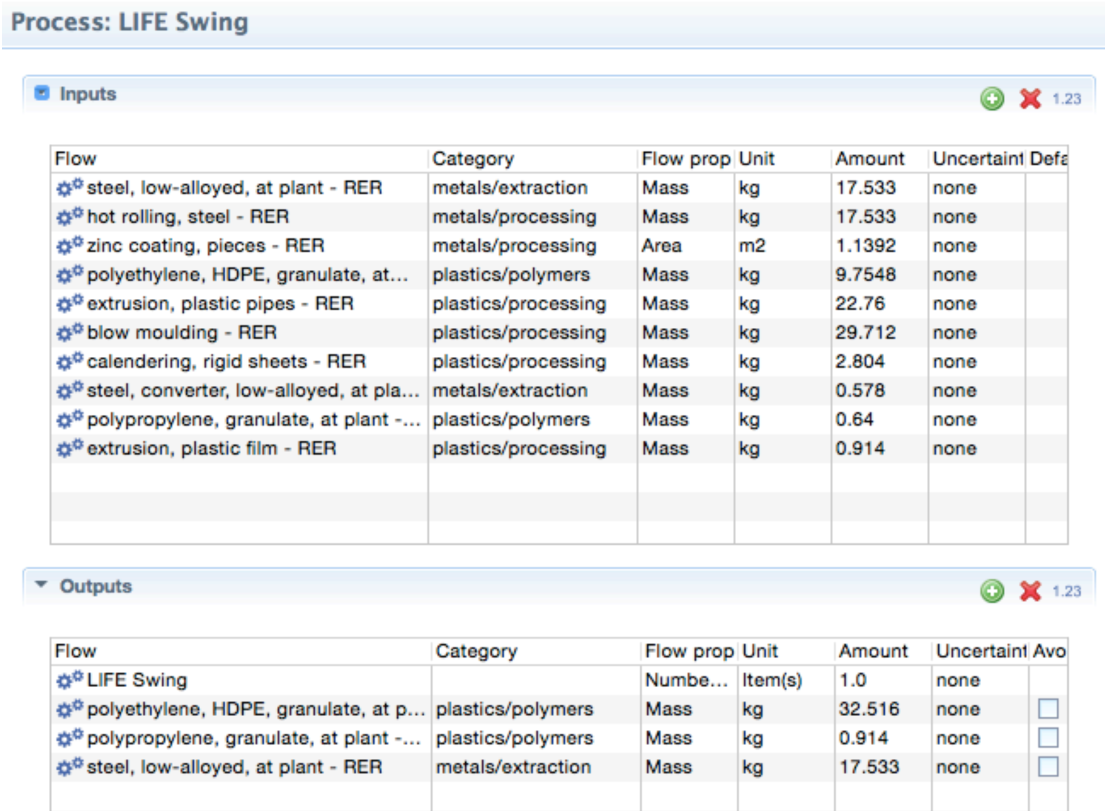
Inputs

Flow	Category	Flow prop	Unit	Amount
steel, converter, chromium steel 18/8, at plant - RER	metals/extraction	Mass	kg	0.8236
steel, converter, unalloyed, at plant - RER	metals/extraction	Mass	kg	148.273
cast iron, at plant - RER	metals/extraction	Mass	kg	0.08
powder coating, steel - RER	metals/processing	Area	m2	2.4844
zinc coating, pieces - RER	metals/processing	Area	m2	2.4844
drawing of pipes, steel - RER	metals/processing	Mass	kg	148.273
polyethylene, HDPE, granulate, at plant - RER	plastics/polymers	Mass	kg	0.487
polyethylene terephthalate, granulate, amorphous, at...	plastics/polymers	Mass	kg	0.4
nylon 66, at plant - RER	plastics/polymers	Mass	kg	0.24
injection moulding - RER	plastics/processing	Mass	kg	1.127

Outputs

Flow	Category	Flow prop	Unit	Amount
HAGS Groupswing Stratus		Numbe...	Item(s)	1.0

Figure 69: OpenLCA HAGS swing inputs/outputs



Process: LIFE Swing

Inputs

Flow	Category	Flow prop	Unit	Amount	Uncertaint	Defa
steel, low-alloyed, at plant - RER	metals/extraction	Mass	kg	17.533	none	
hot rolling, steel - RER	metals/processing	Mass	kg	17.533	none	
zinc coating, pieces - RER	metals/processing	Area	m2	1.1392	none	
polyethylene, HDPE, granulate, at...	plastics/polymers	Mass	kg	9.7548	none	
extrusion, plastic pipes - RER	plastics/processing	Mass	kg	22.76	none	
blow moulding - RER	plastics/processing	Mass	kg	29.712	none	
calendering, rigid sheets - RER	plastics/processing	Mass	kg	2.804	none	
steel, converter, low-alloyed, at pla...	metals/extraction	Mass	kg	0.578	none	
polypropylene, granulate, at plant -...	plastics/polymers	Mass	kg	0.64	none	
extrusion, plastic film - RER	plastics/processing	Mass	kg	0.914	none	

Outputs

Flow	Category	Flow prop	Unit	Amount	Uncertaint	Avo
LIFE Swing		Numbe...	Item(s)	1.0	none	
polyethylene, HDPE, granulate, at p...	plastics/polymers	Mass	kg	32.516	none	☐
polypropylene, granulate, at plant -...	plastics/polymers	Mass	kg	0.914	none	☐
steel, low-alloyed, at plant - RER	metals/extraction	Mass	kg	17.533	none	☐

Figure 70: OpenLCA screenshot of LIFE swing inputs/outputs

The following parameters are extracted using the LCA methods CML 2001 and ReCiPe Endpoint (H,A): Ozone depletion in kg CFC-11; Climate change in kg CO_2 eq.; Depletion of resources in kg of antimony eq.; Human toxicity in DCB eq.; and total impact in points. The results can be seen in **Error! Reference source not found.** below.

Table 6: LCA Comparison HAGS and LIFE swings

Design	Ozone depletion (kg CFC-11 eq.)	Climate Change (kg CO2 eq.)	Depletion of resources (kg antimony eq.)	Human toxicity (kg DCB eq.)	Total impact (points)
HAGS Groupswing Stratus	$1{,}49\cdot10^{-5}$	355,06	2,679	238,34	32,68
LIFE Swing	$4{,}92\cdot10^{-6}$	106,70	1,027	144,736	11,85

As it can be seen, the developed design of LIFE swing improves in all the environmental aspects considered, advancing the overall sustainability of the swing. With this demonstration, the objectives of sustainability are proven accomplished by the new design

8.3.7. Restriction Achievement Check

To ensure that the final design is in fact the best possible design a double check is done in order to make sure that every restriction and objective is met to satisfaction. This step guarantees that the design is in line with the established needs set at the beginning of the project. To do so, a checklist with all the objectives is developed and the final design is analysed by it, completing the checklist with YESY/NO/NA (information not available).

Table 7: Objective checklist

		Objective	Yes/No
ORGANIZATION	1	Compete in European Markets	NA
	2	Improve Sustainability of their products	✓
	3	To increase sales	NA
	4	To become well known	NA
	5	To develop a swing with a low production cost	✓
DESIGNER	7	Aesthetically interesting design	✓
	8	Suitable for exterior environments	✓
	9	Sustainably designed	✓
	10	Mechanically stable	✓
	11	Safe to use	✓
	12	Innovative design	✓
USERS	13	Comfortable Ride	NA
	14	Fun Ride	NA
	15	Safe to use	✓
	16	Not easily broken	✓
	17	Aesthetically pleasing	✓
MAINTEN ANCE WORKERS	18	Difficult to vandalize	✓
	19	Simple maintenance procedure	✓
	20	Easy to handle and install	✓
PUBLIC PROCURERS	21	As inexpensive as possible	✓
	22	Easy maintenance	✓
	23	Sustainable	✓
	24	Difficult to vandalize	✓
	25	Aesthetically pleasing	✓
ENVIRONMENTAL CONSIDERATIONS	26	Sustainable	✓
	27	Reduce amount of material	✓
	28	Recycled materials	✓
	29	Recyclable materials	✓
	30	Sustainably sourced materials	✓/✗
	31	Reduce Ozone depletion potential impact	✓
	32	Reduce Human toxicity impact	✓
	33	Reduce depletion of resources impact	✓
	34	Reduce climate change impact	✓

9. Project Planning

ITEM	TASK	CODE	WORKER ID	DEPENDS ON	TIME (S)
Swing Beam	Punching	A1	W1	-	62,24
	Drilling	A2	W1	A1	60,05
	Bending	A3	W1	A2	120
Transversal Beam	Drilling	B1	W1	-	60,05
	Bending	B2	W1	B1	120
Base body	Rotomolding	C1	RW1	-	1500
	Cutting	C2	W1	C1	223,2
	Milling	C3	W1	C2	120,654
	Sanding	C4	W1	C3	386,4
Base Lateral Lid	Cutting	D1	W2	-	121
	Milling	D2	W2	D1	60,18
	Drilling	D3	W2	D2	63
	Sanding	D4	W2	D3	204
Base Top Lid	Cutting	E1	W2	-	121
	Milling	E2	W2	E1	90,9
	Drilling	E3	W2	E2	61,8
	Sanding	E4	W2	E3	780
Seat Body	Cutting	F1	W2	-	360
	Drilling	F2	W2	F1	62,8
Seat plate	Cutting	G1	W2	-	15,3
	Punching	G2	W2	G1	61,268
	Bending	G3	W2	G2	80
Seat Rod	Cutting	H1	W2	-	60,04
	Bending	H2	W2	H1	80
SEAT	Assembling/Riveting	I	W1	F2, G3, H2	360
PACKAGING ASSEMBLY	Assembling	J		A3, B3, C4, D3,E4, I	600

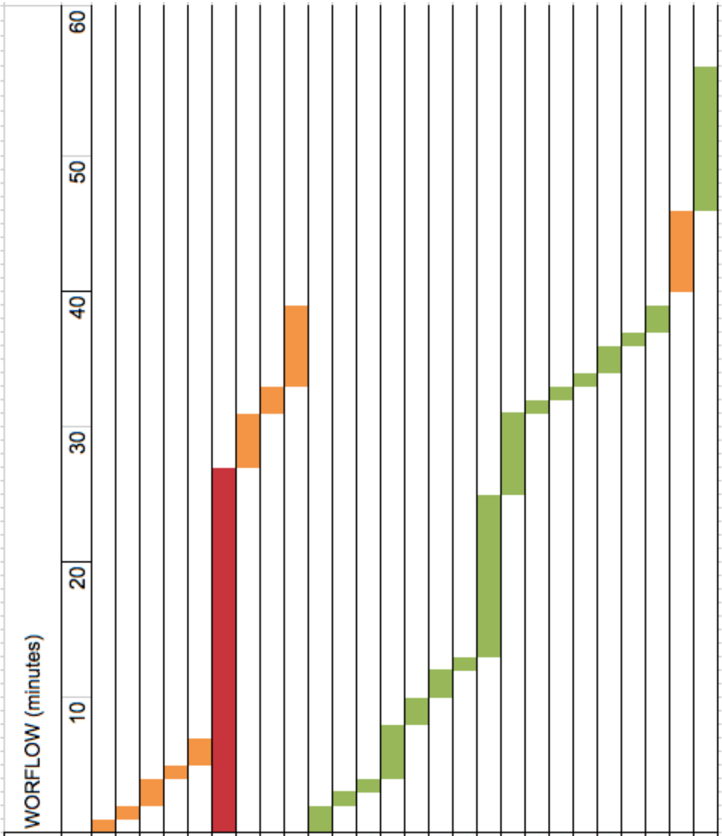


Figure 71: Project workflow

In Figure 71, the project workflow can be seen. Each task has been labelled and the following identified: code, a code is given to each task for easy referral; Worker ID, the tasks are divided into as few workers as possible, here 3 workers; Depends on, the task/s on which a task depends; time, seconds taken to complete a task; and Worflow, a graphic identification of the times and order of tasks.

Using three workers a swing can be manufactured in under an hour if all the materials are already in stock at the factory.

10. PRIORITY OF DOCUMENTS

The general order of preference between documents as established in the standard UNE 157001:2002 is as follows:

- Detail Drawings
- Technical Specification document
- Budget
- Report
- Measurements and dimensions
- Annexes

In order to ensure a correct understanding and to avoid misinterpretations due to incongruences between documents the following order of priority between documents must be taken into account.

Regarding materials and manufacturing procedures, the document of priority is Technical Specification document above all other documents.

In relation to dimensions and product physical details, the documents in Detail Drawings are to be prioritized over any contradicting document.

ANNEXES

2

Table of Contents

Annex 1: Decision Criteria

10.1. LCA COMPARISON

As can be seen, the environmental criteria are essential to the definition of the solution, therefore a small Life Cycle Analysis of the alternatives and a sample swing is made in order to establish a quantitative comparison between alternatives and of the alternatives in relation to a usual swing.

First, the sample swing is analysed. The chosen swing and its technical specifications have been given by AIJU, one of the LIFE Future project partners that is specialised in toys and play areas. The swing set is *Groupswing Stratus* single module by the company HAGS (ref: 8000751) shown in Figure 72, and its specifications can be seen in Figure 73.

Figure 72: HAGS Groupswing

LOS MATERIALES

Material	kg	%
Zink (electro-galvanised)	0.028	0.02
Polyamide (PA)	0.24	0.21
Polyethylene (PE)	0.487	0.32
Stainless steel	0.8236	0.54
Zink (hot-galvanised)	2.9375	1.92
Untreated Steel	148.273	96.89
Glasfiberarm polyester	0.4	0.26
Cast iron	0.08	0.05
	153.3 kg	100%

Figure 73: Swing Materials

All the information about materials and processes is entered into a program called OpenLCA, which helps calculate the total impacts of a product. The data entered can be seen below, in order to adjust to the units in the program for the manufacturing inputs the surface of the steel tubes has been calculated as well as the joined weight of the plastics.

Process: HAGS Groupswing Stratus

Inputs

Flow	Category	Flow property	Unit	Amount	Uncerta
steel, converter, chr…	metals/extraction	Mass	kg	0.8236	none
polyethylene, HDPE,…	plastics/polymers	Mass	kg	0.487	none
steel, converter, unal…	metals/extraction	Mass	kg	148.273	none
cast iron, at plant - RER	metals/extraction	Mass	kg	0.08	none
powder coating, ste…	metals/processing	Area	m2	0.07908	none
polyethylene terepht…	plastics/polymers	Mass	kg	0.4	none
nylon 66, at plant - RER	plastics/polymers	Mass	kg	0.24	none
zinc coating, pieces…	metals/processing	Area	m2	2.4844	none
drawing of pipes, st…	metals/processing	Mass	kg	148.273	none
injection moulding -…	plastics/processing	Mass	kg	1.127	none

Outputs

Flow	Category	Flow property	Unit	Amount	Uncertainty
HAGS Groupswing S…		Number of…	Item(s)	1.0	none

Finally, the impacts are calculated within the program and the results can be seen in image Z. Since different alternatives will be compared its specially interesting to know the impact in points for climate change, human toxicity, resources depletion, ozone depletion and total impact (in points).

LCIA Results

LCIA Results

Impact category	Result	Reference unit
stratospheric ozone depletion - ODP steady state	1.49678E-5	kg CFC-11-Eq
climate change - upper limit of net GWP	355.06412	kg CO2-Eq
resources - depletion of abiotic resources	2.67983	kg antimony-Eq
human toxicity - HTP infinite	238.34023	kg 1,4-DCB-Eq

LCIA Results

Impact category	Result	Reference unit
total w/o LT - total w/o LT	32.68865	points
human health w/o LT - total w/o LT	15.33450	points
resources w/o LT - total w/o LT	10.71621	points
resources w/o LT - fossil depletion w/o LT	10.61359	points
human health w/o LT - climate change, human…	9.39459	points

For the following swing sets, since they are alternatives in the first stages of design all of the quantities and fabrication processes are approximate and therefore the results are only to be used as a guideline, when the final design is selected and detailed an additional LCA will be done to show more exhaustive result.

"Wave": Alternative 1

The first alternative is estimated to have a square base of 1mx1m a height of 2, 40 m and a span of 1,50 m, the overall depth of the material is estimated to be 2,0 cm (this dimension is greatly exagerated to accomodate and overall depth plus details in parts like nerves). The materials chosen are 70% recycled polyethylene and polypropylene, 70% recycled polypropylene rope, 50% recycled steel for reinforcement and steel for swing metal parts. In the following image the inputs in OpenLCA can be seen. Note that the sand used as weight in the inside is not considered in the analysis since it is not transformed and is returned to extraction area when the product is disposed.

Process: Wave Alternative 1

Inputs

Flow	Category	Flow prop	Unit	Amount	Uncert
steel, converter, low-alloyed, at plant - RER	metals/extraction	Mass	kg	7.05	none
extrusion, plastic film - RER	plastics/processing	Mass	kg	0.87	none
sheet rolling, steel - RER	metals/processing	Mass	kg	14.1	none
polyethylene, HDPE, granulate, at plant - RER	plastics/polymers	Mass	kg	8.56	none
polypropylene, granulate, at plant - RER	plastics/polymers	Mass	kg	0.26	none
extrusion, plastic film - RER	plastics/processing	Mass	kg	19.98	none
injection moulding - RER	plastics/processing	Mass	kg	28.54	none

Outputs

Flow	Category	Flow prop	Unit	Amount	Uncertaint	Avoided p	Pedigree u
Wave Alternati...		Numbe...	Item(s)	1.0	none		
polypropylene,...	plastics/poly...	Mass	kg	0.26	none	☐	
steel, converte...	metals/extra...	Mass	kg	7.05	none	☐	
polyethylene,...	plastics/poly...	Mass	kg	8.56	none	☐	

The inputs of plastics only include the amount of virgin material; although the recycled must also be counted for the processing, it does not contribute to the impact deriving from material extraction. In these scenarios the total recycling of the plastic at the end of its life is assumed, therefore, the virgin content in the material is also an output, since it's made available for new uses.

To account for the preparation of the recycled materials the extrusion of those into grain has been taken into account. In this example there are 28.54kg of polyethylene (PE) of those, 8.56 (30%) are virgin and 19.98kg (70%) are recycled.

LCIA Results

LCIA Results

Impact category	Result	Reference unit
stratospheric ozone depletion - ODP steady state	2.26753E-5	kg CFC-11-Eq
climate change - upper limit of net GWP	86.74440	kg CO2-Eq
resources - depletion of abiotic resources	0.84339	kg antimony-Eq
human toxicity - HTP infinite	105.46866	kg 1,4-DCB-Eq

▾ LCIA Results

Impact category	Result	Reference unit
total w/o LT - total w/o LT	8.99122	points
resources w/o LT - total w/o LT	4.01806	points
resources w/o LT - fossil depletion w/o LT	4.00370	points
human health w/o LT - total w/o LT	3.16872	points
human health w/o LT - climate change, human…	2.36797	points

"UNO": Alternative 2

For this alternative the parts are considered to be solid 2 cm sheets of different sizes and a meter long longitudinal beam, all 70% recycled polyethylene. Alongside, the rope is recycled polypropylene and the seat recycled rubber. As with the previous alternative the weighting arid is not considered.

Process: UNO Alternative 2

Inputs

Flow	Category	Flow prop	Unit	Amount	Uncertaint	Default
extrusion, plastic film - RER	plastics/proc…	Mass	kg	84.476	none	
polyethylene, HDPE, granulate, at plan…	plastics/poly…	Mass	kg	25.49	none	
extrusion, plastic film - RER	plastics/proc…	Mass	kg	0.57375	none	
synthetic rubber, at plant - RER	plastics/poly…	Mass	kg	3.56	none	
polypropylene, granulate, at plant - RER	plastics/poly…	Mass	kg	0.1721	none	
injection moulding - RER	plastics/proc…	Mass	kg	3.56	none	
extrusion, plastic film - RER	plastics/proc…	Mass	kg	59.53	none	

▾ Outputs

Flow	Category	Flow prop	Unit	Amount	Uncertaint	Avoidec
UNO Alternative 2		Numbe…	Item(s)	1.0	none	
synthetic rubber, at plant - RER	plastics/poly…	Mass	kg	3.56	none	☐
polypropylene, granulate, at plant - RER	plastics/poly…	Mass	kg	0.1721	none	☐
polyethylene, HDPE, granulate, at plan…	plastics/poly…	Mass	kg	25.49	none	☐

Results for "UNO".

LCIA Results

▾ LCIA Results

Impact category	Result	Reference unit
stratospheric ozone depletion - ODP steady state	9.22729E-6	kg CFC-11-Eq
climate change - upper limit of net GWP	140.54291	kg CO2-Eq
resources - depletion of abiotic resources	1.54714	kg antimony-Eq
human toxicity - HTP infinite	54.84584	kg 1,4-DCB-Eq

LCIA Results

Impact category	Result	Reference unit
total w/o LT - total w/o LT	15.75524	points
resources w/o LT - total w/o LT	7.77233	points
resources w/o LT - fossil depletion w/o LT	7.77124	points
human health w/o LT - total w/o LT	4.73226	points
human health w/o LT - climate change, human…	3.86420	points

"Clever Lock" : Alternative 3

For this alternative, tubes of 5 cm diameter and 3 cm diameter are estimated as well as a base with two injection-molded parts of 5mm thickness, all of 70% recycled polyethylene. As before, the rope considered is from recycled polypropylene with a 3m length.

Process: Clever Lock Alternative 3

Inputs

Flow	Category	Flow prop	Unit	Amount	Uncertaint	De
polyethylene, HDPE, granulate, at plant - RER	plastics/poly…	Mass	kg	6.075	none	
polypropylene, granulate, at plant - RER	plastics/poly…	Mass	kg	0.0861	none	
injection moulding - RER	plastics/proc…	Mass	kg	15.96	none	
extrusion, plastic pipes - RER	plastics/proc…	Mass	kg	6.388	none	
extrusion, plastic film - RER	plastics/proc…	Mass	kg	0.287	none	
extrusion, plastic film - RER	plastics/proc…	Mass	kg	17.6409	none	

Outputs

Flow	Category	Flow prop	Unit	Amount	Uncertaint	Av
Clever Lock Alternative 3		Numbe…	Item(s)	1.0	none	
polypropylene, granulate, at plant - RER	plastics/poly…	Mass	kg	0.0861	none	☐
polyethylene, HDPE, granulate, at plant - RER	plastics/poly…	Mass	kg	6.075	none	☐

LCIA Results

LCIA Results

Impact category	Result	Reference unit
stratospheric ozone depletion - ODP steady state	1.26037E-5	kg CFC-11-Eq
climate change - upper limit of net GWP	45.27634	kg CO2-Eq
resources - depletion of abiotic resources	0.46064	kg antimony-Eq
human toxicity - HTP infinite	18.82218	kg 1,4-DCB-Eq

LCIA Results

LCIA Results

Impact category	Result	Reference unit
total w/o LT - total w/o LT	4.78461	points
resources w/o LT - total w/o LT	2.26935	points
resources w/o LT - fossil depletion w/o LT	2.26904	points
human health w/o LT - total w/o LT	1.52633	points
human health w/o LT - climate change, human…	1.24656	points

"Ashore": Alternative 4

In this alternative two analysis are performed for two scenarios; the first case if the base and the seat were made of reclaimed wood and another if they were made of recycled polyethylene The structure and metal parts will be made of recycled aluminium and the rope of polypropylene.

When made with plastic:

Process: Ashore Alternative 4 PE

Inputs

Flow	Category	Flow prop	Unit	Amount	Uncertaint	De
aluminium, secondary, from old scra…	metals/extraction	Mass	kg	8.7075	none	
sheet rolling, aluminium - RER	metals/processing	Mass	kg	17.415	none	
section bar extrusion, aluminium - RER	metals/processing	Mass	kg	1.0	none	
polypropylene, granulate, at plant - RER	plastics/polymers	Mass	kg	0.1641	none	
polyethylene, HDPE, granulate, at pl…	plastics/polymers	Mass	kg	4.1325	none	
injection moulding - RER	plastics/processing	Mass	kg	13.775	none	
extrusion, plastic film - RER	plastics/processing	Mass	kg	0.574	none	
extrusion, plastic film - RER	plastics/processing	Mass	kg	10.044	none	

Outputs

Flow	Category	Flow prop	Unit	Amount	Uncertaint
Ashore Alternative 4 PE		Numbe…	Item(s)	1.0	none
aluminium, secondary, from old scrap,…	metals/extraction	Mass	kg	8.705	none
polyethylene, HDPE, granulate, at plan…	plastics/polymers	Mass	kg	9.64	none
polypropylene, granulate, at plant - RER	plastics/polymers	Mass	kg	0.1641	none

LCIA Results

LCIA Results

Impact category	Result	Reference unit
stratospheric ozone depletion - ODP steady state	1.27028E-5	kg CFC-11-Eq
climate change - upper limit of net GWP	56.02659	kg CO2-Eq
resources - depletion of abiotic resources	0.50443	kg antimony-Eq
human toxicity - HTP infinite	42.54896	kg 1,4-DCB-Eq

LCIA Results

Impact category	Result	Reference unit
total w/o LT - total w/o LT	5.56597	points
resources w/o LT - total w/o LT	2.44143	points
resources w/o LT - fossil depletion w/o LT	2.43999	points
human health w/o LT - total w/o LT	1.95982	points
human health w/o LT - climate change, human	1.54656	points

When made with wood:

Process: Ashore Alternative 4 Wood

Inputs

1.23

Flow	Category	Flow prop	Unit	Amount
aluminium, production mix, cast alloy, at plant - RER	metals/extraction	Mass	kg	8.7075
sheet rolling, aluminium - RER	metals/processing	Mass	kg	17.415
polypropylene, granulate, at plant - RER	plastics/polymers	Mass	kg	0.1641
extrusion, plastic film - RER	plastics/proces...	Mass	kg	0.574
extrusion, plastic film - RER	plastics/proces...	Mass	kg	0.4018
hardwood, standing, under bark, in forest - RER	wooden materi...	Volume	m3	0.11875
sawn timber (SFM), azobe, planed, air dried, u=15%, C...	wooden materi...	Volume	m3	0.11875
preservative treatment, sawn timber, pressure vessel - RER	wooden materi...	Volume	m3	0.11875

Outputs

1.23

Flow	Category	Flow prop	Unit	Amount
Ashore Alternative 4 Wood		Numbe...	Item(s)	1.0
polypropylene, granulate, at plant - RER	plastics/polymers	Mass	kg	0.4018
aluminium, production mix, cast alloy, at plant - RER	metals/extraction	Mass	kg	8.7075
hardwood, standing, under bark, in forest - RER	wooden materials/e...	Volume	m3	0.11875

LCIA Results

LCIA Results

Impact category	Result	Reference unit
stratospheric ozone depletion - ODP steady state	7.77396E-6	kg CFC-11-Eq
climate change - upper limit of net GWP	88.43835	kg CO2-Eq
resources - depletion of abiotic resources	0.54791	kg antimony-Eq
human toxicity - HTP infinite	154.34318	kg 1,4-DCB-Eq

LCIA Results

LCIA Results

Impact category	Result	Reference unit
total w/o LT - total w/o LT	75.88258	points
ecosystem quality w/o LT - total w/o LT	61.08045	points
ecosystem quality w/o LT - agricultural land oc...	59.37043	points
human health w/o LT - total w/o LT	12.09937	points
human health w/o LT - particulate matter forma...	9.57468	points
resources w/o LT - total w/o LT	2.70284	points

CONCLUSIONS

Table 8: LCA Results

Design	Ozone depletion (kg CFC-11 eq.)	Climate Change (kg CO2 eq.)	Depletion of resources (kg antimony eq.)	Human toxicity (kg DCB eq.)	Total impact (points)
HAGS Groupswing Stratus	1,49·10-5	355,06	2,679	238,34	32,68
A1: Wave	2,268·10-5	86,74	0,843	105,468	8,99
A2: UNO	9,23·10-6	140,54	1,547	54,84	15,75
A3: Clever Lock	1,26·10-5	45,27	0,4606	18,82	4,78
A4a: Ashore (Polyethylene)	1,27·10-5	56,027	0,504	42,548	5,56
A4b: Ashore (Wood)	7,77·10-6	88,43	0,548	154,343	75,88

Table 3 above shows the results of the Life Cycle Analysis. Overall, the most sustainable alternative is A3: Clever Lock, followed closely by A4a: Ashore (polyethylene) and in third place A1: Wave. All three reduce massively the impacts derived from the HAGS design and would be suitable solutions.

10.2. AESTHETICS POLL

A poll was created using Google Forms, a polling application by Google. In this questionnaire, the four following questions were to be answered by all participants:

A1: Wave

Rate the design from 1-5 *

	1	2	3	4	5	
I don't like it at all/ No me gusta nada	○	○	○	○	○	I like it very much/ Me gusta mucho

A2: Clever Lock

Rate A2 design from 1-5 *

	1	2	3	4	5	
I don't like it at all/ No me gusta nada	○	○	○	○	○	I like it very much/ Me gusta mucho

A3: Ashore

Rate A3 design from 1-5 *

	1	2	3	4	5	
I don't like it at all/ No me gusta nada	○	○	○	○	○	I like it very much/ Me gusta mucho

Which design is your favourite?/ ¿Qué diseño le gusta más? *

- A1: Wave
- A2: Clever Lock
- A3: Ashore

ENVIAR

Página 1 de 1

In Table 9 the results can be seen:

Table 9: Poll results

Rate the design from 1-5	Rate A2 design from 1-5	Rate A3 design from 1-5	Which design is your favourite?/ ¿Qué diseño le gusta más?
2	3	5	A3: Ashore
4	2	5	A3: Ashore
4	2	4	A1: Wave
2	4	5	A3: Ashore
5	3	4	A1: Wave
3	2	4	A3: Ashore
1	4	4	A3: Ashore
1	4	4	A3: Ashore
4	2	5	A3: Ashore
3	2	5	A3: Ashore
3	3	4	A3: Ashore
4	3	5	A3: Ashore
5	1	4	A1: Wave
2	3	5	A3: Ashore
4	3	4	A3: Ashore
5	4	2	A1: Wave
3	2	4	A3: Ashore
3	4	3	A2: Clever Lock
5	3	3	A1: Wave
5	3	4	A1: Wave
3	4	5	A3: Ashore

5	2	3	A1: Wave
3	2	5	A3: Ashore
4	3	3	A1: Wave
5	3	4	A1: Wave
1	4	3	A2: Clever Lock
3	1	4	A3: Ashore
4	3	4	A3: Ashore
4	1	4	A1: Wave
2	1	3	A3: Ashore
4	2	4	A3: Ashore
2	2	2	A3: Ashore
4	3	3	A1: Wave
4	4	5	A3: Ashore
3	1	4	A3: Ashore
3	2	4	A3: Ashore
3	4	2	A2: Clever Lock
4	4	4	A1: Wave
4	4	4	A1: Wave
4	3	5	A3: Ashore
2	2	2	A1: Wave
3	2	5	A3: Ashore
5	4	5	A3: Ashore
4	3	4	A1: Wave
3	4	4	A3: Ashore
2	2	4	A3: Ashore
5	5	5	A1: Wave
5	2	4	A1: Wave
3	3	3	A1: Wave
5	1	4	A1: Wave
4	4	4	A3: Ashore

With this information the average ratings were extracted for each alternative:

- A1: Wave **3,49**
- A2: Clever Lock **2,78**
- A3: Ashore **3,96**

And the preferred alternative was determined:

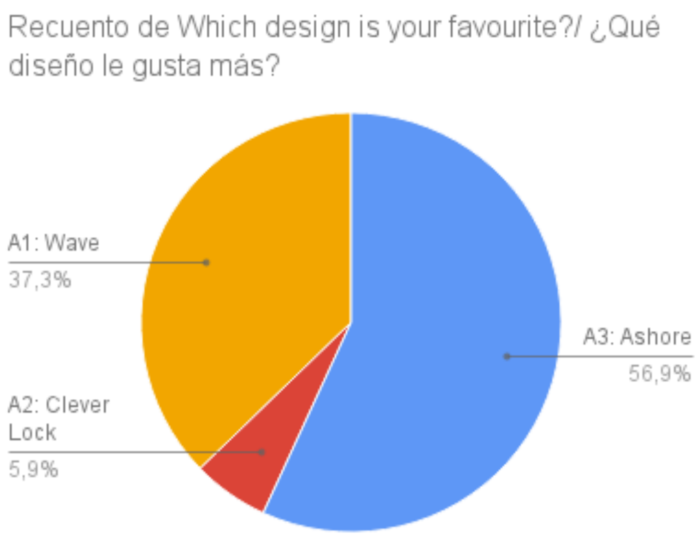


Figure 74: Prefference Pie chart

ANNEX 2: ECODESIGN STRATEGY WHEEL

To compare the final design to the reference swing and see possible fields for future improvement, an ecodesign strategy wheel is completed using the available information on both swings. In an ecodesign strategy wheel each axis symbolized an aspect of the product involved in its sustainability, each one considers a different concept linked to the life cycle like the materials to be used or the maintenance of the product.

To carry out the comparison, each axis of the wheel is considered and a numeric value from 0 to 10 is assigned to each design, 10 being the best possible outcome. The allocation is justified in its corresponding section; sometimes numerical values are used but other times the assignation is discussed as a qualitative matter.

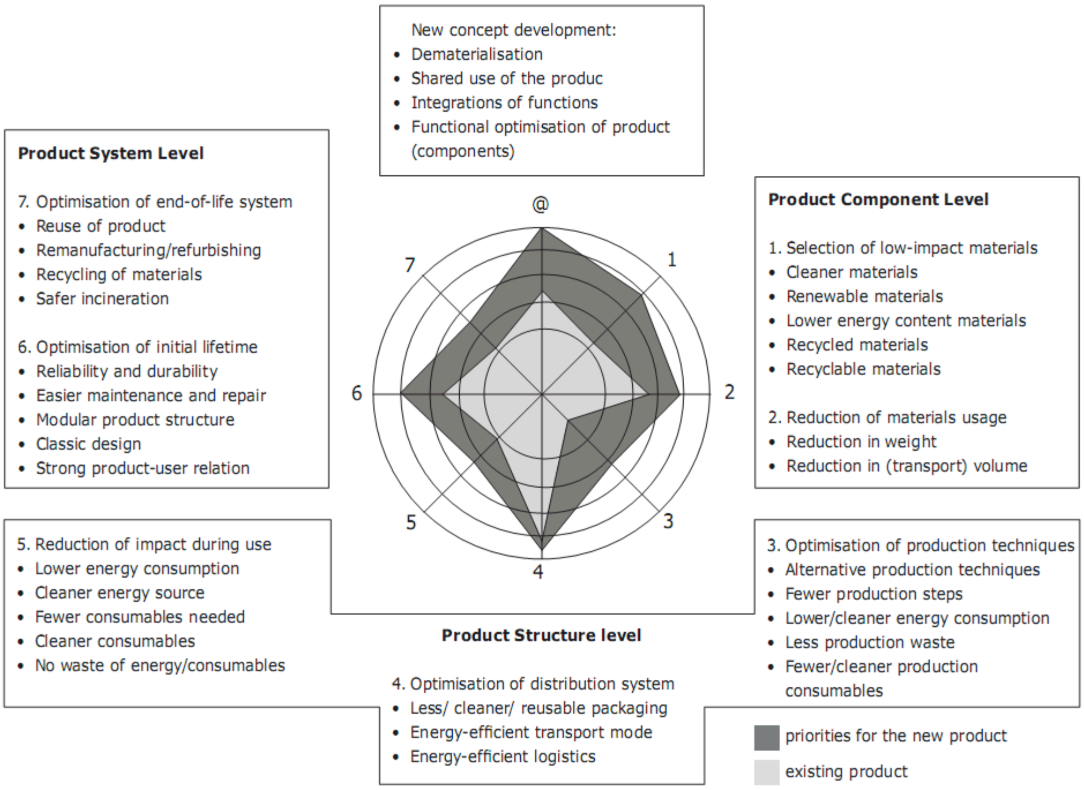


Figure 75: Eco Design Strategy Wheel (Brezet and Van Hemel, 1997)

1. PRODUCT COMPONENT LEVEL

Selection of low impact materials (Renewable, recycled, recyclable…)

In this section the overall percentage of recycled materials are considered. An item being 100% recycled would earn a 10 and one with 100% recycled would earn a 0:

- HAGS: 0% recycled materials (0)
- LIFE: 50% steel is recycled and 70% PE is also recycled since they are the most substantial materials in weight % the design is considered 60% recycled. (6)

The same criterion goes to the recyclability of the materials:

- HAGS: Most of its materials are recyclable, Glassfiber armed polyester has a problematic recycling. (8,5)
- LIFE: All of its materials are recyclable if managed properly in the end of life stage. (9)

TOTAL: HAGS: **4,25**; LIFE: **7,5**

2. REDUCTION OF MATERIALS USAGE

Reduction in weight and in volume (for transport)

Weight:

- HAGS: The total weight of the swing is of 153kg. (7)
- LIFE: The weight of the swing is of 49,10kg and the weight of the sand filling is of 400kg, so in total it is heavier, however the sand is not a manufactured product by the company and can be bought to any local supplier, not necessarily to the manufacturing company do the weight of the sand is not considered here. (9)

Volume:

- HAGS: The volume is small but since the parts are assembled beforehand (soldering) they take up a lot of space in transport (7)
- LIFE: The volume is larger since the body is big and hollow, but the parts are not pre-assembled so transport can be made easier. (7)

TOTAL: HAGS: **7,5**; LIFE: **6**

3. OPTIMISATION OF PRODUCTION TECHNIQUES

Alternative production techniques; move to cleaner/fewer/ less wasteful ones.

Since no information is available on the manufacturing of the HAGS swing, this section is considered a draw between both swings (5).

TOTAL: HAGS: **5**; LIFE: **5**

4. OPTIMISATION OF DISTRIBUTION SYSTEM

Less/cleaner packaging; efficient transport and logistics.

Once again, information in this area is sparce.

TOTAL: HAGS: **5**; LIFE: **5**

5. REDUCTION OF IMPACT DURING USE

Fewer consumables for maintenance.

This section considers the consumables needed for maintenance.

HAGS: This swing is available in different colours that require painting when the layers of paint wear off. The seat has crevices and holes that allow water to seep through when it rains avoiding puddles. (6)

LIFE: This swing has very low maintenance, requiring galvanisation repair every 20 years or more so. The plastic surfaces need no touch ups through the years. (9)

TOTAL: HAGS: **6**; LIFE: **9**

6. OPTIMISATION OF INITIAL LIFETIME

Durability, easy repair, modular products, strong prouct-user relation.

- HAGS: This swing has a durable solid steel structure and a reinforced plastic seat, which make for good durability. (9) The most probable breaking part would be the seat and it is more likely to be replaced than repaired. If the structure was to break it would have to be replaced completely or repaired since the product is not modular at all, its built as a unit (5). The shape of this swing is attractive and quite innovative as are its playing options (8)
- LIFE: The steel structure is solid and the weighted base fixes into place, the polyethylene base can be, however, less durable in the long run (6) . Its structure is made in separate modules to ensure that damage to a part of the swing can be overcome by replacing that part and preserving the rest of the swing (10). The different shape makes the LIFE swing an attractive item, building good product-user relations that can help the user take better care of the object and like it for a longer time (9)

TOTAL: HAGS: **7,3**; LIFE: **8,3**

7. OPTIMISATION OF END-OF-LIFE SYSTEM

Reuse/recycling or remanufacturing.

- HAGS: The larger part of the materials can be recycled easily. (9) Reuse is rare in the public procurement sector, but very attainable in the private sector (5). After inquiring it was found that the manufacturer does not reclaim back the products for remanufacturing or repurposing. (2)
- LIFE: The larger part of the materials can be recycled easily. (9) Reuse is rare in the public procurement sector, but very attainable in the private sector (5). The sand used for the base is intended to be re-acquired by the company all times for reusing, and any other part can be used after for remanufacturing in the company (9)

TOTAL: HAGS: **4,3**; LIFE: **7,6**

8. NEW CONCEPT DEVELOPMENT

Shared use, integration of functions, functional optimisation.

TECHNICAL SPECIFICATIONS

3

Table of Contents

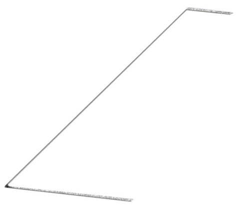
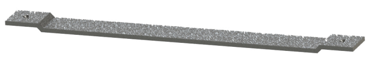
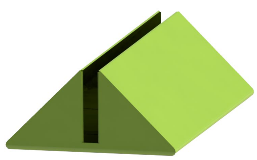
INTRODUCTION

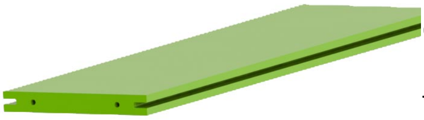
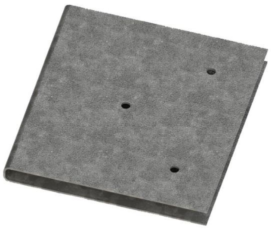
This document encloses all the technical specifications related to the product at hand, the LIFE swing. All the materials, machinery, manufacturing processes, product details, assembly, packaging and international standards necessary for the achievement of the project are included in the document.

DESCRIPTION

This project defines the development and manufacturing of the LIFE swing set: a swing for exterior use with a weighted base and a reduced environmental impact. In the Table 10 below all the different components are collected (including commercial elements) their materials are detailed and the main manufacturing processes are listed. In the next sections all the materials, processes, standards and conditions are specified.

Table 10: Description of parts

	Part	Material	Dimensions	Manufacturing Processes (not out-sourced)
2x	 Swing beams	Steel S275JR	4450x60x 8mm	Punching, drilling, bending and cold galvanising
2x	 Transversal Bars	Steel S275JR	700x60x 8mm	Bending, drilling and cold galvanising
1x	 Base Body	Polyethylene (±70% recycled from urban waste)	29,72kg (1500x900x 400mm)	Rotomoulded, Cut, milled (grooving tool) and sanded.

2x	 Lateral Lids	Polyethylene (±70% recycled from urban waste)	0,26kg (340x100x 10mm)	Cutting, drilling and sanding
1x	 Top Lid	Polyethylene (±70% recycled from urban waste)	1,143kg (1500x100x 10mm)	Cutting, drilling and sanding
1x	 Seat Body	EPDM Rubber	1,072kg (900x200x7 mm)	Cutting and hole punching.
2x	 Seat plates	Stainless Steel	100x200x 1mm	Cutting, deburring and hole punching.
2x	 Seat rods	Stainless Steel	140mm x 4mm diameter section	Cutting, deburring and bending.
1x	 Weighted filling	White Sand	0,300m^3	Extraction

4x	Bars screws	Galvanised steel	M6 x 12mm	
4x	Base Screws	Galvanised steel	M3,5 x16mm	
6x	Seat Rivets	Steel	M4 x 16mm	Impact (plastic deformation) joined

MATERIALS AND COMMERCIAL ELEMENTS

In this section, the materials used for the attainment of this swing are detailed. All materials are described and the minimum acceptable properties to maintain the established quality are considered.

The materials used here are:

- Structural Steel: S275JR steel is used in the bars that form the structure and support the forces of the swing. It is chosen based on its ability to withstand stress, its recyclability and its low cost compared to other metals. In this case the recycled content in the metal is of 50%.
- Polyethylene: Polyethylene (PE) with a 70% of recycled content and 30% virgin content. The ultimate goal of this urban element is to be as sustainable as possible, so the maximum content of recycled material is key. PE is also resistant to environmental conditions and UV light.
- EPDM Rubber: both virgin and reutilised synthetic rubber from vehicle pneumatics is compacted to shape the seats of the swing. It is chosen for the importance of the material reuse and the good comfort and adaptability to the use of the seat.

The commercial elements are:

- Screws used in the bars: DIN 7991 m6x12mm in A2 stainless steel.
- Screws used in the base: TORX – Plastite CF WN 1423 Galvanized Steel in M3,5 and with a length of 16mm
- Rivets in the Seat assembly: DIN 660-4x16-St-A-9 in galvanised steel

10.3. STEEL

- S275JR steel (BS EN 10025-3:2004), also known as A633 Grade A in ASTM nomenclature[2], is chosen based on its ability to withstand stress, its recyclability and its low cost per kg. It is used in the long and transversal bars that can be seen below.

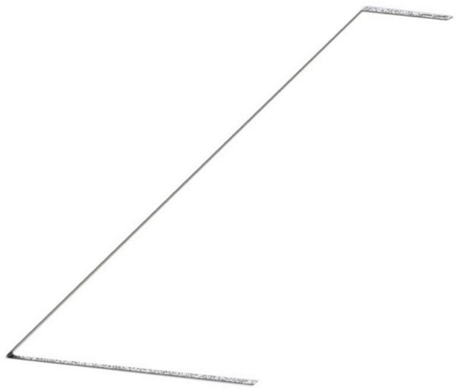


Figure 76: Beam

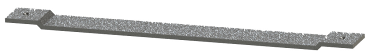


Figure 77: Transversal Bar

The properties of this metal are stated in the table below:

Table 11: Steel Properties

Steel	
Density	7800 - 7900 Kg/m3
Young's Modulus	205-221 GPa
Yield Strength	275 MPa
Tensile Strength	410 - 510 MPa
Hardness (Vickers)	79 - 141
Fatigue strength at 10^7 cycles	194 MPa (min)
Fracture toughness	26 – 38 MPam
Recyclability	High

- Stainless steel is used in the metal plates of the seat and the triangular rods as well as in the commercial elements used for joining. For these parts the steel is already galvanised and hence, protected from corrosion. The selected steel is an AISI 316, a type of austenitic steel.

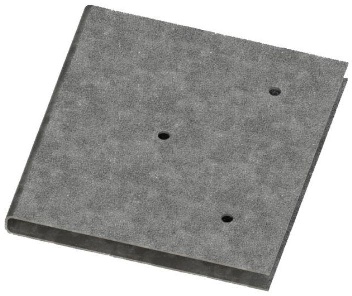


Figure 78: Seat plate

Figure 79: Seat Rod

10.4. POLYETHYLENE

The strengths of High Density polyethylene are its high recyclability and availability in the local area, its good endurance of environmental conditions and its low cost. The desired amount of recycled content is of 70%, variations of 60% to 75% are also accepted for the larger part, the body of the base. The lids come from outside the manufacturing company as sheets in the desired thickness, in this occasion it is highly advised to look for the highest possible recycled content from the PE sheet suppliers, and always at least 30% recycled content. The mix of polyethylene is to be enriched with pigments to obtain the desired colours, though the colours may vary depending on the colours of the recycled content, and so the customer must be warned.

For European markets the standard ISO/TR 10358 is applied to the use of this material. It is used in the following parts of the swing:

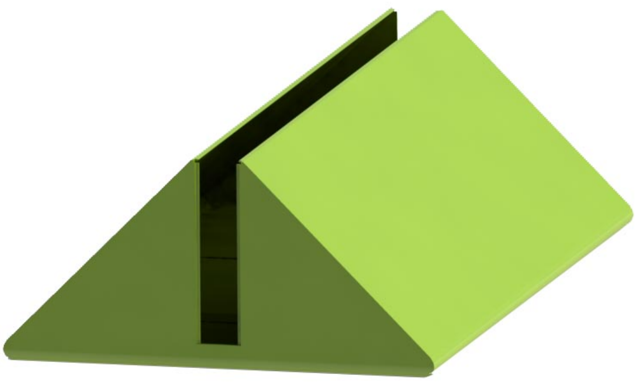


Figure 80: Base Body

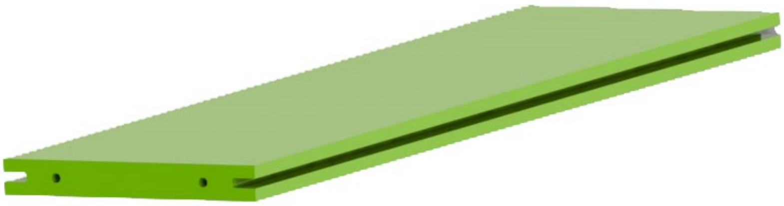


Figure 81: Lateral Lid

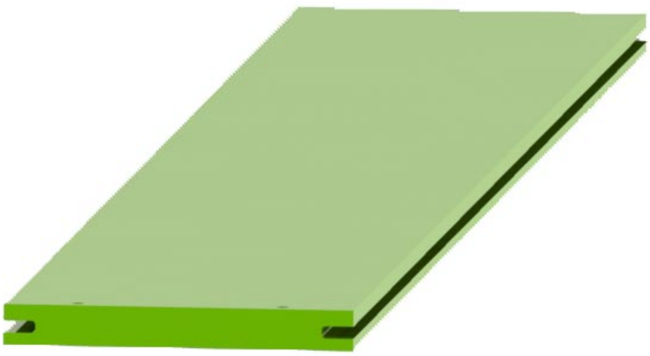


Figure 82: Top Lid

The properties of polyethylene can be seen below:

Polyethylene	
Density	980 Kg/m3
Young's Modulus	1,07 GPa
Yield Strength	29 MPa
Tensile Strength	31 MPa
Hardness (Vickers)	7,4 – 9,9
Fracture toughness	1,52 MPam
Water absorbtion	0,01%
Recyclability	YES
Moldability	Very good
Weldability	Excellent

Other properties and recommendations:

- Mold temperature: 30 to 50ºC
- Molding pressure range: 82,5 to 103 MPa
- Excellent durability in fresh and salt water and weak acids and even strong alkalis, acceptable durability in strong acids and UV radiation.
- Highly recyclable, not biodegradable.

10.5. EPDM RUBBER

This material was chosen because of its flexibility/elasticity combined with its resistance, which makes it a comfortable and efficient material for the seat. Recycling of tire rubber is very important since its deposit in landfills leads to many environmental and safety hazards including gas emissions and insect plagues. It was found that a good way to recycle this rubber was to add it as filler for the manufacturing of other rubber products, ideally in a proportion of 10%, which is encouraged to be maximized when possible, however since the sheets are bought outside of the company this depends on the negotiations with the supplier.

Figure 83: Seat body

An overview of its properties can be seen below:

EPDM	
Density	1000 -1100 Kg/m3
Young's Modulus	0,0097 GPa
Yield Strength	10,4 - 20,2 MPa
Tensile Strength	10,4 – 20,2 MPa
Elongation	315 – 615 % strain
Hardness (Shore)	80
Fatigue strength at 10^7 cycled	2,16 to 8 MPa
Impact strength	600 kJ/m^2
Water absorbtion	0,012%
Recyclability	NO

Other properties and recommendations:

- Molding pressure range: 82,5 to 103 MPa
- Excellent durability in fresh and salt water and weak acids and even strong alkalis, good durability in UV radiation.
- Not recyclable, but reusable and valid for downcycle and combustion.
- Excellent ozone and oxidation resistance and good heat stability.

The minimum acceptable conditions are those specified and tested in the following standards:

- UNE ISO 815: Rubber, vulcanized or thermoplastic -- Determination of compression set.
- UNE ISO 4662: Rubber, vulcanized or thermoplastic — Determination of rebound resilience
- UNE ISO 1431-1: Rubber, vulcanized or thermoplastic. Resistance to ozone cracking. Part 1: Static and dynamic strain testing

10.6. SAND FILLING

The sand filler main attributes are: its inexpensiveness, its availability and interchangeability for other sands in different countries, its density (1300kg) and its inertness and enduring of environmental conditions.

This material can be provided by the swing manufacturer, however, due to the environmental and economic cost of transporting that many kilograms of sand, it is recommended that the sand is bought in the location area and not transported by the swing manufacturer.

Manufacturing Machinery and Devices

This section considers all of those manufacturing processes to be carried out by the company. It details the recommended machinery and devices and some of its most relevant characteristics.

COLD GALVANISING

In the case of the swing, cold zinc galvanising will be necessary since its easier to apply and requires no immersion tank or out-sourcing, for this procedure to yield the same benefits as hot galvanising the applied zinc layer must be of at least 75 µm. To do so an industrial grade zinc coat must be applied such as Tekasol Zinc 98 or Hummel 96 or any other commercial product with at least 92% zinc content, though 98%+ is preferred.

ROTOMOULDING

This fabrication process is ideal for large hollow pieces manufactured with plastics; it is specially used with high and low-density polyethylene. Although slower, rotomolding has lower mould and machinery costs and is preferable for small productive volumes. When producing by rotomolding its important to consider wall thickness and sufficient edge rounding (since wall thickness decreases in them). Openings are achieved through mould insulation to avoid material build-up in those areas. Tolerances of 0,2 to 1mm are obtained and roughness of up to 1,6 microns

For the moulding of the Base Body a medium carbon steel mould is ideal to produce a series of 500 units. The machinery used can be either one of the following rotational moulding machines: Rock and roll machine, clamshell machine, vertical machine, shuttle machine, swing arm machine or carrousel machine. The difference between these machines is the number of chambers and parts they can do and the spinning axises.

Figure 84: www.rockandrollmachine.in Rock and roll Machine

MACHINING: MILLING

The milling of plastics, contrary to metal milling, involves high cutting speeds and small advance speeds. The tools of preference when working with plastics are made of HSS and hard steel. In this specific operation a groove is made on two sides of the lids and a frontal face milling is done in the sides of the base body.

Any computerized milling machine is good for the job as long as the dimensions of the working table fit the parts to be machined.

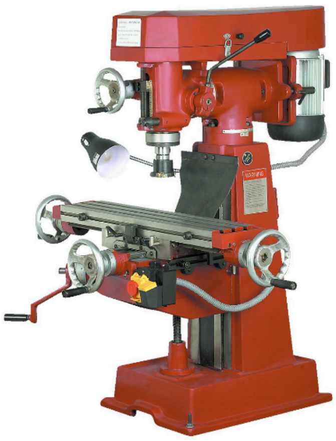
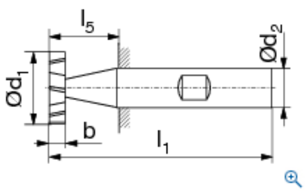


Figure 85: Milling machine www.harborfreight.com/vertical-milling-machine-40939.html

The tool selected for the achievement of the grooving is a high speed steel grooving bit, to use in plastics and harder materials. The specifications can be seen in Figure 86.



$d_{1\ h12}$ DC	16,5 mm
l_5 LPR	16 mm
l_1 OAL	56 mm
$d_{2\ h6}$ DCONMS	10 mm
$a_{p\ max}$ CDX	5,95 mm
Z ZEFP	6

Figure 86: Grooving bit properties

Figure 87: Grooving bit

DRILLING

The milling machine can be used with a drill bit to drill the holes in the steel bars in the parts where they will be screwed together. This is done by using a HSS-Co DIN 388 drill bit of the desired diameter. This special drill bits are good for working on alloyed metals and carbon steels, the selected drill bit is by Bosch and has a 135º point angle. When working with the steel in the beams a refrigerating solution and a slower speed (15 -20 m/min) are necessary.

COMPRESION MOULDING

The main part of the seat is made of this rubber part, from recycled tire rubber and virgin synthetic EPDM rubber. To manufacture this part the recycled rubber is added as filler to the virgin matrix and the mixture is fed to the mould to be formed by compression moulding. This process is ideal for elastomers and thermosetting polymers and especially good for rubber since it allows for in-mould vulcanization, optimizing time and improving the result.

With this process tolerances of 0,15 to 1mm are obtained, and a roughness of up to 1,6 microns.

DEBURRING AND SANDING

This is usually a manual process in which any large imperfections and protuberances are cut out and sharp edges are smoothed down improving aesthetics and safety. Many manufacturing machines already incorporate a deburring station for their pieces, but others don’t and have to be done later on. Sanding can also be done mechanically using sandpaper at no more than 10m/s, but for fine dimensions and complex geometries manual sanding is preferred. Deburring is to be done with a metal file both for steel parts and HDPE parts and sanding is to be done using a 120 grain sanding paper.

HOLE PUNCHING

A punching machine is used to make holes of different shapes and sizes onto metal and other material sheets. For the punching of the beam holes an oval shaped punch like that shown in Figure 89, for the punching of the metal plate and body seat a 4mm diameter round punch like the one in Figure 89. The tolerances obtained range from 0,015 to 0,8 microns, depending of the tool and dimension of the punch.

Figure 88: Punching machine www.nargesa.com

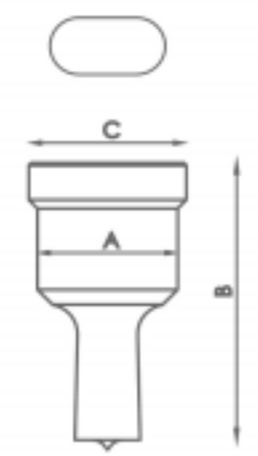


Figure 89: Oval Punch

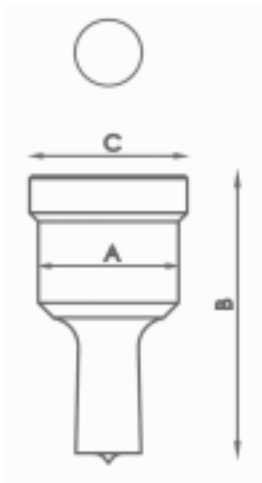


Figure 90: Round punch

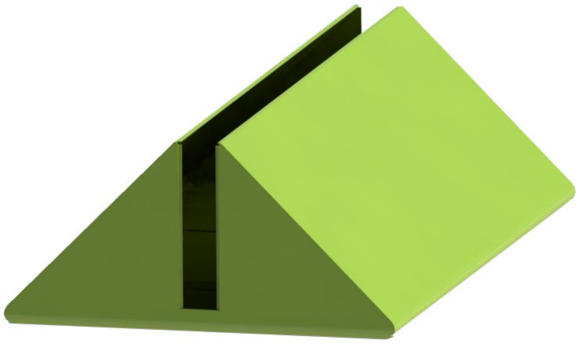
RIVETING

An orbital riveting machine is used to shape the rivets used in the joining of the seat plates and the seat body. The machine uses a forming tool that spins pressing onto the rivet and deforming it into the final shape, the process takes 2-3 seconds. This process is considered “clean” leading to low environmental impacts, though noise generation can be a health problem for workers and correct safety measures must always be applied.

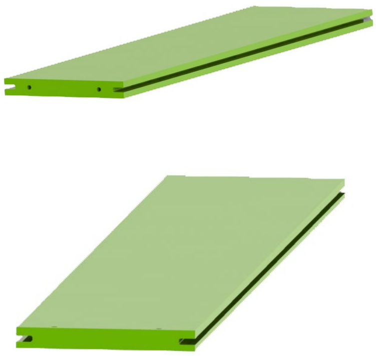
Figure 91: Orbital riveting machine www.sairiveting.com

10.6.1. MANUFACTURING SEQUENCE

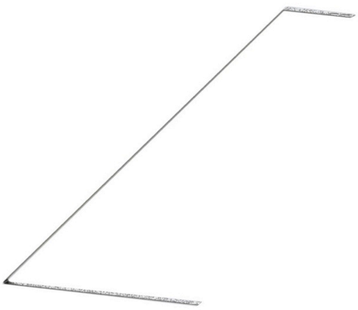
BASE BODY[3]



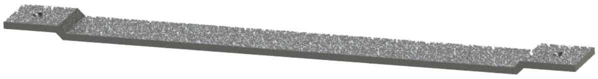
SLIDING LIDS (Lateral and Top Lids)



STEEL BEAMS

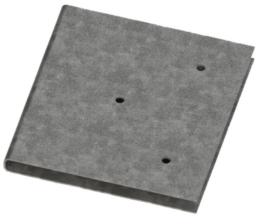


TRANSVERSAL BARS



Sheet Rolling (out-sourced) → Drilling → Bending → Cold Galvanising (Zinc)

SEAT PLATE



Galvanised Sheet Rolling (out-sourced) → Punching → Bending

SEAT ROD

Rod extrusion (out-sourced) → Machining/ sawing → Bending

SEAT BODY

Cutting to length → Cutting rounded shape → Punching

ASSEMBLY

The assembly of the finished swing is divided in two parts, one to be done as part of the production and another to be completed in the installation site.

FACTORY ASSEMBLY

Once all the parts have been manufactured the product is assembled and packaged for transport to do so there are the following steps:

12. Pass the Seat Rod (SR) through the Seat Plate (SP), then
13. Slide a side of the Seat Body (SB) through the Seat Plate so the holes on each component fit together.
14. Pass the three rivets through the holes
15. Fix the rivets using the riveting machine
16. Repeat all steps in the other part of SB.
17. Place the Base Screws (BS), the Structure Screws (SS) in a small bag.
18. Place the bag detailed above along with the transversal bars (TB) and the rope (R) inside the Base Body (BB)
19. Slide the Lateral Lids (LL) in place on either side of the base body (BB)
20. Slide the Top Lid (TL) on top of the base body fitting the holes with the holes in the Lateral Lids
21. Place the Base Screws in place and screw them in.
22. Place the foam edge protectors on the sides of the Longitudinal Beams (LB) and the corner protector on the bent corner.

The swing set is now ready for transport.

ON-SITE ASSEMBLY

When arriving at the site the following instructions are followed to assemble the swing set.

11. Unpack all the packaged items
12. Select a levelled and appropriate ground that satisfies safety conditions
13. Screw the Transversal Bars (TB) on to the Longitudinal Beams (LB)
14. Loop the ropes (R) around the holes in the Longitudinal Beams and secure in place.
15. Lift structure to an upright position
16. Place the Base Body (BB) in place on top of the aforementioned structure
17. Fill the base with the sand filling
18. Slide the Lateral Lids (LL) in place on either side of the base body (BB)
19. Slide the Top Lid (TL) on top of the base body fitting the holes with the holes in the Lateral Lids
20. Place the Base Screws in place and screw them in.

The swing is now assembled and ready for use.

USE CONDITIONS

The LIFE Swing set is produced to be installed, used and disposed under a set of conditions that ensure its safety, durability and its sustainability. The conditions and instructions detailed below are to be followed by the manufacturers, installers, users and public owners of the swing set.

Installation:

The swing set must be placed in an adequate area. This area must have a levelled and appropriate ground material; the recommended placing is on top of a springy rubber playground.

The area surrounding the swing must be sufficiently large. The area around the swing, especially in the direction of movement, must be free of all obstacles, including mobile parts of other play equipment. The size of this area must be as large as that indicated in the standard UNE EN 11076 or any applicable local legislation. This safe area must not interfere with the safe area of another swing or equipment.

During the installation, all joints and parts must be inspected carefully.

Use:

To enjoy safely the swing the user must not exceed the maximum weight established by the standard calculations, 69 kg.

The swing is not to be pulled perpendicularly to the direction of movement with a horizontal force of over 70kg (686N).

A good use and care of the equipment maximises its life span, so an appropriate and civilised use is always recommended.

When broken during the use, the manufacturing company is to be contacted and the broken part replaced or repaired when possible.

Disposal:

All parts are to be recycled, if possible used for remanufacturing in the same company. Disposal to recycling plants and green parks is strongly advised to maintain the environmental improvements.

Applicable Stardards

The most significant standards and normalized tests to pass for this swing are those specified in the Spanish and European standards, UNE-EN 1176-1 and UNE-EN 1176-2, which enclose all the safety and performance criteria that must be met by the swing detailed in this project.

Such tests include impact testing for the seat, structural integrity and impact and falling area determination.

In a broader spectrum, all of the following standards are to be consulted and applied in the project materialisation:

- General criteria for the drawing-up of the documents which make up a technical project. (UNE 157001:2014)
- Environmental management. Life cycle assessment. Principles and framework (ISO 14040:2006).
- Environmental management. Life cycle assessment. Requirements and guidelines (ISO 14044:2006).
- Environmental management. Environmental communication. Guidelines and examples (ISO 14063:2006).
- Technical drawings. General principles of presentation. (ISO 128:1996)
- Playground equipment and surfacing. Part 1: General safety requirements and test methods. (UNE-EN 11761-1:2009)
- Playground equipment and surfacing. Part 2: Additional specific safety requirements and test methods for swings. (UNE-EN 1176-2:2009)
- Playground equipment and surfacing. Part 7: Guidance on installation, inspection, maintenance and operation. (UNE-EN 1176-7:2009)
- Playground equipment. Guidelines for the application of UNE-EN 1176-1.

Modification Conditions

Chief project engineers and production responsible engineers may alter some features of the project to improve manufacturing, economy and efficiency traits suitable to the time and shape of the company. However, these changes are never to interfere with the main functions of the individual parts or the swing as a whole. The changes are not to interfere or diminish the specifications and restrictions set by the project. Most importantly and under no circumstances any changes are not to impoverish the structural integrity of the swing set or the safety quality.

BUDGET

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MATERIALS AND COMMERCIAL ELEMENTS

MATERIALS

STEEL BEAM

5m lengths of the desired width and thickness are bought from Ferros Puig, in Barcelona. The price for a 5m 60x8mm section is of 12,96€, and one section is needed for each part.

TRANSVERSAL BEAMS

As with the steel beams, 5m lengths of the desired width and thickness are bought from Ferros Puig, in Barcelona. The price for a 5m 60x8mm section is of 12,96€, and one section is needed for 7 parts, meaning that 1/7th of the length is used in each part.

ROPE

The rope is bought from a large distributing business and is from the company FIERO, it comes in rolls of 105meters and each roll has a price of 1881€. Since a rope section in the swing is 160cm long, each section costs up to 28,22€.

BASE BODY

This element is made of virgin and recycled polyethylene, with a combined price of 1,092€/kg of material.

BASE LIDS

These elements are made from polyethylene sheets, bought from a manufacturer in 10mm sheets of 3000x1500mm. For the top lid a single sheet yields 30 lids, and for the lateral a sheet yields 90 lids.

SEAT BODY

The rubber component of the seat is made entirely of EPDM rubber, bought by a rubber product manufacturer in Catalunya called Codema. They sell 1x2m sheets of 7mm thickness for 35,4€, since one sheet can be used for 10 seats, the price per seat is of 3,54€.

SEAT PLATE

The seat plate is also brought from Ferros Puig. It is sold in sheets of 1x2m long and since each plate is 10x20cm, 100 plates can be made from a single 11,95€ sheet.

SEAT ROD

Ferros Puig also sells small diameter steel bars. 4mm rods are priced at 1,37€ per meter length. Since the desired length per rod is of 14cm, 7 full rods can be extracted from a meter, making the price of each rod add up to 0,19€ accounting for losses.

BASE FILLING

The sand filling is bought from La Casa de la Construcción, located in Teruel. The white sand comes in sacs, 1300kg cost 59,12€ so the 400kg needed in a swing will be 18,21€.

COMMERCIAL ELEMENTS

BASE SCREW

The selected screws are TORX – Plastite CF WN 1423 Galvanized Steel in M3,5 and with a length of 16mm. When buying over 500 units, the price drops to 0,11€ per screw.

SEAT RIVETS

The rivets selected for the seat assembly are 4mm in diameter and 16mm in length and are identified as DIN 660-4x16-St-A-9. A pack of 250 costs 82,50€, giving a unit price of 0,33.

BEAM SCREWS

The screws used in the bars are DIN 7991 m6x12mm in A2 stainless steel. A pack of 500 can be bought for 65,30€, therefore the price for one screw is of 0,13€.

MATERIAL COST										
Part	Reference	Amount	Material	Size	Units	Comercial unit	Price per comercial unit (€)	Used amount of unit (loss included)	Price per part	Total Price (€)
Longitudinal Beam	LB	2	Steel	4,45	m	5m	12,96	1	12,96	25,92
Transversal beam	TB	2	Steel	0,7	m	5m	12,96	0,14285	1,85	3,70
Structure Screws	SS	4	A2 Stainless steel	M6x12	mm	500 units	65,3	0,002	0,13	0,52
Rope	R	2	Polipropylene	1,6	m	105m	1881,00	0,015	28,22	56,43
Base Body	BB	1	Polyethylene	0,03121	m3	1kg	1,092	29,712	32,45	32,45
Base Lateral Lid	BLL	2	Polyethylene	350x100x10	mm	3x1,5m	68,70	0,011	0,76	1,53
Base Top Lid	BTL	1	Polyethylene	1500x100x10	mm	3x1,5m	68,70	0,033	2,29	2,29
Base Screw	BS	4	Galvanised Steel	M3,5		500units	54,00	0,002	0,11	0,43
Seat body	SB	1	EPDM Rubber	900x200x7	mm	1x2m	35,40	0,1	3,54	3,54
Seat plate	SP	2	Galvanised Steel	100x200	mm	1x2m	11,95	0,01	0,12	0,24
Seat rod	SR	2	Steel	0,14	m	1m	1,37	0,143	0,20	0,39
Seat Rivet	SS	6	Steel	M4x16	mm	250 units	82,50	0,004	0,330	1,98
Base filling	BF	1	White sand	400	kg	1300kg	59,12	0,308	18,21	18,21
										147,63 €

MANUFACTURING COST

In this section the costs deriving directly from the manufacturing processes are considered. This includes the utilities – such as moulds, saw files, slotting mills… For this section, since the production of the swing is placed in a company which already produces play areas and urban furniture, it is considered that most of the necessary equipment is already owned by the company. This includes the CNC milling machine, the automated punching machine, the profile bending machine, the manual sander, and the compression-moulding machine. The rotational moulding machine is considered as a new acquisition for the production of the LIFE swing, and its payback will be calculated in the viability section.. The time of use of those machines is calculated to determine the workforce wages.

STEEL PUNCHING

The beams are punched to obtain the holes through which the rope will pass, this is done with an oval punch from the company Nagresa, compatible with the MX340G Punching machine. The cost of the punch is of 69€ and the approximate amount of used is estimated to be 500, giving a cost of 0,13€ per use. For punching in the metal plate, a round punch with a 4mm diameter has a cost of 16€, estimating 1500 uses, the price per plate (6 punches) is of 0,064€.

BENDING

A bending machine or tube bender is used in the company to bend the different steel parts so no unit cost is considered from this operation.

GALVANISING

For the protection of the metal parts, HEMPEL'S Galvocoat 160E0 is used due to its hight zinc content (98%). The cost of the product is 34€/L and since a layer of over 75µm is desired, two coats will be needed for the whole surface, yielding 427ml per longitudinal beam. Therefore the cost per part is 14,52€. For the transversal beams, following the same logic, the price per part is of 2,28€.

ROTOMOLDING

The company Depsan Rotomoldeo was contacted to inquire about the price of the mould necessary for the Body Base part. A price of 1200€ was established for a steel mould since it has a relatively simple geometry but a very large size. For the expected batch of 500 units, the unitary cost of the mould is 2,56€.

CUTTING

All the cutting operations done to the polyethylene pieces are made by an electric saw with a special file for PP and PE produced by Bosch, with a price of 7,50€ for a pack of 3. The approximate unitary cost is 0,025€ per part.

MILLING

Plastic milling requires its own milling bits and inserts, and they are different depending on the application. For the grooving in the sides of the lids a slotting mill from WNT Mastertool is used. The price of the component is 63,50€ and it has a very long durability, so it is estimated that 2000 units can be made using only one slotting mill, giving a cost per unit of 0,032€.

SANDING

Sanding operations are to be done using a metal file for deburring and ridding of sharp angles and with a smooth sanding sheet with a 120-grain. The price of a sanding sheet is of 0,35€ and it is estimated that at least half is used in sanding the base body, a quarter is used in the top lid and an eighth is used in the lateral lid. Giving costs of 0,175€, 0,088€ and 0,044€.

DRILLING

The cost of a HSS drill bit for plastics with a 3,5 diameter is of 6,95€. Therefore, estimating a long life of 2000 uses, the price for 4 drills on each lid is 0,0139€.

For metals, the cost of a HSS-Co DIN388 bit is of 3,35€, used for a shorter life, approximately 200 uses, giving a price of 0,016€ for each drill.

MANUFACTURING COST						
Part	Reference	Amount per swing	Process	Equipment repayment (molds, milling inserts, ...)	Material used	Total
Swing Beam	SB	2	Punching	0,138		0,276
		2	Drilling	0,01675		0,034
		2	Bending	0		0,000
		2	Galvanising	0	14,520	29,040
Transversal Beam	TB	2	Drilling	0,01675		0,034
		2	Bending	0		0,000
		2	Galvanising	0	2,280	4,560
Base body	BB	1	Rotomolding	2,56		2,560
		1	Cutting	0,025		0,025
		1	Milling	0,032		0,032
		1	Sanding	0,175		0,175
Base Lateral Lid	BLL	2	Milling	0,032		0,064
		2	Drilling	0,0139		0,028
		2	Sanding	0,044		0,088
Base Top Lid	BTL	1	Milling	0,032		0,032
		1	Drilling	0,0139		0,014
		1	Sanding	0,088		0,088
Seat Body	SB	1	Cutting	1,30		1,300
		1	Drilling	0,0139		0,014
Seat plate	SP	2	Cutting	0,066		0,132
		2	Punching	0,064		0,128
		2	Bending	0		0,000
Seat Rod	SR	2	Cutting	0,066		0,132
		2	Bending	0		0,000
						38,75 €

WORKFORCE COSTS

To calculate the workforce costs an average hourly wage of 12€/h has been considered for general workshop employees and a special wage of 15€/h has been considered for specialist employees working in the rotational moulding machine and the compression moulding machine. The approximate times of use for each machine per unit have been calculated using the speeds of the machinery and accounting for extra time per part for handling and inspecting (usually 60 seconds). Assembly times are considered separately and the end of the table. To extract the final values the estimate time per process is multiplied by the hourly wage of the worker and the total cost is added.

WORKFORCE COST									
Part	Reference	Amount	Process	Speed	Time (s)	Extra time	Time total	Hourly Rate	Cost
Swing Beam	SB	2	Punching	7,1mm/s	2,24	60	62,24	12	0,41
		2	Drilling	0,15m/min	0,05	60	60,05	12	0,40
		2	Bending	Manual	60	60	120	12	0,80
Transversal Beam	TB	2	Drilling	0,15m/mim	0,05	60	60,05	12	0,40
		2	Bending	Manual	60	60	120	12	0,80
Base body	BB	1	Rotomolding	10rpm	600	900	1500	15	6,25
		1	Cutting	0,5m/min	163,2	60	223,2	12	0,74
		1	Milling	200m/min	0,654	120	120,654	12	0,40
		1	Sanding	0,25m/min	326,4	60	386,4	12	1,29
Base Lateral Lid	BLL	2	Cutting	60m/min	1	120	121	15	1,01
		2	Milling	200m/min	0,18	60	60,18	12	0,40
		2	Drilling	0,2m/min	3	60	63	12	0,42
		2	Sanding	0,25m/min	144	60	204	12	1,36
Base Top Lid	BTL	1	Cutting	60m/min	1	120	121	15	0,50
		1	Milling	200m/min	0,9	90	90,9	12	0,30
		1	Drilling	0,2m/min	1,8	60	61,8	12	0,21
		1	Sanding	0,25m/min	720	60	780	12	2,60
Seat Body	SB	1	Cutting	60m/min	240	120	360	15	1,50
		1	Drilling	0,15m/min	2,800	60	62,800	12	0,21
Seat plate	SP	2	Cutting	60m/min	0,3	15	15,3	12	0,10
		2	Punching	7,1mm/s	1,268	60	61,268	12	0,41
		2	Bending	Manual	20,000	60	80,000	12	0,53
Seat Rod	SR	2	Cutting	60m/min	0,04	60	60,04	12	0,40
		2	Bending	Manual	20	60	80	12	0,53
SEAT	SB, SP, SR, SS , SN	1	Assembling/ Riveting	Manual	360		360	12	1,20
PACKAGING ASSEMBLY		1	Assembling	Manual	600		600	12	2,00
									25,19 €

Total Unitary Cost

To calculate the selling price the direct costs are added up (material, manufacturing and workforce costs) and a 10% indirect cost is considered. To this final Industrial cost, the commercialisation costs are added (20%). Finally, a company profit of up to 50% is considered, giving a selling price of 418,91€, **506,89€** with a 21% tax. This price would be rounded to **505€**, to make it more appealing to customers.

DIRECT COSTS	
Material	147,63 €
Manufacturing	38,75 €
Workforce	25,19 €
Total	**211,57 €**

UNIT COST	
Direct Costs	**211,57 €**
Indirect Costs (10% Direct Costs)	21,16 €
Total Industrial Cost	**232,73 €**
Comercialization cost (20% Industrial cost)	46,55 €
Total Comercial cost	**279,28 €**
Company profit (50% total cost)	139,64 €
Selling price (Before Tax)	418,91 €
Selling price with IVA/VAT 21%	**506,89 €**

Project Viability Study

To calculate this project's viability the net present value (NPV) and payback are calculated. To do so an initial investment of 25 000€ is considered, corresponding to the purchase of a rock and roll rotational moulding machine (which has been considered as not already owned by this company). The first year an investment of 3150€ is made to purchase the necessary moulds, that will last for 1000 units the rotomoulding one and 2000+ the compression-moulding ones. The anticipated sales start at 100 units the first year, increasing to 150 on the second and third year and falling to 100 again on the fourth year. A yearly inflation of 4% is taken into account. With this data the following table is completed to calculate the NPV:

Table 12: NPV calculation

Year	0	1	2	3	4
Investment	25000	1200	0	0	0
Units sold	0	100	150	150	100
Income	0	50500,0000	75750,0000	75750,0000	50500,0000
Expenses	0	27927,5735	41891,3602	41891,3602	27927,5735
Profit	0	22572,4265	33858,6398	33858,6398	22572,4265
Cash Flow		21372,4265	33858,6398	33858,6398	22572,4265
NPV/VAN	-25000	-4449,5899	26854,6259	56954,8334	76249,8382

As can be seen in Table 12, the payback point is sometime in the second year period. The payback happens when the NPV is zero, which happens in this case after 1,07 years (1 year and 25 days).

DETAIL DRAWINGS

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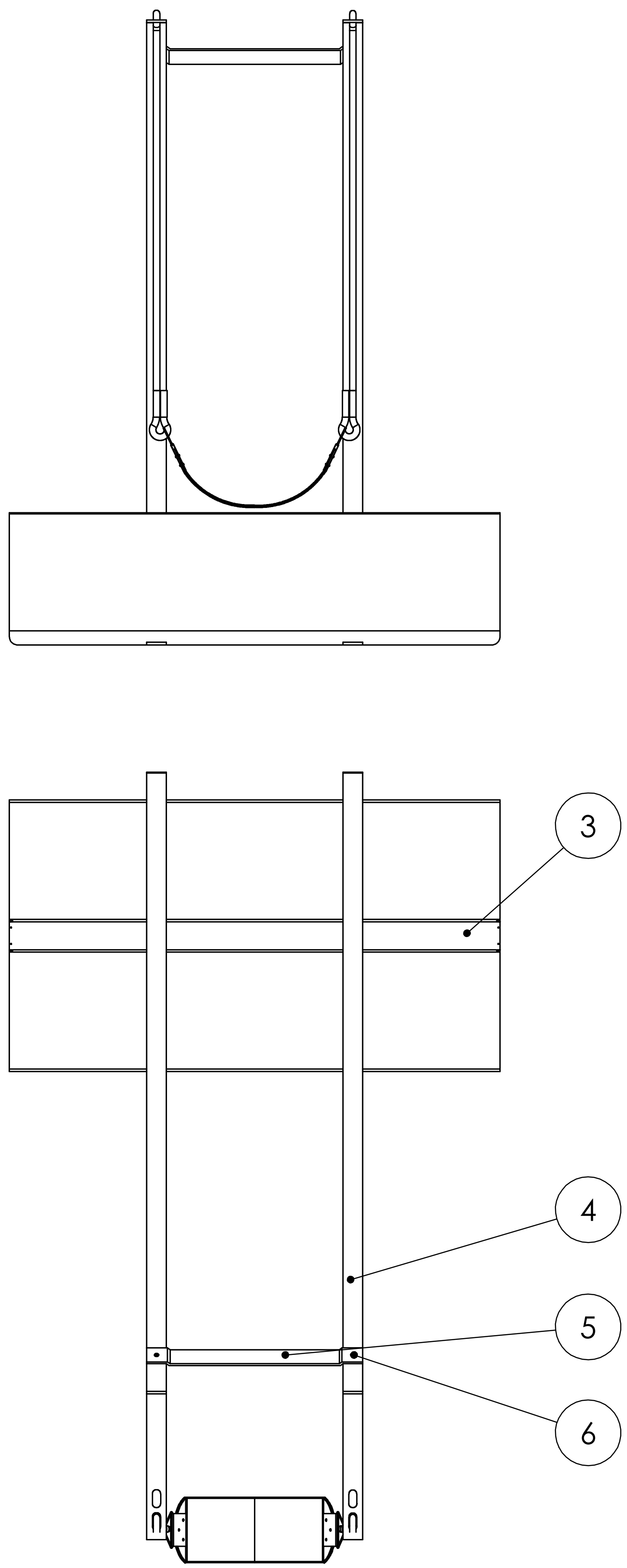
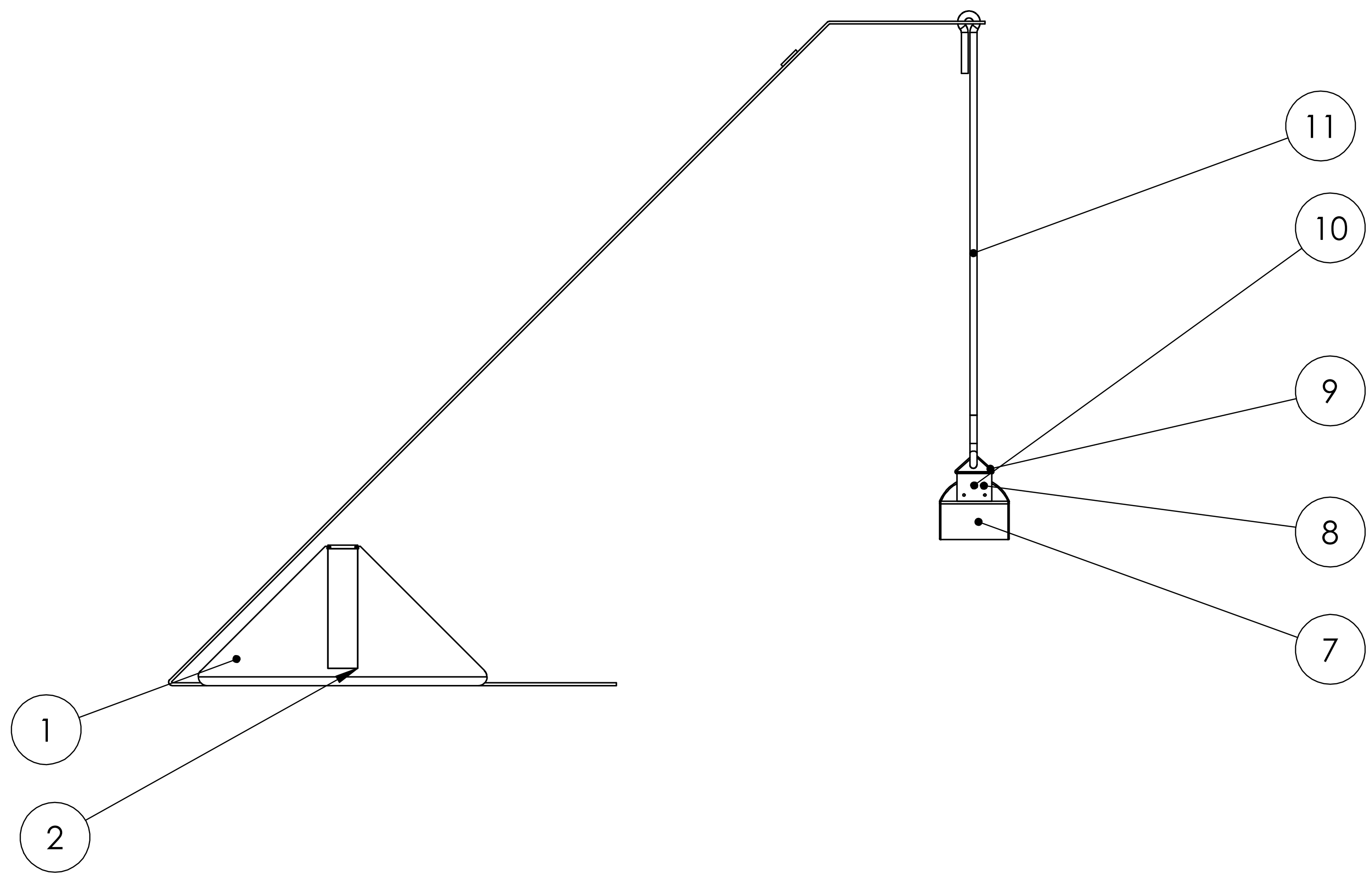
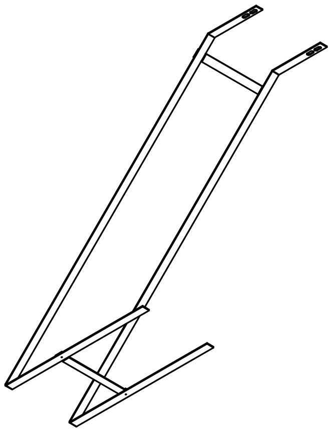
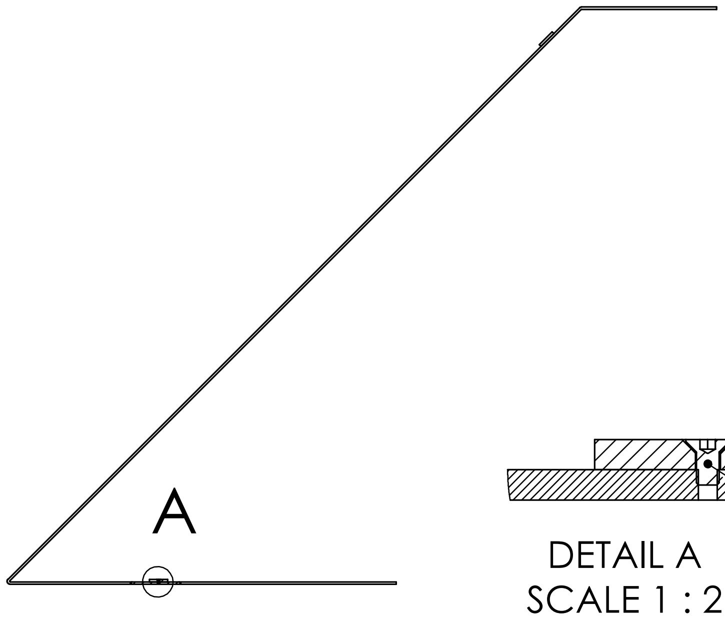


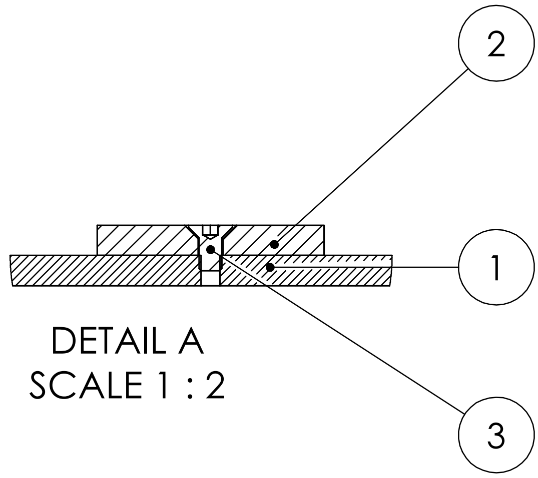


ELEMENT NUMBER	PART	MATERIAL	AMOUNT
1	BaseBody	Polyethylene	1
2	Lateral Lid	Polyethylene	2
3	Top Lid	Polyethylene	1
4	Beams	S275JR Steel	2
5	Transversal Bar	S275JR Steel	2
6	DIN 7991 - M6 x 12 --- 12N	Galvanised Steel	4
7	Seat Body	EPDM Rubber	1
8	Seat plate	Galvanised Steel	2
9	Seat rod	Galvanised Steel	2
10	DIN 660-4x16-St-A-9	Galvanised Steel	6
11	Rope	Polypropylene	2

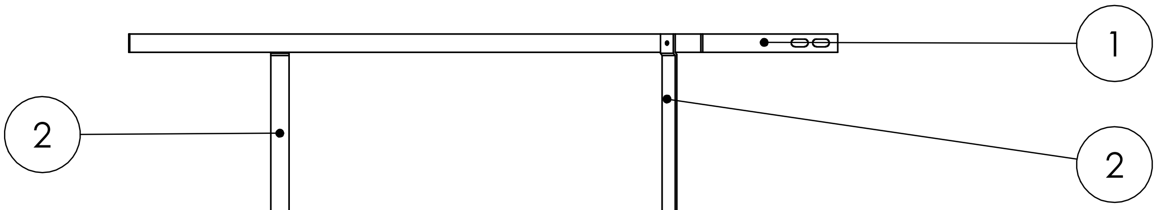
Description: LIFE Swing Set			Drawing: 1 Sheet: 1
Scale 1:20	Units: mm	Universitat Jaume I	Author: Gemma E. Tido Pérez	Date 25/10/17





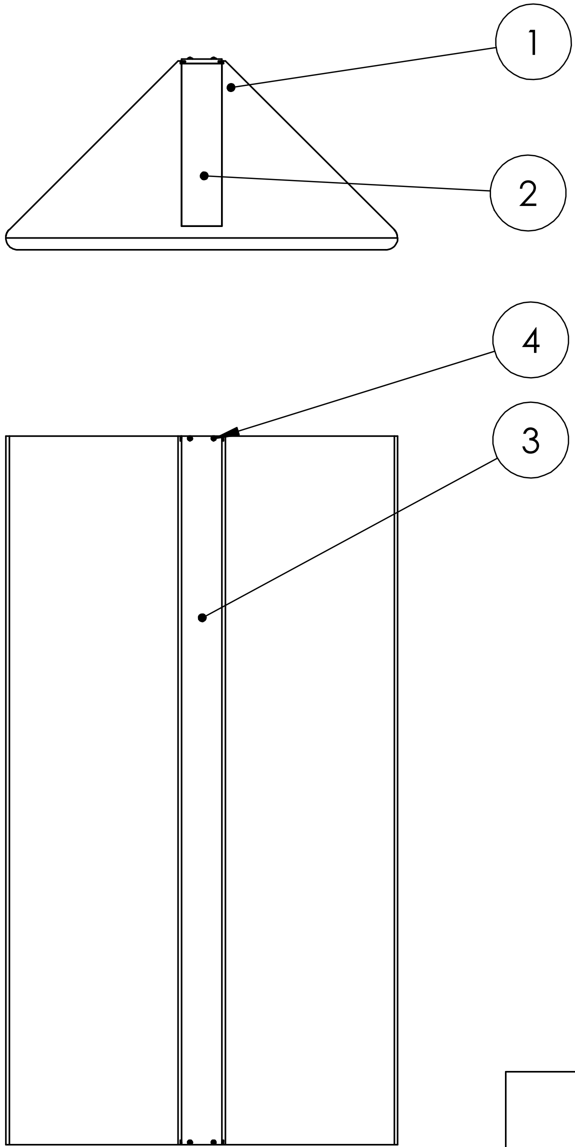


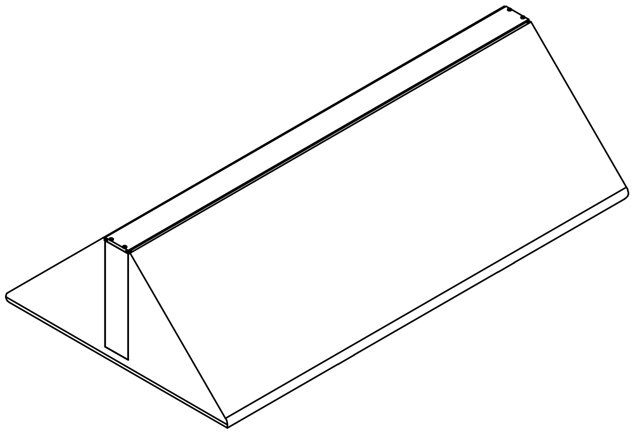
DETAIL A
SCALE 1 : 2



ELEMENT NUMBER	PART	AMOUNT
1	Beams	2
2	Transversal Bar	2
3	DIN 7991 - M6 x 12 --- 12N	4

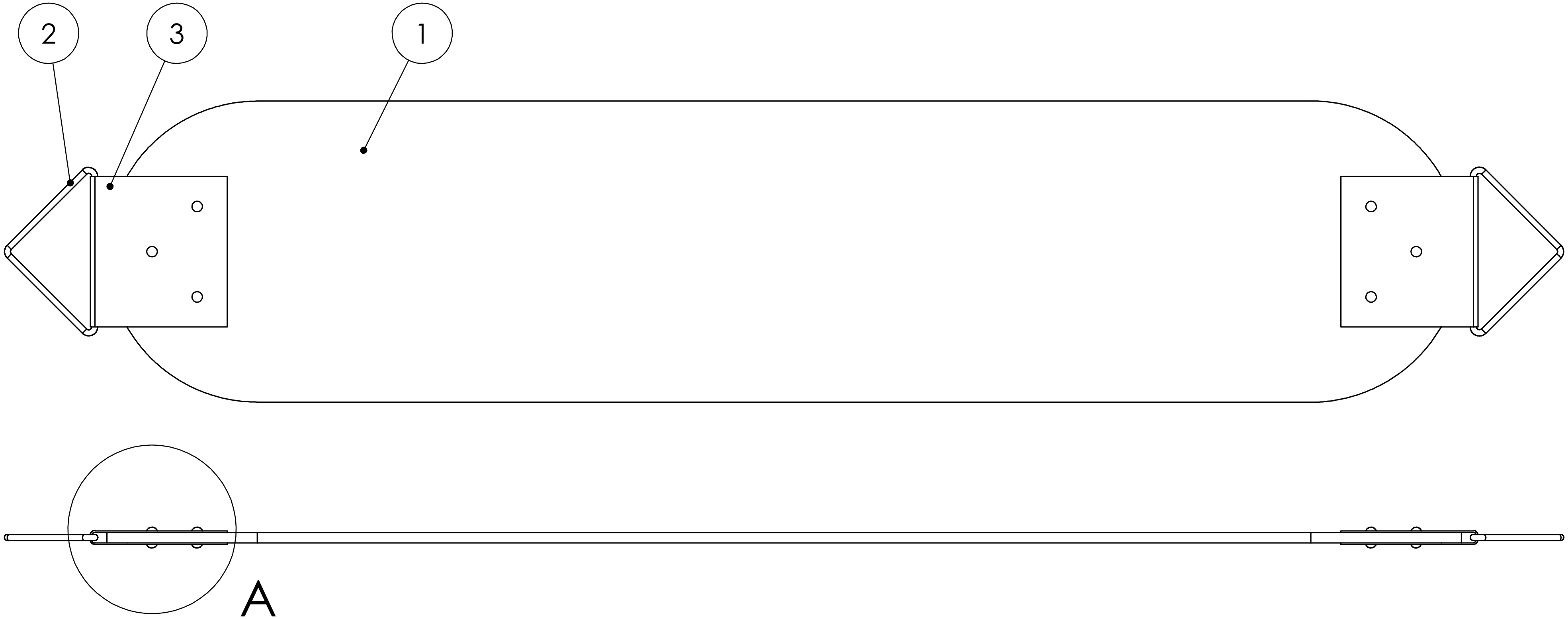
	Description: Assembled Structure		Drawing: 2 Sheet: 1
Scale 1:25	Units: mm	Universitat Jaume I	Author: Gemma E. Tido Pérez	Date 25/10/17

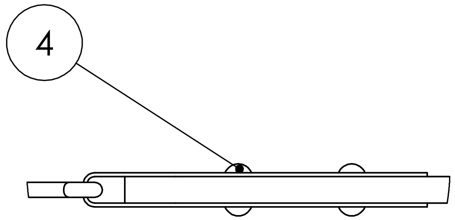




ELEMENT NUMBER	PART	AMOUNT
1	BaseBody	1
2	Lateral Lid	2
3	Top Lid	1
4	DIN 967 - M4 x 16 - Z --- 14.6N	4

		Description: Assembled Base		Drawing: 3 Sheet: 1
Scale 1:16	Units: mm	Universitat Jaume I	Author: Gemma E. Tido Pérez	Date: 25/10/17

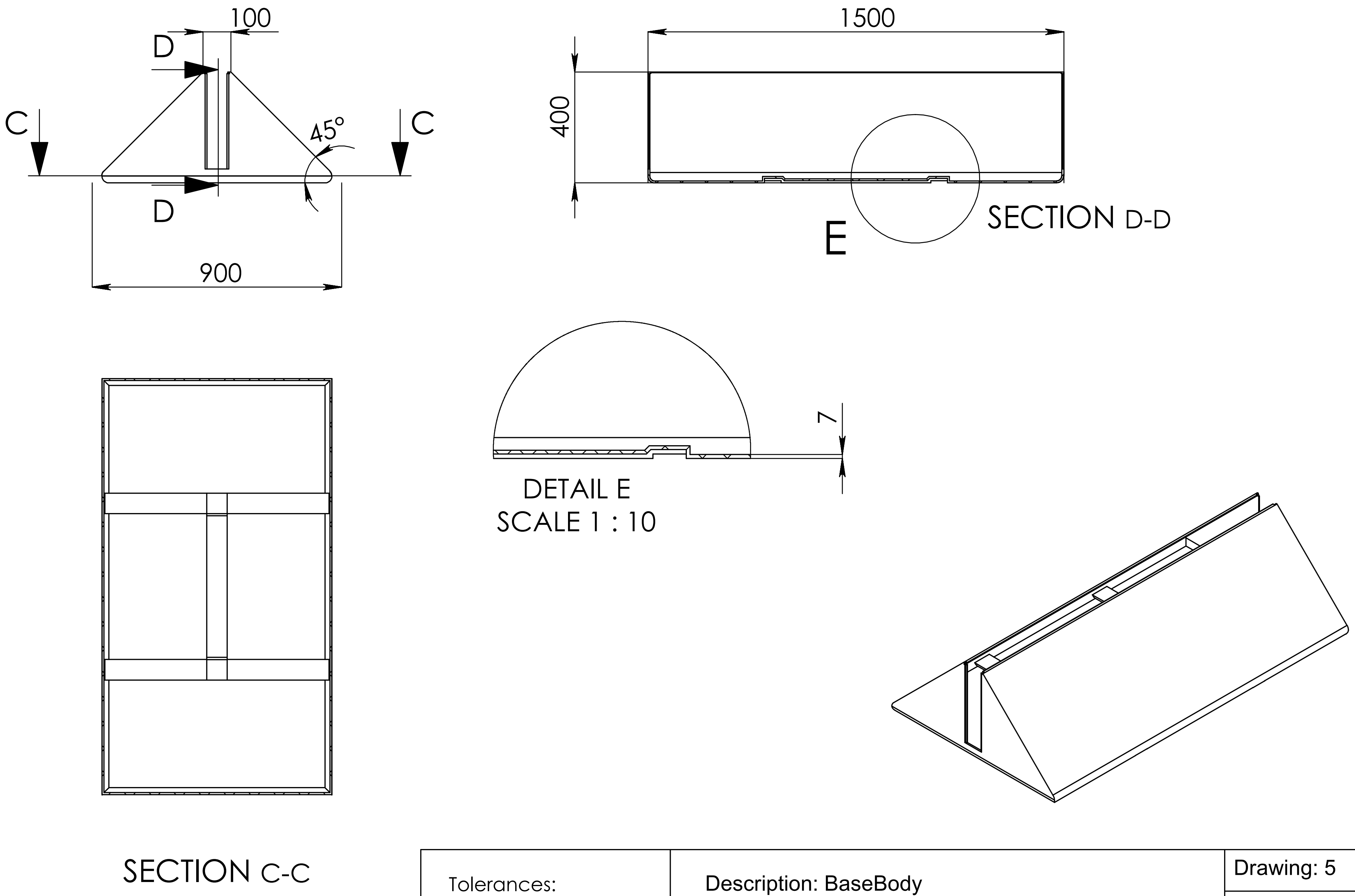




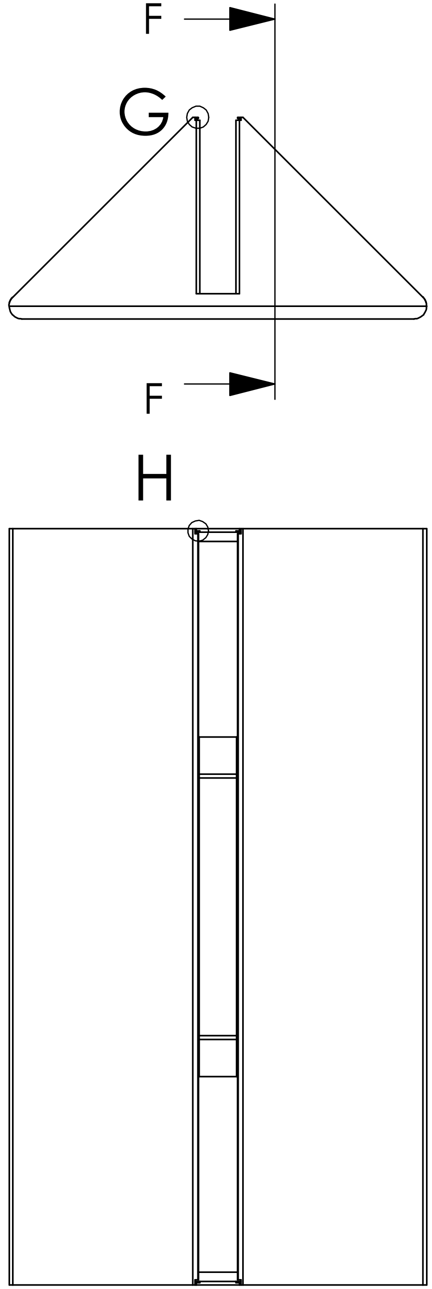
DETAIL A
SCALE 1 : 2

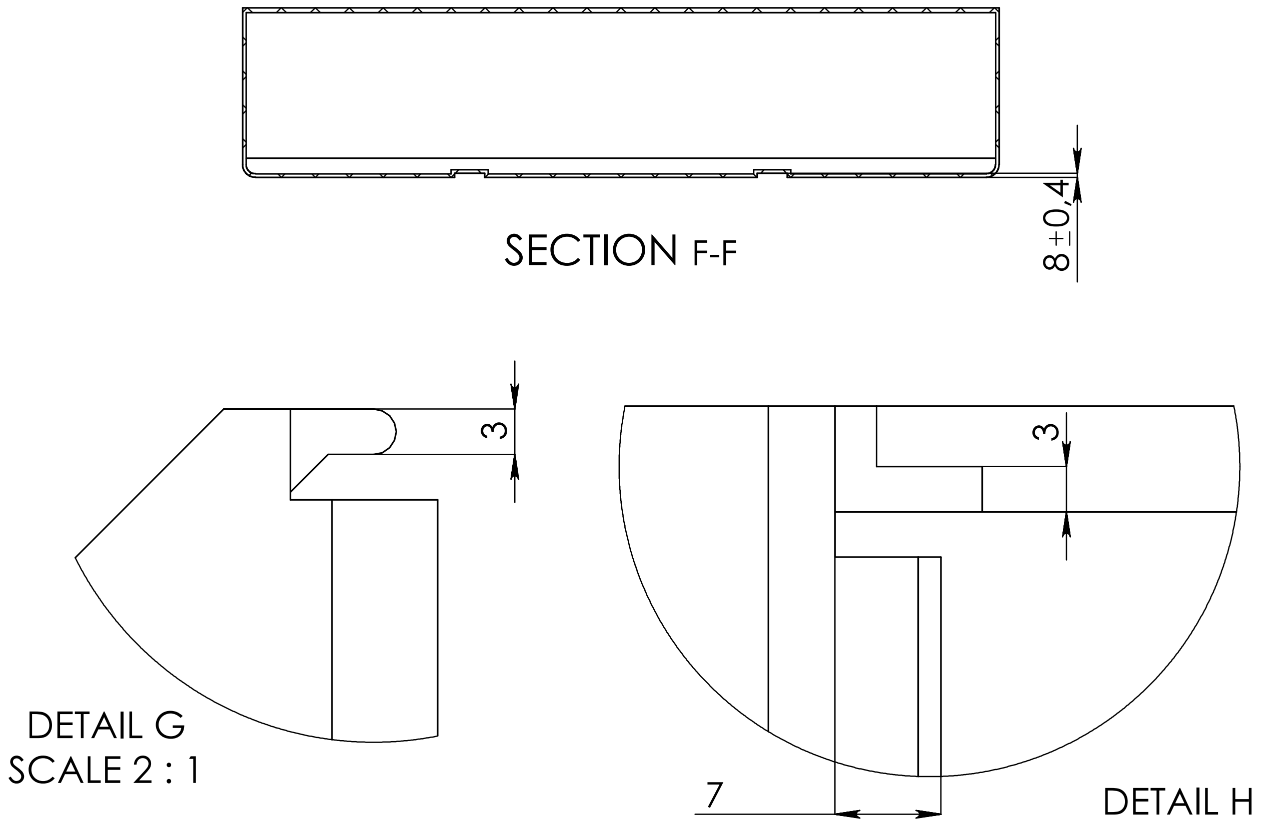
ELEMENT NUMBER	PART	MATERIAL	AMOUNT
1	Seat Body	EPDM Rubber	1
2	Seat rod	Steel	2
3	Seat plate	Steel	2
4	DIN 660-4x16-St-A-9	Steel	6

	Description: Seat Assembly		Drawing: 4 Sheet: 1
Scale 1:4	Units: mm	Universitat Jaume I	Author: Gemma E. Tido Pérez	Date: 25/10/17

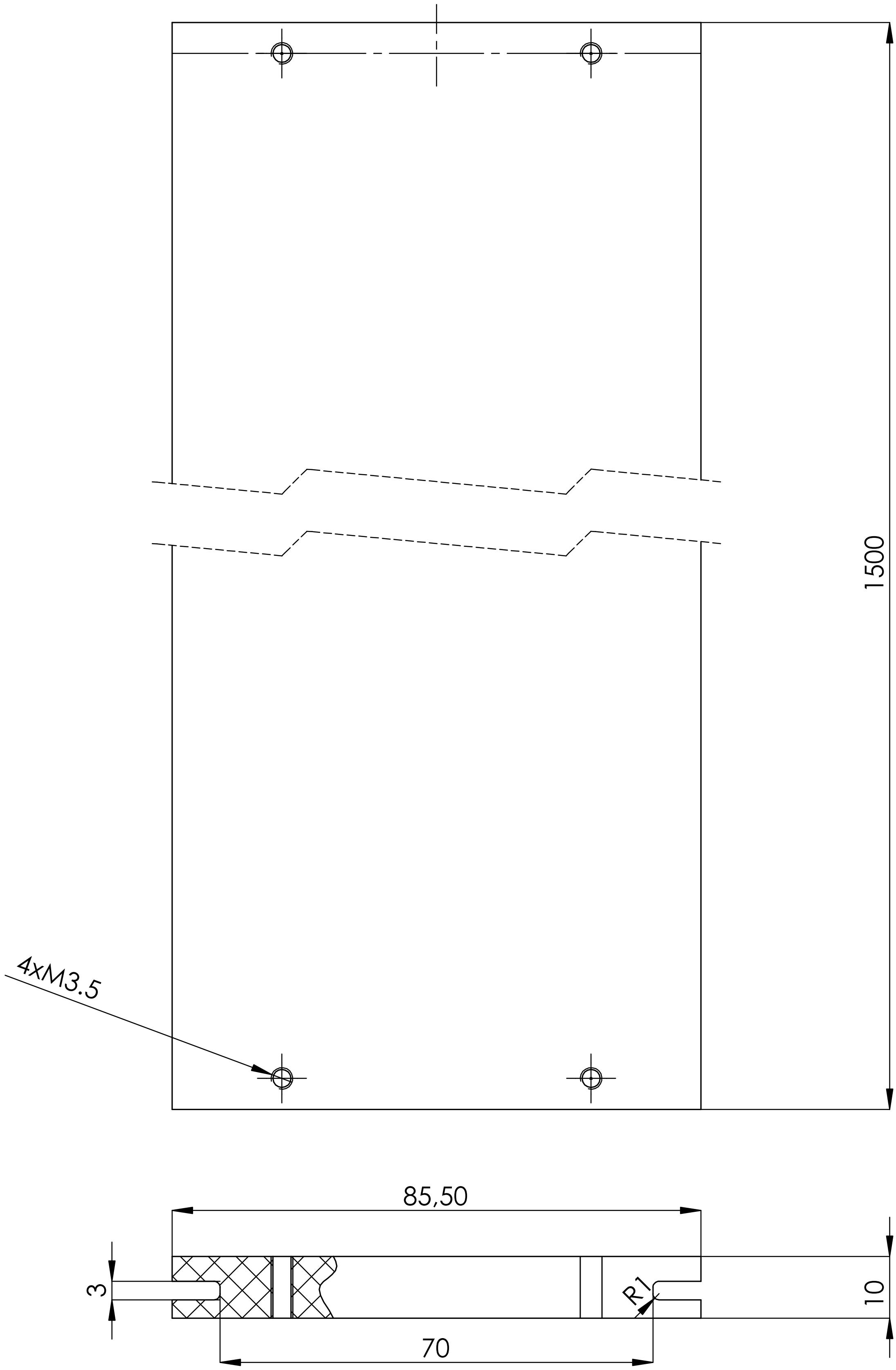


Tolerances: Longitudes: +-0,4%		Description: BaseBody		Drawing: 5 / Sheet: 1
Escala 1:20	Units: mm	Universitat Jaume I	Author: Gemma E. Tido Pérez	Date: 25/10/17

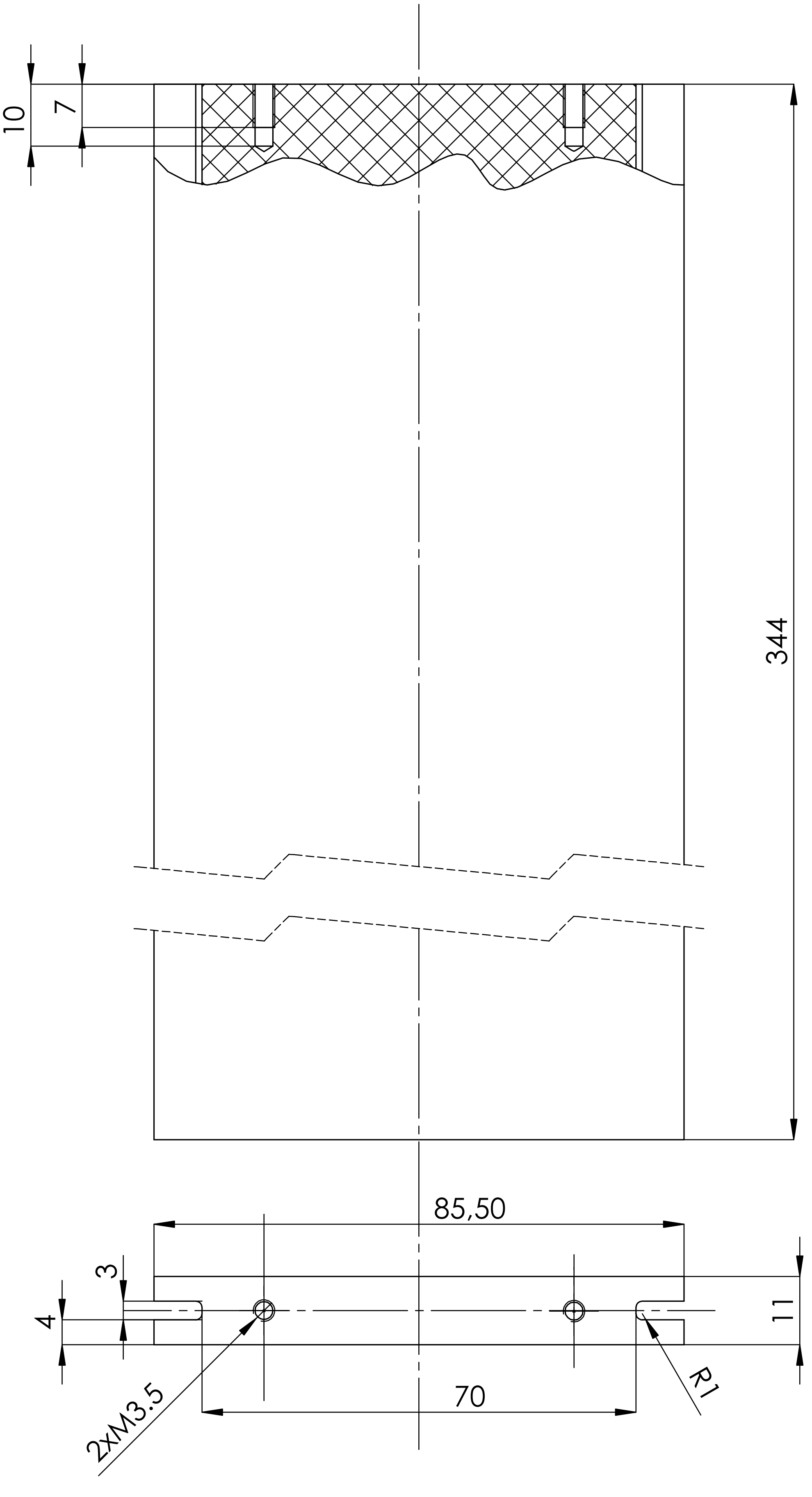




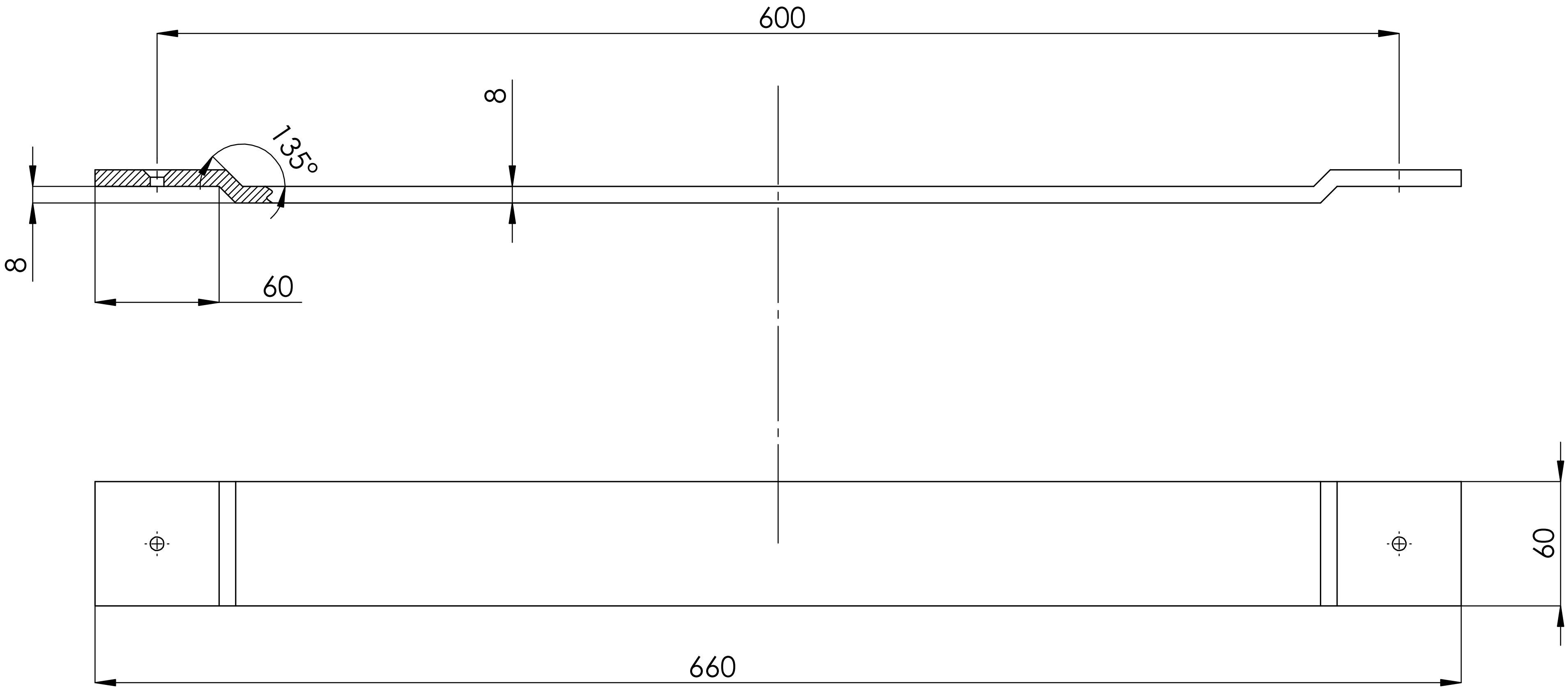
Tolerances: Longitudes: +-0,4%		Description: BaseBody		Drawing: 5 Sheet: 2
Escala 1:15	Units: mm	Universitat Jaume I	Author: Gemma E. Tido Pérez	Date: 25/10/17



	Description: Top Lid		Drawing: 6
			Sheet: 1
Escala 1:1	Units: mm	Universitat Jaume I	Author: Gemma E. Tido Pérez	Date 25/10/17



Unspecified tolerances: +-0,2mm	Description: Lateral Lid		Drawing: 7
			Sheet: 1
Escala 1:1	Units: mm	Universitat Jaume I	Author: Gemma E. Tido Pérez	Date 25/10/17



Description: Transversal Bar

Drawing: 8

Sheet: 1

Scale 1:3

Units: mm

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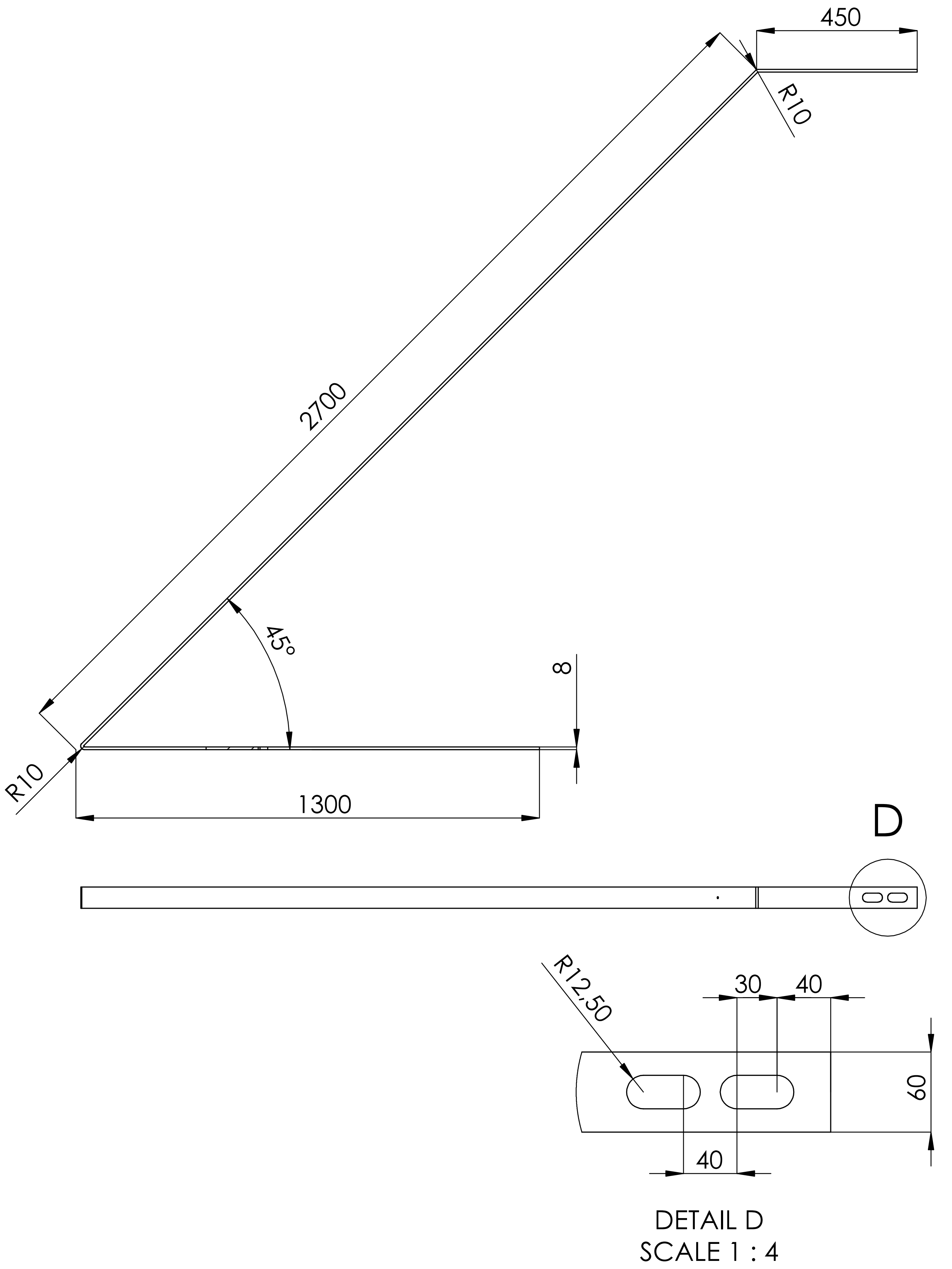
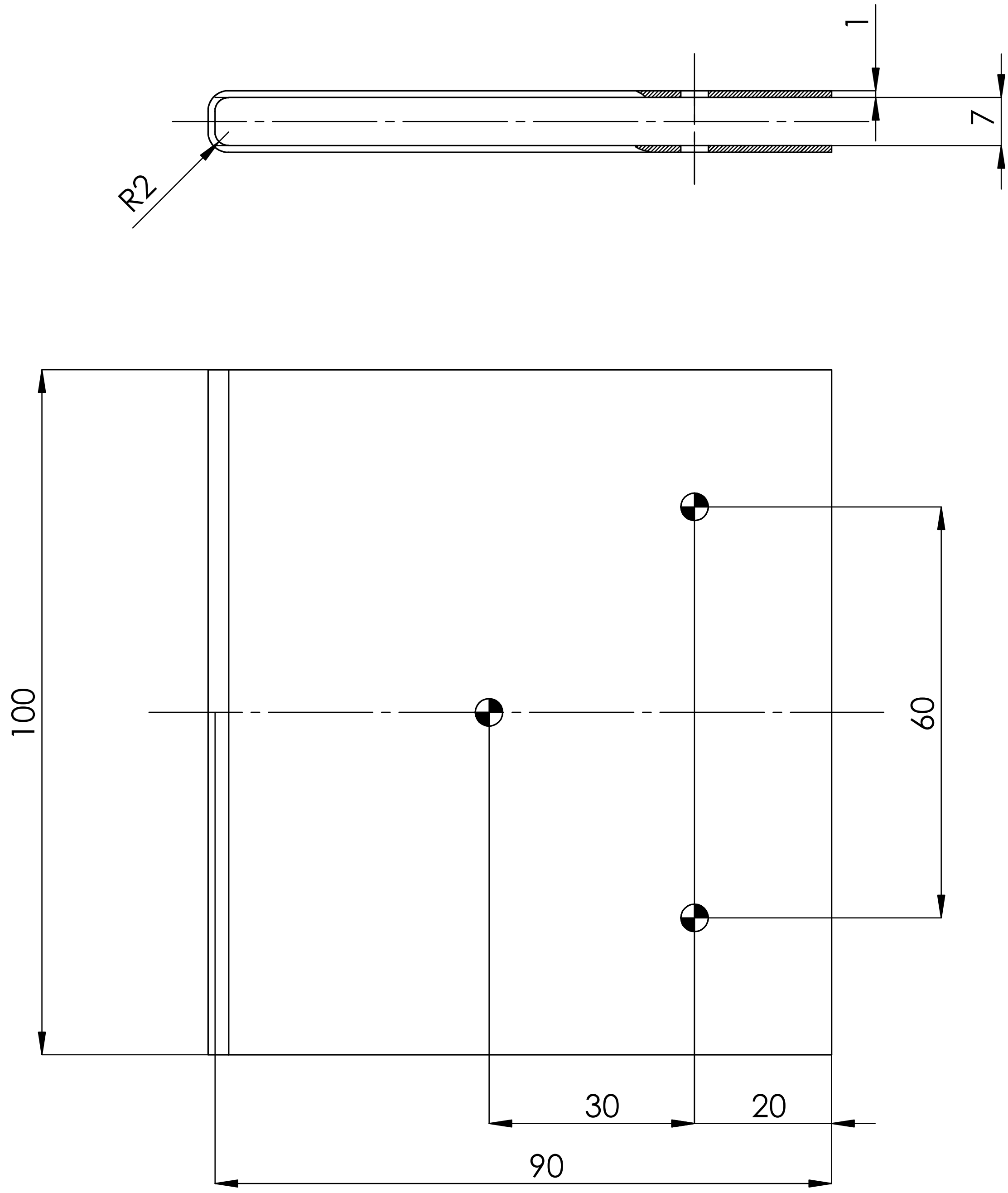
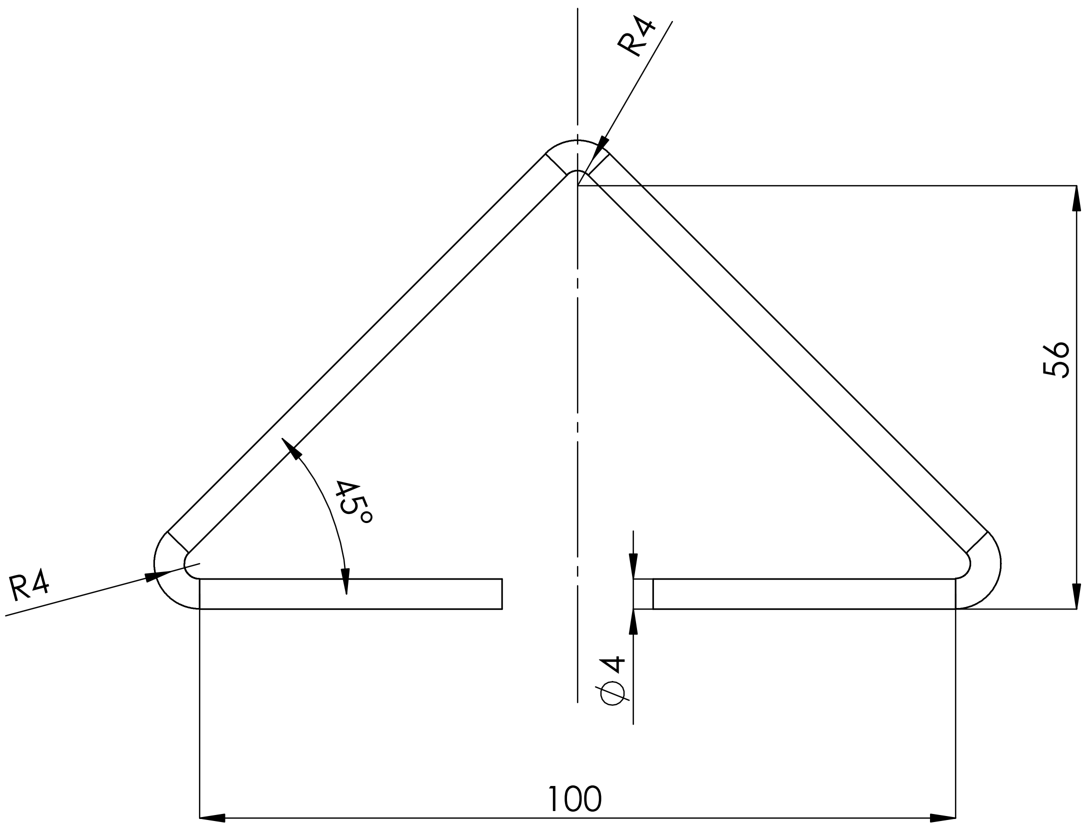


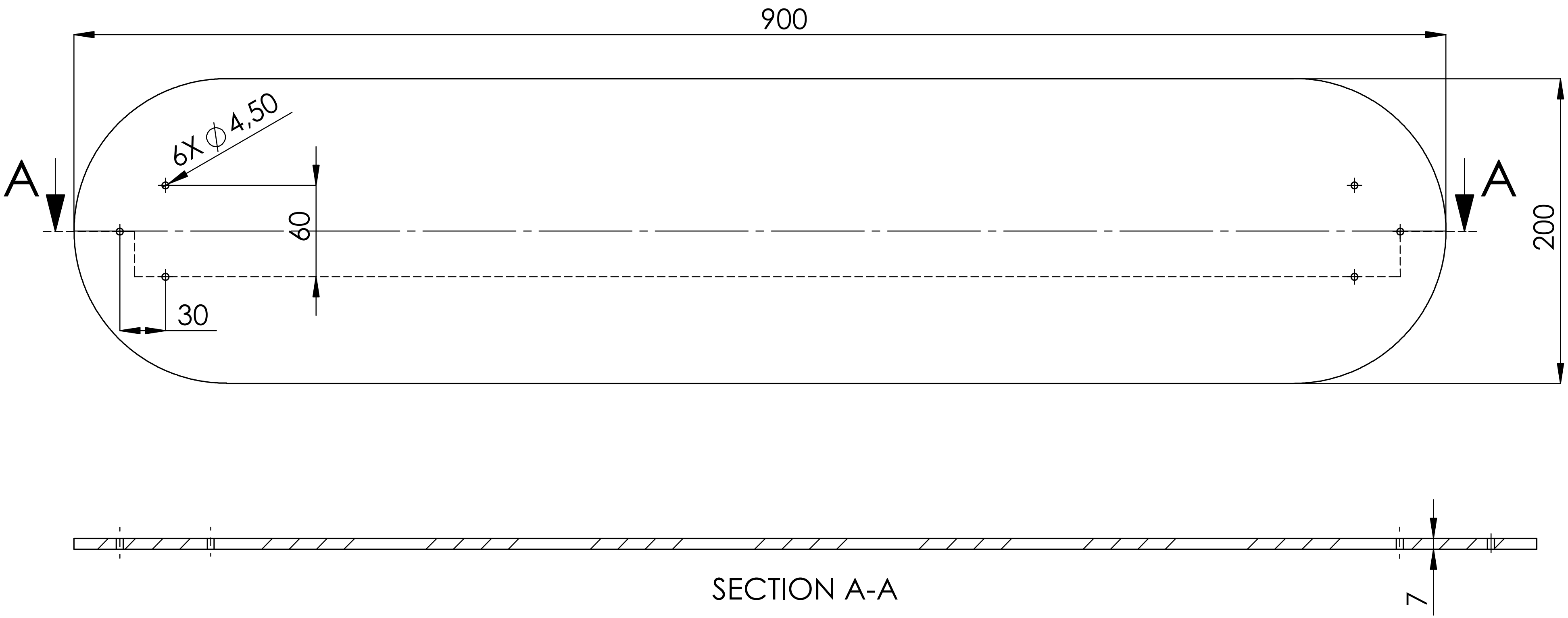
		Description: Beams		Drawing: 9
				Sheet: 1
Scale 1:15	Units: mm	Universitat Jaume I	Author: Gemma E. Tido Pérez	Date 25/10/17



	Description: Seat plate	Drawing: 10 Sheet: 1
Scale 1:1 | Units: mm	Universitat Jaume I | Author: Gemma E. Tido Pérez	Date 25/10/17



		Description: Seat rod	Drawing: 11
			Sheet: 1
Scale 1:1	Units: mm	Universitat Jaume I	Author: Gemma E. Tido Pérez	Date 25/10/17



SECTION A-A

Description: Rubber Seat

Drawing: 12

Sheet: 1

Scale 1:4

Units: mm

Escuela Superior de Tecnología

Author:

Gemma E. Tido Pérez

Date:

25/10/17