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Social responsibility in Mechanical Engineering

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Abstract

The economy that we live in makes us, repeatedly, look for solutions that seek to bring more comfort and well-being to people. We constantly see innovative ideas that promise to improve the lives of thousands of people and in fact, over the years, we have been able to see a technological rise that has greatly improved the lives of individuals. The problem is when this quest for development, innovation and profit began to neglect some essential factors for social well-being. Consequently, social responsibility, over the years and with the negative impacts arising from this search for unbridled development, has become an extremely relevant issue. A main concern can be highlighted: the need to reconcile economic progress with the preservation and maintenance of the environment health, without neglecting well-being, security, equity and the guarantee of conditions for a dignified life in society. Bearing this in mind and observing that mechanical engineering is present in several places in the developed world, it becomes increasingly necessary to link the needs arising from social responsibility with the activities in which mechanical engineering is involved.

The present thesis, therefore, seeks to analyze the different topics that involve the theme. Initially, we went through a theoretical survey of the literature about the subject. It introduces us a bit of history about the development of social responsibility in mechanical engineering. Bearing in mind all the pre-existing concept in the state of the art, a methodology is developed through a layered analysis of the most important topics for the practical development of a mechanical project, always connecting social responsibility with mechanical engineering.

After contextualizing and developing the methodology, we move on to practical implementation. To illustrate the concepts more clearly, a problem highly related to the theme of social responsibility in mechanical engineering is presented: an accessibility project that enables the autonomy of wheelchair users when using their cars. It is very common for those, when using cars, to need help from others to store the wheelchair and to get into the car properly. The project seeks to bring a solution/alternative to improve the quality of these people lives.

Several topics are analyzed. As, analyzed, such as, for example: the stakeholders, the project advantage in the society, environmental and economic scope, which patents have already been developed in this area. Additionally, several mechanical analyzes were performed with the aid of computational finite element calculation and 3D CAD design. The mechanical dimensioning was carried out meeting the needs of materials with properties and characteristics appropriate to the theme of social responsibility and the required mechanical behavior.

Keywords: social responsibility, society, environment, economy, mechanical engineering, project methodology.

Resumo

A economia em que vivemos nos faz, recorrentemente, procurar soluções que busquem trazer mais conforto e bem-estar às pessoas. Constantemente vemos ideias inovadoras que prometem melhorar a vida de milhares de pessoas e de facto, com o passar dos anos, pudemos ver uma ascensão tecnológica que melhorou muito a vida dos indivíduos. O problema é quando essa busca por desenvolvimento, inovação e lucro começou a deixar de lado alguns fatores essenciais ao bem-estar social.

Consequentemente, a responsabilidade social, com o passar dos anos e com os impactos negativos advindos dessa busca pelo desenvolvimento desenfreado, tornou-se um assunto extremamente relevante. Podemos destacar uma principal preocupação: a necessidade de conciliar o avanço económico com a preservação e manutenção da saúde do meio ambiente, sem deixar de lado o bem-estar, a segurança, equidade e a garantia de condições para uma vida digna em sociedade. Tendo isso em vista e ao observar que a engenharia mecânica se encontra presente em diversos locais no mundo desenvolvido, começa a ser cada vez mais necessário atrelar as necessidades advindas da responsabilidade social com as atividades em que a engenharia mecânica está envolvida.

A presente tese, portanto, procura analisar os diferentes tópicos que envolvem a temática. Inicialmente, no trabalho, passamos por um apanhado teórico da literatura sobre o assunto. Verifica-se um pouco da história e o desenvolvimento da responsabilidade social na engenharia mecânica. Tendo em vista todo o conceito pré-existente no estado da arte é desenvolvida uma metodologia por meio de uma análise por camadas dos tópicos mais importantes para o desenvolvimento prático de um projeto mecânico conetando sempre a responsabilidade social com a engenharia mecânica.

Após a contextualização e desenvolvimento da metodologia passamos à implementação prática. Para ilustrar os conceitos com maior lucidez, uma problemática altamente relacionada com o tema da responsabilidade social em engenharia mecânica é apresentada: um projeto de acessibilidade que viabilize a autonomia dos utilizadores de cadeiras de rodas ao utilizarem os seus automóveis. É muito comum às pessoas que necessitam o auxílio de cadeiras de rodas, ao utilizarem automóveis, precisarem de ajuda de outros tanto para guardar a cadeira de rodas quanto para conseguirem entrar adequadamente no automóvel. O projeto busca trazer uma solução/alternativa para melhorar a qualidade de vida dessas pessoas.

Vários tópicos são analisados, como, por exemplo: as partes interessadas, qual a vantagem do projeto no âmbito social, ambiental e económico, quais trabalhos e patentes já foram desenvolvidas nesta área. Adicionalmente foram feitas diversas análises mecânicas com auxílio de cálculo computacional por elementos finitos e desenho em CAD 3D. Foi feito o

dimensionamento atendendo as necessidades de materiais com propriedades e características adequadas ao tema da responsabilidade social e ao comportamento mecânico requerido.
Palavras-chave: responsabilidade social, sociedade, meio ambiente, economia, engenharia mecânica, metodologia de projeto.

To my family in Brazil: André, Cássia, Bruno, Didu & Capitu.
And to those people that most support me at Portugal: Bernardo Rocha, Luiz Azevedo and Azevedo's family.

Thank you all!

“Someone’ s sitting in the shade today because someone planted a tree a long time ago.”

Sir Warren Buffett

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Sem vocês essa tese não seria possível, obrigado.

Table of contents

List of Figures

List of tables

Abbreviations

AA 1000	Accountability 1000
CAD	*Computer Aided Design*
Cos	Cosine
CRS	Corporate Social Responsibility
DJSI	Dow Jones Sustainability Index
EMS	Environmental Management System
EU	European Union
GRI	Global Report Initiative
ISEA	Institute of Social and Ethical Accountability
ISO	International Organization for Standardization
OHSAS	Occupational Health and Safety
SA 8000	Social Accountability 8000
SAI	Social Accountability International
Sin	Sine

Symbols

A_1	Area 1 [m^2]
A_2	Area 2 [m^2]
A_3	Area 3 [m^2]
d	Distance [m]
D_1	Diameter 1 [m]
D_2	Diameter 2 [m]
D_3	Diameter 3 [m]
Fa	Frictional force [N]
FF	The force required for the forward motion [N]
FR	Force required for the return movement [N]
I	Moment of inertia of the section [kg. m^2]
MF	Bending moment [N.m]
N	Normal reaction [N]
P	Weight [N]
P_b	Arm weight [N]
P_1	Pressure in area 1[$N.m^{-2}$]
P_3	Pressure in area 3 [$N.m^{-2}$]
r	Radius at the center [m]
T	Cable traction force [N]
σ	Stress [$N.m^{-2}$]
μ	Static friction coefficient

Chapter 1- Theoretical Introduction

1.1. Introduction

The branch of Mechanical Engineering, with the development of industry, has become very important in the world economy and is present in various activities of the society daily life. We can observe products associated with mechanical engineering in our houses and workplace due to the presence of air conditioning, electric ovens, pans, fans, blenders, and in the industry of food, clothes, leisure. Examples of those applications we can find in the farm machines, in power generation plants, roller coasters in amusement parks, planes, boats, trains, automobiles, bicycles, motorcycles. The examples are extensive and the impacts that a mechanical engineering project can generate are enormous, positively and negatively. The positive impacts are easy to perceive, through the examples mentioned above we can conclude that many current activities would be completely unfeasible without the collaboration of mechanical engineering. However, it is also necessary to visualize that there are many risks derived from such activities, because of residual pollution, the safety of industrial employees and product users. In addition, today, the same problem occurs with mechanical engineering in every area that moves the economy, that is, a duality that must be balanced: the search for the financial rise of companies and their consequent environmental and social impact. Having this perception, it is easy to understand the importance of the theme of social responsibility in mechanical construction projects. In order to better observe in which situations social responsibility is present in the field of mechanical projects, this work will be divided into the different aspects that have been observed throughout history and that must be observed today to enable a good technological development. Points such as professional ethics, environmental pollution and the economic point of view will be presented and analyzed individually. It will be important, as well, to analyze studies already developed in this area, from companies, universities projects.

After a complete analysis of how social responsibility should be approached in mechanical engineering, a case study project will be made, taking into account the topics initially addressed in the contextualization of this work.

1.2. Objectives

Among the main objectives of the thesis about the social responsibility in mechanical engineering we can highlight:

- Link the importance of not only making a profit but making a profit sustainably in a mechanical project.
- Analyze the parts of a mechanical project from a different perspective, considering the social and economic concerns.
- Check scale impacts when adopting a social point of view when designing a mechanical design.
- Show in practice, with a model project, the methodology developed for the constitution of the socially sustainable mechanical project.

1.3. Outline

The first chapter has a theoretical survey of the literature about social responsibility in mechanical engineering. There is a bit of history about the development of the subject, ending with some norms and rules that are present in the industry today.
The second chapter is a layered verification technique of the most important topics to structure an analysis methodology for the practical development of a mechanical project, observing all the important aspects that connect social responsibility with mechanical engineering.
The third chapter goes through the practical implementation of the methodology. To illustrate the concepts more clearly, a problem highly related to the theme of social responsibility in mechanical engineering is presented: an accessibility project that enables the autonomy of wheelchair users when using their cars. Several topics are analyzed using the methodology introduced in the second chapter.
Finally, in **the fourth chapter**, a conclusion overview of the work is presented together with some possible future developments related to the project.

1.4. Literature Review

1.4.1. Social responsibility – Definition

Social responsibility is discussed in various fields today. However, this term came up with the original idea in the business environment through "Corporate social responsibility". The work [1] deals well the subject and seeks to define the definition of what social responsibility is through the compromise between: social, environmental, and economic sustainability. Starting from the idea that society needs goods that are supplied by an industry that seeks profit, it is necessary to define the limits that this relationship encounters. The unbridled use of the environment, human capital and other assets is not viable without thinking about the negative consequences that this can generate for future generations. At the same time, it is not ethically correct to use labor in superhuman conditions to achieve better financial results, but no company will be able to collaborate to avoid such problems if it does not make a profit in its business. Therefore, we can observe some definitions of social responsibility, such as that of the World Business Council for Sustainable Development: “continuing commitment by business to behave ethically and contribute to economic development while improving the quality of life of the workforce and their families as well as of the local community and society at large” [2]. As much as there are several different definitions, they all end up agreeing on the same essence that can be summarized by these 3 essential points: society, the environment, and the economic development that we aim for. We cannot achieve some of these goals and leave any others aside if we seek to develop a more pleasant world with a better quality of life for all.

Knowing that the origin of the term, social responsibility came from the concept of Corporate social responsibility, it is important to better understand what this term means in the current corporate world that completely influences the profession and the branch of mechanical engineering and mechanical engineering at large.

1.4.2. Social Responsibility - Corporate Social Responsibility (CRS)

Industrial development from the 1800s onwards generated a growing concern for worker well-being and productivity among industrialists. Growing criticism of the emerging factory system, working conditions and the employment of women and children was being brought to light. In 1971, the concept of “social contract” between business and society was introduced by the Committee for Economic Development. This contract brought the idea that companies operate and exist by public consent and, therefore, there is an obligation to contribute to the needs of society [3]. Nowadays, in practice, the concept of CRS can be somewhat controversial for

personal and political interests. CSR proponents, for example, see it as a vehicle for transforming companies to create shared economic, social, and environmental value for themselves and their stakeholders. In contrast, some skeptics within the business world see CSR as an intrusion on free market principles. Despite these varied assessments of CSR from both academia and the business world, it remains a dominant organizational framework for debating the responsibilities of companies to their stakeholders and society. It is difficult these days to find successful for-profit companies that lacked the commitment of responsible professionals in their history [4].
Within this theme, it is possible to verify milestones in history that reaffirm the importance of this discussion, such as the creation of the Dow Jones Sustainability Index. According to [1] “environmental conditions, environmental movements, environmental regulations and self-realized business profitability were the main indicators of the evolution of sustainability. Recognizing its importance, in 1999 the Dow Jones Industrial Average started a new index called the “Dow Jones Sustainability Index” (DJSI) to track the financial performance of leading sustainability-oriented companies around the world.” Since, like other indices of great importance in the world, the Dow Jones Sustainability Index is used by investors, shareholders in order to identify companies with prosperous characteristics in the world, which then shows us an impossibility of thinking about economic development. social responsibility for the survival, beyond humanity, of the companies that intend to act in the market.
According to Dow Jones, “The quality of a company’s strategy and management and its performance in dealing with opportunities and risks deriving from economic, environmental and social developments can be quantified and used to identify and select leading companies for investment purposes”. The DJSI index reviewed corporate reports on sustainability, environment, health and safety, financial and any relevant special reports.
As the most engineers in the world work for corporations, they must therefore navigate CSR as an area of expertise in their own professional lives. Currently, the closest we come to finding social responsibility in the engineering world communicates with the ethics and conduct standards that need to be seen when working in the industry. It is essential to understand the reason for the existence of these codes of conduct, their origins and the importance of the existing norms.

1.4.3. The History of Engineering Ethic

The 20th century was pivotal in the history of Engineering Ethic. There were a series of significant structural failures about this time. Entities began to require formal credentials or licensing involving some combination of educational, experience, and testing requirements. Most engineering societies adopted formal codes of ethics [5].
Some objectives of the Engineering Code of Ethics serve as an example to realize its importance:

• Hold paramount the safety, health, and welfare of the public;
• Perform services only in areas of their competence;
• Issue public statements only in an objective and truthful manner;
• Act for each employer or client as faithful agents or trustees;
• Avoid deceptive acts;
• Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession;

By that, we can consider some questions when starting a project in the mechanical engineering area thinking about the engineer's ethical code, such as: How many people are affected by this project? What pressures might an engineer encounter during the design and development processes involved in this project? What types of obstacles and potential dangers are inherent in this project?

Ethics in the engineering profession is of special notoriety and importance because engineering projects directly affect people's lives. The engineering profession encompasses professionals working for companies with regulations, bureaucracies and rules but also self-employed professionals who provide services independently and who have as a form of control their registration or professional license. There is a high likelihood of competing priorities, such as controlling costs, minimizing risk to the public, and meeting expected timelines, in engineering project, the necessity for various disciplines or entities to collaborate on engineering projects is high, and this increases the possibility for ethical issues such as conflicts of interest, inappropriate treatment of confidential information, differing stakeholder interests. Engineering projects can be resource heavy, there can be a significant amount of financial, environmental, and human resources involved [5].

1.4.4. Social Responsibility Environment Point of View

With the advent of the industrial revolution, the increase in demand for energy sources was inevitable and consequently the price of the most common forms of energy, that is, sources derived from carbon. By that, started a growing trend of expectations by stakeholders that businesses should be more energy efficient and potentially change or alter their product designs to suit a new energy economy. This interaction requires developing strategies of interweaving economic, environmental, and social causes to deliver equity, affordability, and profitability that in turn will offer the sustainability [1].

Thus, some focuses have become common among companies to achieve their goals related to companies/environmental projects. We can list a few:

1. Maintain management systems to assist with implementation of **sustainability objectives.**
2. Aim to **use resources efficiently** and to minimize waste, usage of water, energy, and their consumables in the office environment.
3. Develop a strategy to move toward **minimizing carbon emissions** in its operations.
4. Endeavor to **prevent pollution** within the scope of its activities.
5. Develop a strategy for the firm to **move toward sustainable** procurement of the goods and services used in its operations.
6. Deliver **projects recognized for their sustainability credentials**, in line with client expectations.
7. Evaluate projects with **respect to their sustainability risks** and opportunities.
8. Achieve performance that ensures the **firm's economic, environmental, and financial viability.**

An interesting but extremely important curiosity taken from the source [21] shows in figure 1 how many Earths would be needed so that we could continue to live sustainably if we lived according to some countries.

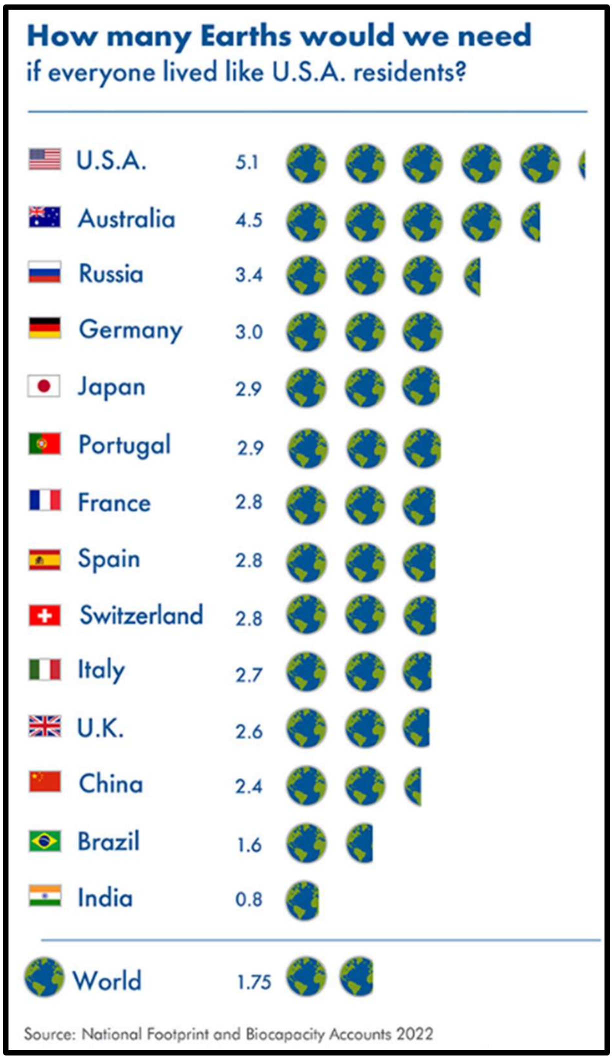


Figure 1 - How many Earths would be needed to live sustainably - [21]

Therefore, if we all lived like Portugal in 2022, for example, we would need approximately 2.9 Earths to be able to continue living sustainably.

1.4.5. Social Responsibility in Mechanical and Construction Design

As we have seen, there are numerous reasons why we should consider the study of social responsibility in mechanical engineering projects. We know that due to the mechanical industry there are several aspects that are positively or negatively influenced by this branch of science studies. For example, the environment due to the extraction of materials, their use, their end of life, as well as the wellbeing of people inserted in this industry, in the extraction of materials, manufacture of projects in addition to the people who will enjoy the goods of this industry, so it is logical to understand how mechanical engineering can be used positively in the future, inspired by all the work that has already been done.

1.4.6. Sustainable Development

Among the points of view of social responsibility presented above, the importance of the study of sustainable development in mechanical engineering is perceptible, since it is a profession that is based on the search for evolution and development in social and economic fields.

For that, we need to know what sustainable development is. According to [6] sustainable development has to do with our relationship with the natural environment on which we depend for food, water, energy and raw materials. Every sustainable development has at least three facets: environmental, social and economic. Technological development without regard for environmental and social impacts brings undesired consequences: degradation of air, water and land, loss of biodiversity, resource depletion, and increasing inequality.

1.4.6.1. Materials

As every type of structure needs raw materials, whether in the construction of buildings, paving the streets, production of clothes, mechanical engineering projects would be no different. It is up to us to think what kind of attention materials have in using the most different types of types available on Earth to deliver the high technological level that a current industry demands.

In order to understand a little about the advance in the use of these materials in engineering, it is interesting to understand one of its history.

The **earliest "engineering" materials** were those of nature: stone, wood, fibers, bark, skin, hide and bone. Their applications were largely mechanical (housing and tools) or thermal (clothing and protection). Subsequent advances in technology and science-stimulated bursts of material development: thermochemistry in the seventeenth century, then of electrochemistry in the eighteenth and nineteenth centuries, **so that by the mid-twentieth century almost the entire periodic table was accessible for engineering purposes**. The growth of polymer and ceramic sciences in the first half of the twentieth century delivered new structural materials.

Since 1971, when the last of the actinides was isolated, material developers have had access to all 92 of the stable elements of the Periodic Table [6].

In a surprisingly short space of time, we have become dependent on this treasure chest of elements and the materials made from them. Many products, today, draw on a much wider spectrum, some of which occur only as lean, highly localized ores, or are extracted only as a by-product of another element, making their supply uncertain. Our dependence on some of these is now so extreme that Governments classify them as "critical" and regard access to them as a strategic necessity [6].

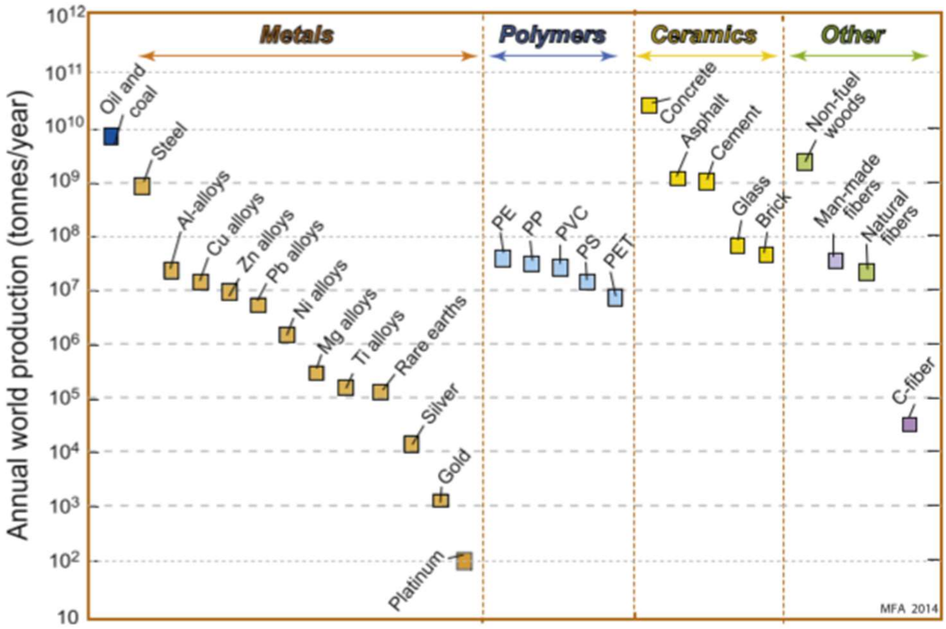


Figure 2- Primary production of the materials used in the greatest quantities [6]

In figure 2 we can see, to conclude the discussion, the primary production of the materials used in the greatest quantities.

Critical materials

Materials are now marketed globally. Some ores and raw materials needed to make some of them are widely available, allowing a free market to exist globally. Others, however, are more restricted geographically, and for this reason, the nations from which they come may limit supply for various reasons such as their own policies, economy. The so-called critical materials are precisely those that have limited access or that are essential for national security or economically important. It is common for countries to have lists of these critical materials and based on this they develop strategies to guarantee supply by negotiating international agreements and seeking new sources or stockpiling.

For example, we have the US list (table 1), the lists act as warnings, alerting manufacturers of potential supply risk [6].

Table 1- US list of critical materials [6]

Critical Materials–US List			
Chromium	Cobalt	Dysprosium	Erbium
Europium	Gallium	Germanium	Indium
Iridium	Lanthanu	Lithium	Manganese
Neodymium	Osmium	Palladium	Platinum
Praseodymium	Rhodium	Ruthenium	Samarium
Scandium	Tantalum	Tellurium	Terbium
Thulium	Tin	Tungsten	Yttrium
Antimony	Beryllium	Bismuth	Cerium

One way to understand the importance of these materials in the modern world is to compare similar components at different times, in the past, when technological requirements was not as great as the current ones, we used to live in a world in which we were not so hostage to a such a wide range of materials, and this becomes explicit in figure 3.

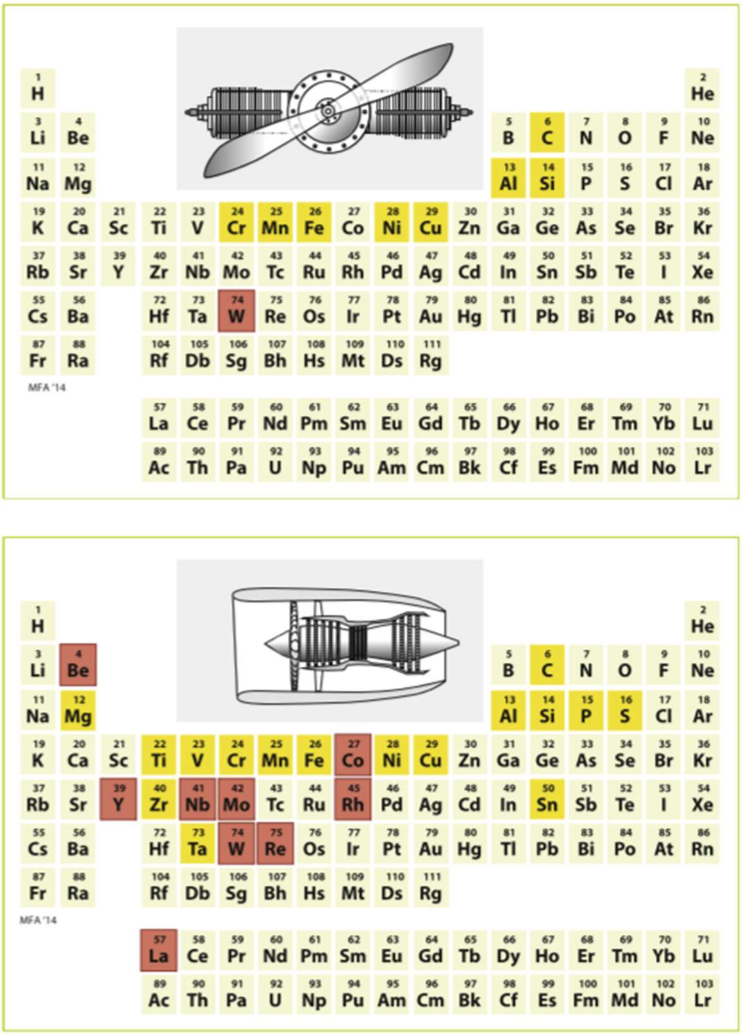


Figure 3- Comparison of the use of materials for construction of similar objects at different times [6]

We can see that in the old turbines, in addition to requiring less materials for their manufacture (elements in the periodic table painted in yellow), the materials considered critical (elements in the periodic table painted in red) were much less necessary.

We can also see how these critical materials are distributed across countries according to the official EU website, figure 4.

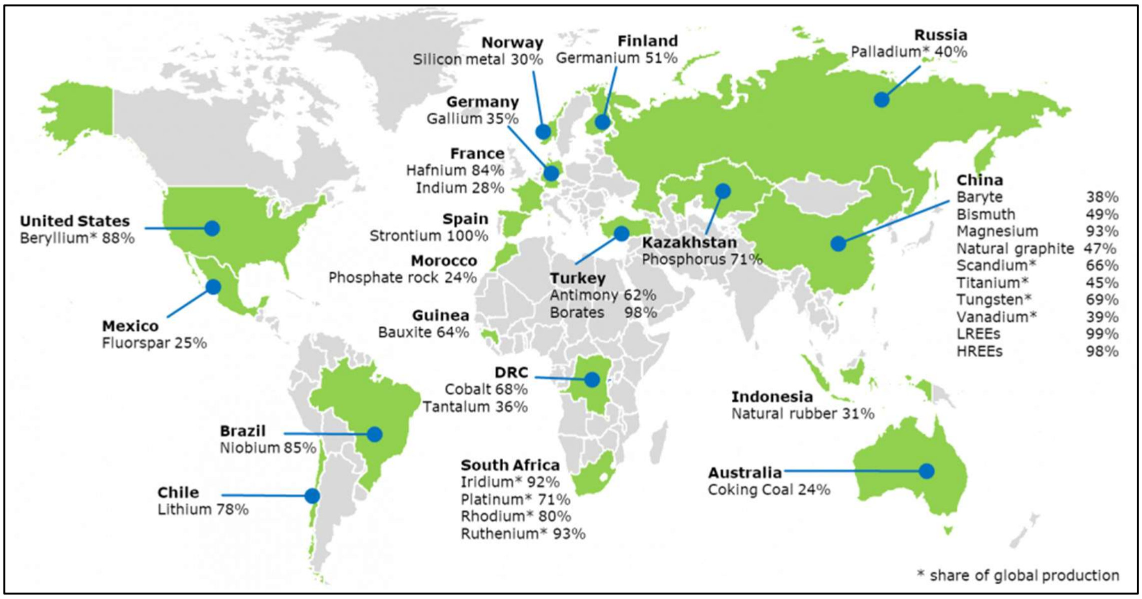


Figure 4 - Countries accounting for largest share of EU supply of CRMs [7]

Analyzing the figure 4, we realize that it is not possible for a country to be self-sufficient today and, consequently, the existence of exposure to the risk of the politics of other countries is evident.

1.4.6.2. Energy

When thinking about social responsibility, it is also evident that we can't forget the topic of energy. We all know that energy has been an extremely recurring problem in political discussions, electric cars are increasingly looking to the future to circumvent the carbon footprint due to combustion-powered cars, also the energy plants and industries are concerned throughout their production process to reduce the environmental impact on water, air, forests. Therefore, in design and mechanical construction, it is impossible to ignore the importance of knowing how to use energy properly.

Humanity has so far only managed to discover and make use of four sources of energy, these are: hydrocarbon fuels, sun, moon and nuclear. However, if we check which source we actually use in society, we will have fossil fuels dominate the picture, providing about 86% of the total. Nuclear delivers about 7% as we can see in figure 5. Renewables – hydro, wind, wave, biomass, solar heat and photovoltaics – add up to just another 7%. These sun-driven energy pools are enormous, but unlike fossil and nuclear fuels, which are concentrated, they are distributed, making the energy hard to capture [6].

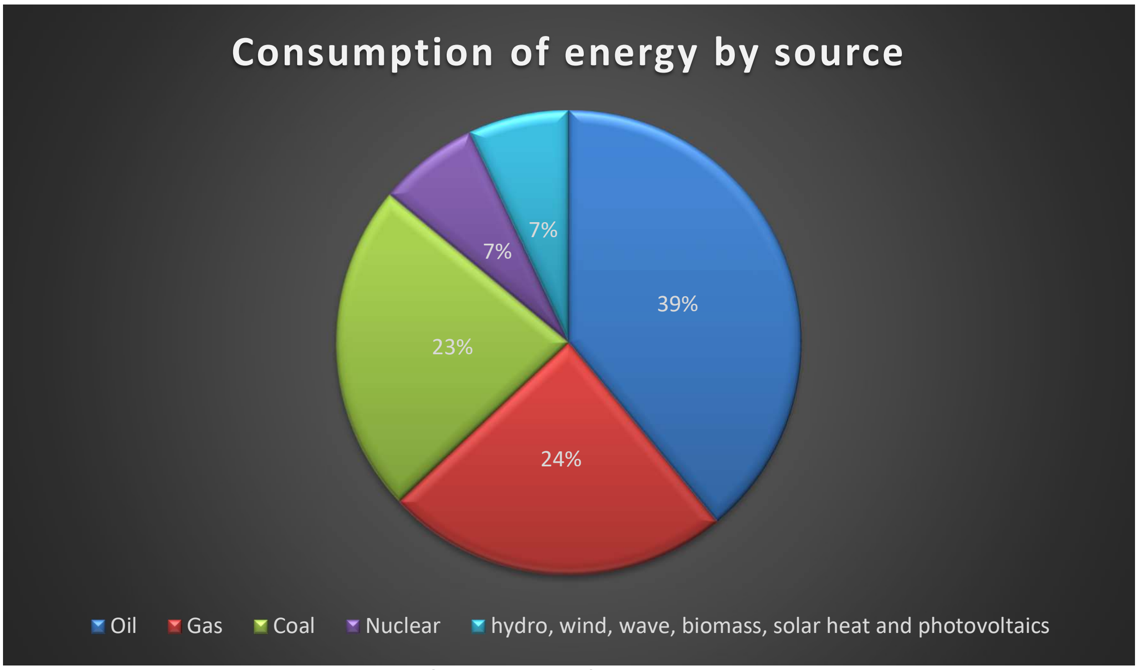


Figure 5- Consumption of energy by source [6]

1.4.6.3. A Circular Materials Economy

With the rise of the industrial revolution and its fruits, such as large-scale mining, global trade, materials costs dropped a lot initially. However, over time this has spurred the creation of an industrial culture that has an increasingly open approach to material resources, where they are turned into products, used and then discarded. In fact, for years, there was, on the part of the industry, the mentality of making products with a short life, precisely to generate a consumption cycle. Basically, there was no incentive to conserve the materials and reuse them, since next month their price would be cheaper. The flow of materials through the economy followed a linear path summarized as: take – make – use – discard [6].

As the years passed, the inevitable began to become evident: the stress on the global eco-sphere starts to become a concern. In the current reality in which the prices of raw materials are no longer something to be trivialized by industries and where ecological concerns become enormous, an incentive has begun to conserve materials instead of rejecting them.

Materials are normally produced and manufactured into products that go into service where they remain during their useful life. However, in the circular model showed at figure 6, end-of-life disposal as landfill or waste is not an option. Instead, the product is reused less demandingly, or refurbished to give it a second life, or dismantled into its component materials for recycling.

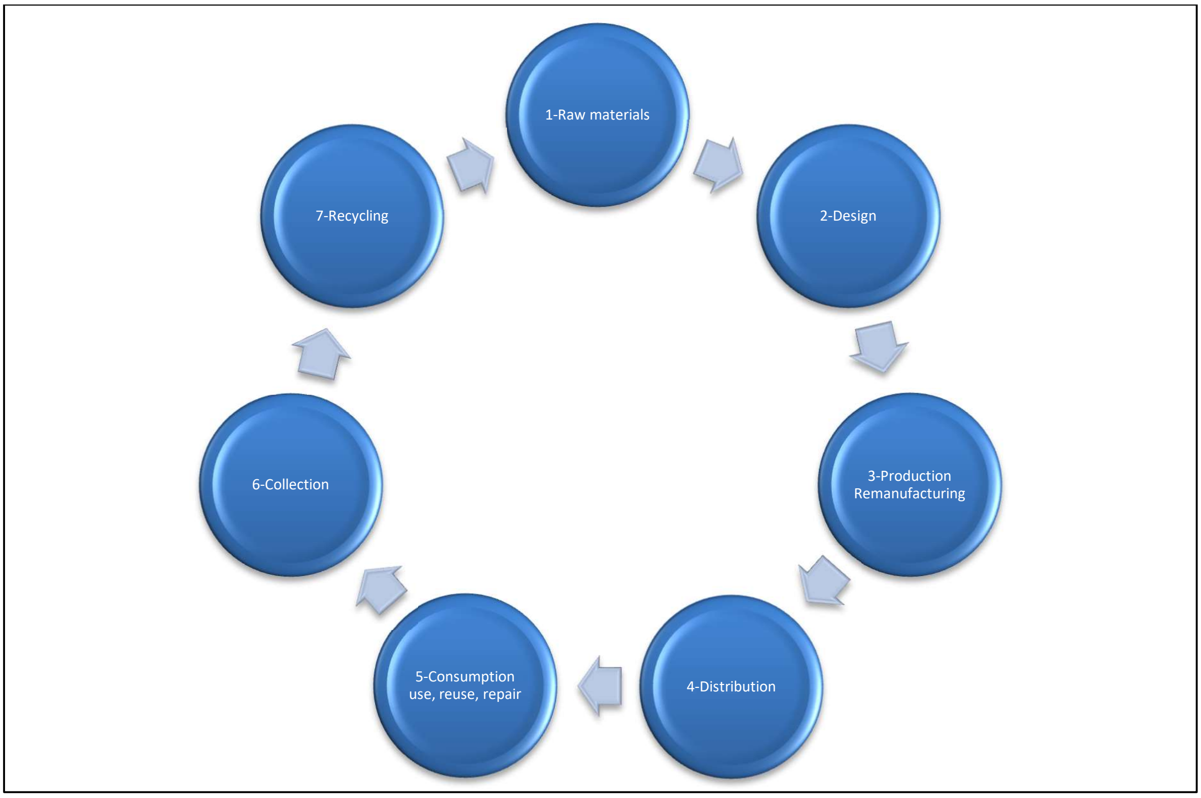


Figure 6- Circular Materials Economy

The circular economy, in addition to the concept of efficient recycling, means considering the use of renewable energies, the use of materials that allow, properly, the manufacture of products and later their reuse with as little reprocessing as possible. For this to work, you need to take a different approach to design in many ways, to retain or regenerate materials during multiple manufacturing cycles and seek to reduce the use of critical materials, resulting in a low-carbon economy with reduced social, economic, and environmental costs.

Figure 7 illustrating the labeled periodic table shows that the share of secondary raw materials in the total demand for materials is over 50% only for a very limited number of raw materials. This shows that even for materials for which overall recycling rates are relatively high, the contribution of recycling to meeting material demand is relatively low.

This is because their recycling is not economically viable, the appropriate technologies available for recycling are insufficiently developed or because these materials are incorporated into products stored in use for long periods of time such as buildings and infrastructure components of countries. In some cases, this can also be explained because demand is growing very fast, for example in the use of low-carbon technologies, batteries or electrical or electronic devices [7].

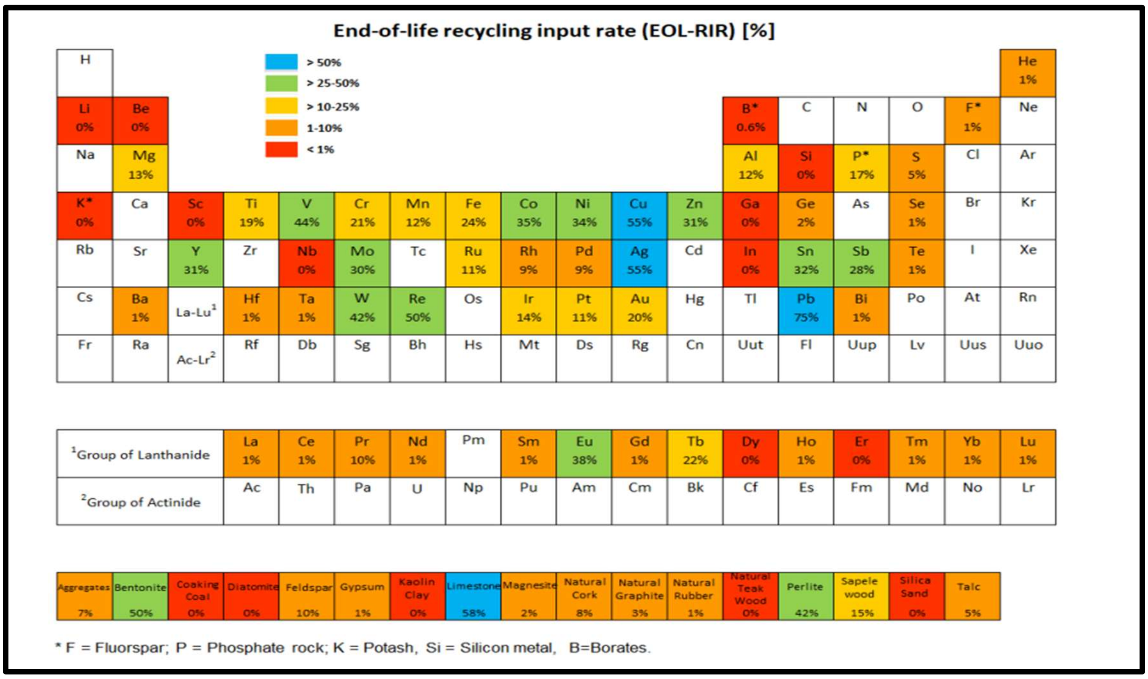


Figure 7- End-of-life recycling input rate [7]

Creating a circular materials economy

One way to think about designing in a circular materials economy is to look for ways to provide more materials services with less materials production. Two strategies and their components are listed in table 2.

Table 2- Strategies for provide more materials services with less materials production

Better stuff: improved material technology	Better design and longer product life
Improved material extraction and yield	Design for longer product life
New and improved materials	Design for reuse, repair and recycling
	Repair and re-manufacture

1.4.6.4. Circular Product Design Strategies

Remembering to include circular economy concerns at an early stage of the product design process is important, because once the product specification is being made, only small changes

are possible – it is difficult to make changes as the features, infrastructures and activities were committed to a particular product project [6].
To illustrate what has been said, we can see in figure 8 the famous graph that shows the cost of changing a project due to its lifetime, logically projects in their initial phase are easier and cheaper to change when compared to projects in more advanced stages.

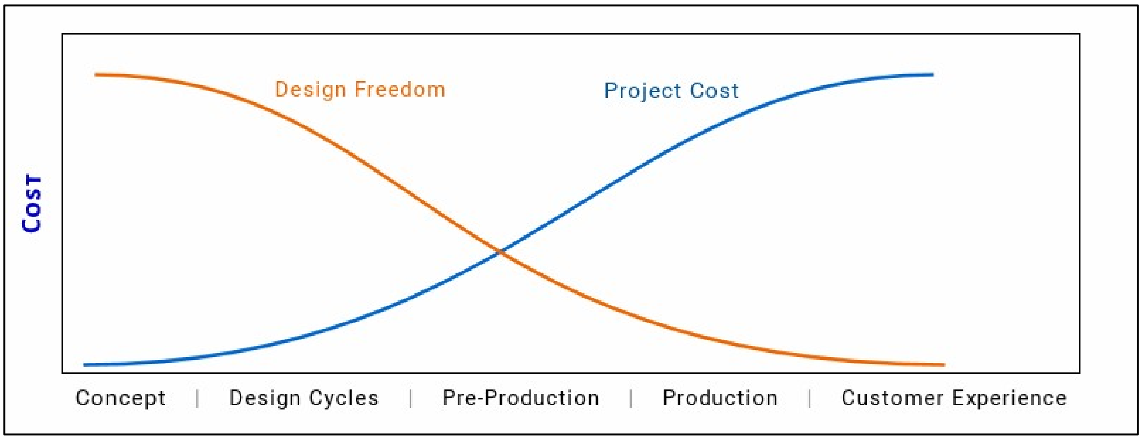


Figure 8- Management of Project Change [20]

The cost of each change increases because we have more time, money and energy invested. When we put a lot of effort into something and then change plans later, it means discarding at least part of what we've done. The effect of activities in the early stages is amplified in later stages. This includes design changes and enhancements. An engineering change request also fits this. This is not to say that an engineering change request is bad, quite the opposite. Changes that improve your product or improve your ability to sell the product, or reduce the cost of production, or improve the customer experience are almost always worth it. However, the ideal is to identify them as early as possible so that the impact on the cost of changes is minimal. Hence, the importance of this prior analysis [20].

1.4.6.5. Designing Long-Life Products

Here is understood the importance of creating products that will be loved, appreciated or trusted for longer, that is, a design for durability.
Material selection for durability is an important part of the design process. A reliable design has a high probability that the product will operate for a specified period without experiencing a chargeable failure when maintained in accordance with the manufacturer's instructions.
Another essential design strategy to decrease resource loops is to implement a design for product life extension. This strategy is concerned with extending the period of use of goods through the introduction of service cycles to prolong the life of the product, including reuse of the product itself, maintenance and repair [6].

1.4.7. Sustainable Development in Mechanical Engineering - Normative References and Social Responsibility Indicators

To be able to carry out good work related to social responsibility, in addition to developing our own and innovative ideas on the subject, it is also necessary to seek to know all the work that has already been developed in the area. This is why it is interesting to visualize the main normative documents and indicators on the theme that are recurrently used to plan, implement, monitor and endorse projects or practices that an organization wants to adopt.

As is done by many institutions that are concerned with the subject, for the various reasons already explained above, such norms and indicators of social responsibility must be used to direct the objectives of projects in the mechanical area to reconcile the social, environmental and economical pillars that are always present in its surroundings.

The main standards that we will treat as an example are:

1.4.7.1. SA 8000 – Social Accountability 8000

SA 8000 is a voluntary standard that helps to verify by audit through the requirements that they offer as parameters to be followed and attended by organizations. Such requirements include preserving workers' rights, being a standard based on international conventions regarding human rights, child labor, forced labor, health and safety, freedom of association, discrimination, disciplinary practices, working hours, remuneration and management. The standard has its guidelines based on international human rights norms and national laws [8].

The SA 8000 standard was first conceived in 1997 by Social Accountability International (SAI). SAI is an association of different types of organizations: trade unions, organizations defending human rights and children's rights, academies, industries [9]. SA 8000 was an important resolution in the corporate world when it comes to the institutionalization of business ethics through accountability standards, being generally the most representative social responsibility standard, since it offers an internationally accepted and respected verification system for the ethical performance and a comprehensive description to create decent working conditions in companies [9].

For a company to become a member of SA 8000, it is necessary to complete a self-assessment module and go through some procedures, such as formulating its own program to implement the social responsibility policy. It must notify its suppliers and employees of its purpose to implement the measures proposed by the SA 8000 program, encourage its suppliers to adopt internationally recognized standards for workplaces, and inform them that it will terminate business relationships with supplier companies that are below recommended standards [10].

When the program begins to be operational, the company must request a pre-assessment of the audit. The SA 8000 certificate, obtained after all audit procedures, will be valid for three years,

with, during this period and every six months, an assessment of adherence to the principles and standards issued by the SA 8000 program [10].
Some social responsibility requirements that are specified in the fourth edition of the standard edited in 2014, replacing the previous versions of 2001, 2004 and 2008 are:

- Child labor
- Forced or Compulsory Labor
- Health and safety
- Freedom of Association & Right to Collective Bargaining
- Discrimination
- Disciplinary Practices
- Work schedule
- Remuneration
- Management system

1.4.7.2. AA 1000 – Institute of Social and Ethical Accountability – ISEA

The Accountability 1000 Framework – AA1000 – is a social accountability standard developed by ISEA – Institute of Social and Ethical Accountability, a professional entity that works in the area of corporate and social responsibility, based in London. It aims to support organizational learning and general, social and ethical, environmental and economic performance and, consequently, contribute towards a path towards the sustainable development of an organization [11].
This standard is a way of encouraging management based on principles of quality and ethics, ensuring reliability and transparency to stakeholders through demonstrations and reports published by the organization. In this way, the AA 1000 defines best practices for accountability to ensure the quality of ethical social accounting, auditing and reporting. It was designed to help companies, shareholders, auditors, consultants and certifying organizations, and can be used alone or in conjunction with other accountability standards, such as the Global Report Initiative (GRI), and standard standards such as those of the International Organization for Standardization (ISO) and Social Accountability - SA 8000 [10].
In a very simple definition, its function is to guarantee the quality of the information presented in the reports, providing mechanisms for evaluating and verifying data, mainly for non-financial information [12]. It's like a socio-environmental accounting. Some of the benefits generated by the AA1000 are:

- alignment of companies' activities to their values
- understanding of how stakeholders perceive the impacts inherent to the business
- better risk management and competitive advantage

Therefore, the contributions of the AA 1000 are the processes and definitions that support the practice of corporate social responsibility. Establishing guidelines for a process of continuous improvement in the ethical and socially responsible management of an organization, based on communication and interrelationships between stakeholders [10].

1.4.7.3. Environmental Management – ISO 14001

ISO 14000 is a series of standards and guidelines formulated in 1996 by ISO, with the purpose of standardizing environmental management programs in industries worldwide [14].

ISO 14001 is the most recognized international standard for environmental management systems. The nature of ISO 14001 allows it to be applied to a full range of sectors, scopes and business activities. It provides a framework through which an organization can deliver environmental performance improvements in line with its environmental policy commitments. ISO 14001 specifies requirements for an organization to proactively identify and understand the environmental aspects of its activities, products and services and the associated environmental impacts [13].

ISO 14001 is designed to be compatible and harmonized with other recognized management systems standards, including ISO 9001. Therefore, it is ideal for integration into existing management systems and processes [13].

The implementation of this standard should be sought by companies that wish to establish or improve an Environmental Management System, be confident about the environmental policies practiced or demonstrate compliance with sustainable practices to customers and external organizations. The ISO 14000 series comprises five aspects:

1. Environmental Management System (EMS)
2. Environmental audit
3. Environmental labeling
4. Environmental performance assessment
5. Life cycle assessment.

Standards are classified into two types: notes and guidance specifications. The ISO 14000 series takes a systematic approach and provides a tool to enable organizations to control the impact of their activities, products and services on the environment, thus contributing to socially responsible practices [15].

1.4.7.4. Occupational Health and Safety – OHSAS 18001

OHSAS 18001 was formulated by international certifying bodies based on international standards related to the topic of occupational health and safety. The standard was first published in 1999, after studies by a group of certification bodies and standards bodies from Ireland, Australia, South Africa, Spain and Malaysia [16].

It defines good practice requirements in occupational health and safety management for organizations of any size, provides guidelines to create a health and safety framework, allowing to bring all relevant controls and processes into one management system [17].

The main benefits of OHSAS 18001 are:

- Creating the best possible working conditions in your organization
- Identifying hazards and defining controls to manage them
- Reduction of accidents and work-related illnesses, reducing costs and downtime
- Employee engagement and motivation with better and safer working conditions
- Demonstration of compliance for customers and suppliers

Companies must develop the following criteria in order to meet this certification [16]:

- Establish an occupational Health and Safety management system in order to reduce risks for employees and other interested parties;
- Implement, maintain and continually improve an occupational Health and Safety management system;
- Ensure the organization's compliance with its defined Occupational Health and Safety policy;
- Demonstrate compliance to third parties;
- Seek certification and/or registration of your Occupational Health and Safety management system by an external organization;
- Make a self-determination and declaration of compliance with the specifications of the standard;

Such measures help, as previously mentioned, to minimize costs, due to the low worker absenteeism, decrease in the risk of accidents, increase in worker satisfaction and health, obtain better operational results, decrease the number of occupational diseases and improve the image. of the company towards society and employees [18].

1.4.7.5. Guidelines on Social Responsibility – ISO 26000

In November 2010, the International Standard ISO 26000 – Guidelines on Social responsibility was published, which was launched in Geneva, Switzerland. According to ISO 26000, social responsibility is expressed by the desire and purpose of organizations to incorporate socio-environmental considerations into their decision-making processes and to take responsibility for the impacts of their decisions and activities on society and the environment. This implies ethical and transparent behavior that contributes to sustainable development, that is in compliance with applicable laws and is consistent with international norms of behavior. It also implies that social responsibility is integrated throughout the organization, is practiced in its relationships and takes into account the interests of stakeholders [19].

The standard provides guidance for all types of organization, regardless of size or location, on:

- concepts, terms and definitions referring to social responsibility;
- history, trends and characteristics of social responsibility;
- principles and practices relating to social responsibility;
- the central themes and issues related to social responsibility;
- integration, implementation and promotion of socially responsible behavior throughout the organization and through its policies and practices within its sphere of influence;
- stakeholder identification and engagement;
- communication of commitments, performance and other information regarding social responsibility;

It is a guideline standard, without the purpose of certification, that allows a better understanding of social responsibility as it describes the historical and contemporary contexts related to the theme and the important factors and conditions that affect its nature and practice. It is interesting to mention some of the principles and central themes that are addressed in the second standard [19].

Principles:

Accountability: self-responsibility for actions and decisions, responding for their impacts on society, the economy and the environment, rendering accounts to governance bodies and other interested parties, declaring their mistakes and the appropriate measures to remedy them.

Transparency: Providing interested parties with all information about the facts that may affect them in an accessible, clear, understandable and timely manner.

Ethical behavior: Acting in a manner accepted as correct by society - based on the values of honesty, equity and integrity, towards people and nature - and in a manner consistent with international norms of behavior.

Respect for the interests of interested parties (Stakeholders): Listening to, considering and responding to the interests of people or groups who have an interest in the organization's activities or may be affected by it.

Respect for the Rule of Law: The minimum starting point for social responsibility is to fully comply with the laws of the place where you are operating.

Respect for International Standards of Behavior: Adopt provisions of international treaties and agreements favorable to social responsibility, even if there is no legal obligation.

Right to humans: Recognize the importance and universality of human rights, taking care that the organization's activities do not harm them directly or indirectly, ensuring the economic, social and natural environment they require.

Central themes:

1. Organizational governance;
2. Human rights;
3. Labor practices;
4. Environment;
5. Fair operating practices;
6. Consumer issues;
7. Community involvement and development;

Chapter 2- Practical Implementation of Social Responsibility in Mechanical Construction Projects

After introducing the importance of social responsibility in today's industrial world, we must observe how we can implement solutions in practice when developing projects in the area of mechanical engineering. For this, inspired by [6], we propose an analysis of the problem by layers or by parts. The first step is based on defining the problem:

1. **Problem definition**: Any articulation of sustainability has an underlying motive/prime objective.
2. **Identify stakeholders and their concerns**: Stakeholders are individuals, groups or organizations that are in any way affected by the articulation.
3. **Fact finding**: In order to understand the problem in a way we look for facts and the facts need to be researched.
4. **Reflection and conclusion**

2.1. Problem Definition

In this first step, it is necessary to define a problem of a product that already exists on the market or a product to be developed introduced in the scope of social responsibility and from that we must introduce our primary objectives. For example, to reduce the carbon footprint, increase industrial safety or user safety, among other problems that the project may introduce in the world. Then, we should look at whether solving the problem versus the difficulty of solving it will make any difference to the impact of the problem as a whole. This analysis becomes clearer when we look at the example in [6]: "The legislation requiring supermarkets to provide only bio-degradable plastic bags will make a difference only if plastic bags from supermarkets constitute a significant fraction of all plastic bags. Similarly, an articulation has a timescale. Insisting on bio-degradable bags within 12 months assumes that the supply chain for the bio-degradable film used to make them can cope with the resulting demand within that time. It is not possible to judge the viability of the articulation without knowing how large it will be and how soon it should happen".
Every sustainable technology project has a **motive**, a **scale**, and an allotted **time** for implementation (which is often defined by the government's strategic plan or economic goals). Mass construction of solar panels, for example, to provide electrical energy (**motive**) on a large

scale will make a significant contribution only if it provides a significant part of national or global energy (**scale**). However, this will require large amounts of materials and space. The large amount of materials for building solar panels, the land for implementation and associated costs to achieve an energy production target can, depending on the approach taken, be socially unacceptable because the investment cost is very large in a short period of time (**time**). Anticipating the consequences of the scale and timing of an articulation on material, economic and social resources is an important task in analyzing its feasibility as a sustainable development.

2.2. Identify Stakeholders and their Concerns

Stakeholders are individuals, groups or organizations that are somehow affected by the project. The creators of the project and the shareholders/owners in question want to see it succeed. Others may have reservations or express direct opposition, so it is important to identify stakeholders and their concerns.

An interesting method to check possible problems and important points can be visualized by a checklist by topics and questions. According to [6], stakeholder analysis means identifying them as well as their concerns, their influence and the ways in which they interact. The three main questions to ask are:

- Who are they?
- What do they want?
- How will they try to get it?

Examples of possible stakeholders can be seen in table 3:

Table 3- Possible stakeholders [6]

Local or National Government	**Suppliers**	**Customers (existing and potential)**
Owners	**The public or local community**	**Lobbyists and interest-groups**
Employees	**Trade unions**	**Investors, shareholders**
Health and planning authorities	**The press, television, social media**	**Managers, colleagues or team**
Alliance partners	**Business partners**	**The scientific community**

2.3. Fact Finding

First, we must define which types of facts are obviously important to be observed in the articulation of the project in question, such as:

- Facts that establish what materials and energy are needed. What environmental impact will it have, if it is legal, if there are regulations that must be followed (such as those already noted in the previous topics), the cost.
- Facts that report stakeholder concerns. What information is needed to confirm or disprove them?
- Essential infrastructure facts. In other words, the products or services will have to be available to support the joint if it goes ahead.

An interesting way of finding these facts can be introduced with a segmented analysis, as can be seen in the figure 9 based on the literary source [6].

Figure 9- Fact finding to be observed in the articulation of the project [6]

This segmentation is based on the premise of conducting a survey based on 6 groups of relevant information. These groups are listed in the table 4.

Table 4- Relevant information that we must have for the project formulation

Materials	What is the bill of materials for a unit of the proposed articulation?
	Is the material supply-chain secure?
	Are any of the materials listed as “critical”? If so, why?
	Given the scale of the articulation, will the demand for critical materials stress the supply chain?
	Where are the materials sourced? What is the human-rights record of the country of origin?
	How much transport is involved in material sourcing and manufacture?
	Are materials used efficiently?
Environment	What does an eco-audit or life cycle assessment of the articulation reveal?
	What is its carbon footprint? Is it less than current practice?
	Does the articulation provide its function with less dissipation of material resources than current practice?
	Can the materials of the product be recycled? Does a recycling infrastructure exist?
	Do the materials, manufacture, use or disposal of the articulation pose any threat to the bio-sphere?
Society	Will the articulation, if implemented, create jobs?
	If it creates wealth, will it be shared equitably?
	Are plans in place to invest some of this wealth in the local community?
	Are aspects of manufacture, use or disposal of the product inequitable or exploitative?
	Does it contribute to human well-being, national and personal self-esteem and pride
	Does it increase self-sufficiency and resilience?
	Does it clash with cultural or societal norms?
	Is the design inclusive, or does it exclude some members of society?
Economics	What is the cost-benefit balance of the articulation?
	What is the pay-back time?
	What other projects are deprived of resources in order to fund the articulation?
	What subsidies or credits exist to support articulations seen as sustainable?
Legislation	What legislation or regulatory measures are relevant to the implementation of the articulation?

	What legislation or regulation bears on the production, use and disposal of the materials of the articulation?
	What restrictions do these impose on the sourcing or disposal of the materials required for the articulation?
	Does the articulation comply with any existing or anticipated legislation?
	What legislation, not yet enacted, is anticipated?
Energy	Does the articulation use energy over its life?
	What is the duty cycle?
	What is the source of power?
	Is energy storage involved? How is the energy stored?
	Have energy-efficiency, life-expectancy and maintenance been considered?

2.4. Reflection and Conclusion

The last step is the reflection on the process and the discussion of possible alternatives. An adequate way of carrying out this reflection is by carrying out a methodological questioning confronting objectives, expectations, and results.

Has the main objective been achieved? It was achieved in a scale that makes a significant difference? Can the analysis suggest a new and more productive way to achieve the main objective? What are the problems, unintended consequences, or obstacles? Is the implementation sustainable to be done in the short term? And in the long run? Is it possible to make community and industrial sacrifices for the positive results planned in the long term? Are there other ways to achieve the desired goal? Would they require existing or radically new technology or infrastructure? Could changing human behavior make the goal no longer necessary or desirable?

Chapter 3- Example of a Practical Approach to Social Responsibility in Mechanical Engineering

To contextualize the use of the social responsibility approach in mechanical engineering, it was decided to develop a project that would have a broad and social utility, taking into account the needs of society and the stages of project production that will be analyzed with the stages already contextualized previously.

For this, it was thought to demonstrate the steps for planning a structure for the transfer of the wheelchair and its user, the wheelchair user, to a car. The project was designed in such a way as to achieve an adaptable structure considering its assembly into the car to make the product cheaper and to be able to use it for different wheelchair users, without the need of an exorbitant financial investment. It is important to bear in mind that this type of equipment seeks to provide complete availability so that the user can achieve his goals, autonomously, without the need for help or assistance from another person.

For the complete analysis, we will go through the steps described above.

3.1. Some literature review for the wheelchair problem

A bibliographic review was carried out to obtain information on the state of the art of existing equipment not only structurally similar, but also with objectives in common with the work presented. The patents found are listed in the table 5:

Table 5- Bibliographic review of patents related to the wheelchair theme

Number	Code	Name
1	US 2004/0256827 A1	Vehicle conversion assembly and method of converting a vehicle
2	US 9603759 B2	Vehicle wheelchair lift
3	BR 102013023589-0 A2	Cadeira de rodas com adaptação automotiva
4	PI 9605326-7 A2	SISTEMA PARA BAIXAR, LEVANTAR E GUARDAR

		CADEIRAS DE RODAS NO TETO DE AUTOMÓVEIS
5	US 20200022852	Carrier assembly for a wheeled mobility device
6	US 2006/0027619 A1	DRIVER ACCESSIBLE WHEELCHAIR CARRIER
7	CN106236422B	A kind of standing rehabilitation wheelchair car
8	US4376611A	Car top carrier for wheelchair
9	US 6729829 B2	WHEELCHAIR VEHICLE ACCESS SYSTEM
10	KR200153955Y1	Motor vehicle structure adapted for disabled person using a wheelchair

Patents No. 1 [23], No. 2 [24], No. 9 [25] and No. 10 [26] are patents that, despite being very interesting, fall into the sense of projects that seek solutions from complex and radical changes in the structure of the car. Despite being useful and interesting solutions, they demand great cost and application difficulty, limiting the target audience. In the case of patents No. 4 [27], No. 5 [28], No. 6 [29] and No. 8 [30] we can find more minimalist and simple ways of transporting the wheelchair, even closer to the proposed project in question. Just as the patents mentioned above find effectiveness to fulfill the main objective, although each patent has its particularity, in general, all of them present a simpler and more accessible project to be applied.

Finally, with regard to patents No. 3 [31] and 7 [32] we have alternatives to facilitate the adaptation of the wheelchair user, patent No. 3, in turn, presents a more simplistic arrangement in which an adaptation is made by transforming the wheelchair itself into the driver's seat, to carry out the transport of the user. Already patent No. 7 seeks a slightly more far-fetched way to bring a wheelchair user from one place to another. Despite being a more complex alternative, it has the possibility of not only being used to transfer the wheelchair user to the car, but also for other places, such as transferring the wheelchair user to bed, using the bathroom, etc.

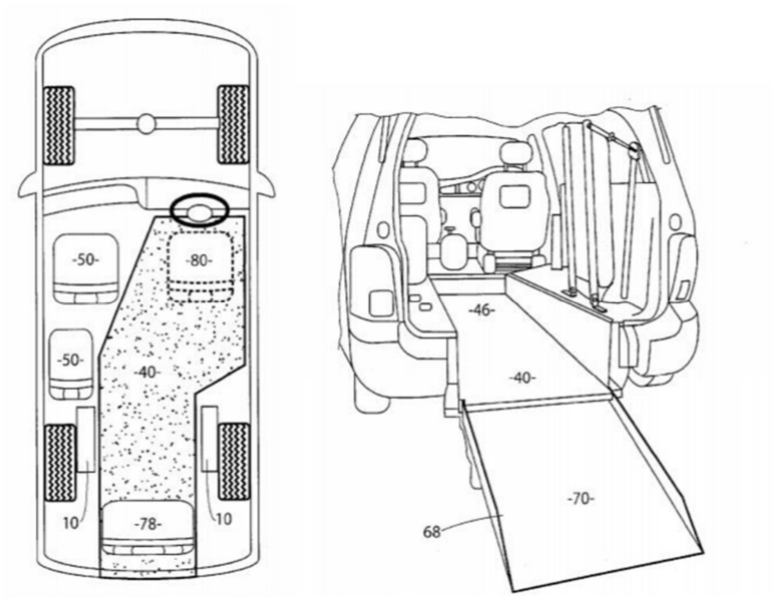


Figure 10- Patent Nº. 1 - AU 2004200859 B9. “Vehicle conversion assembly and method of converting a vehicle”

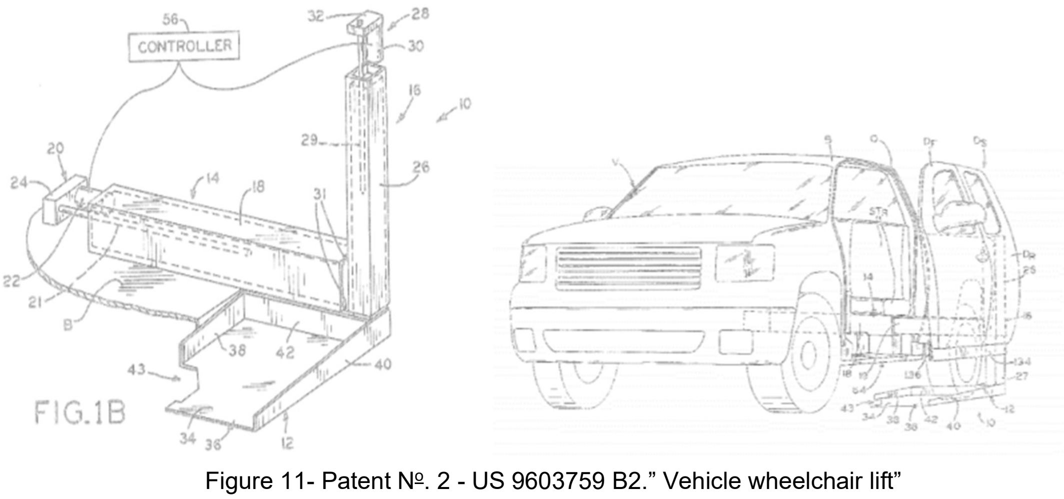


Figure 11- Patent Nº. 2 - US 9603759 B2.” Vehicle wheelchair lift”

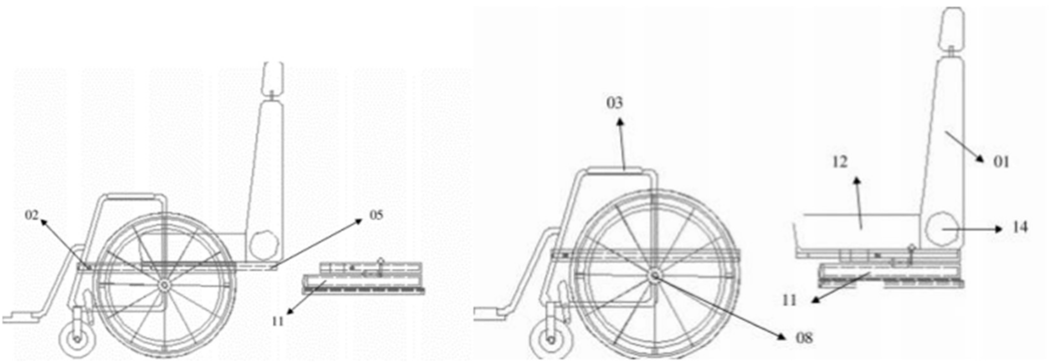


Figure 12- Patent Nº. 3 - BR 102013023589-0 A2. “Cadeira de rodas com adaptação automotiva”.

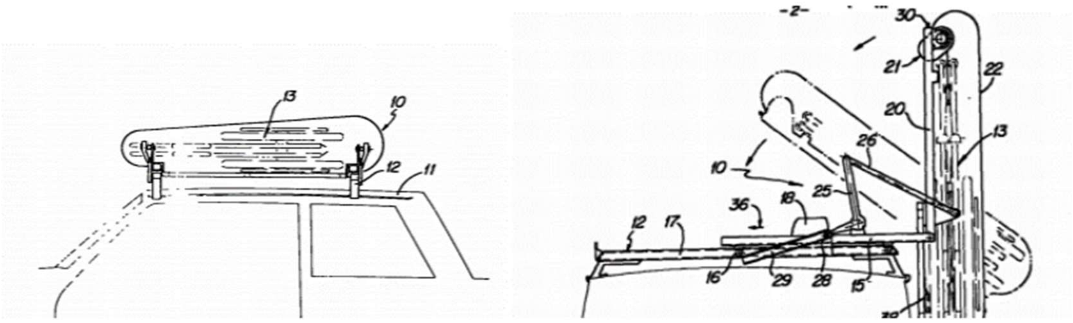


Figure 13- Patent Nº. 4 - PI 9605326-7 A. “Sistema para baixar, levantar e guardar cadeiras de rodas no teto de automóveis”

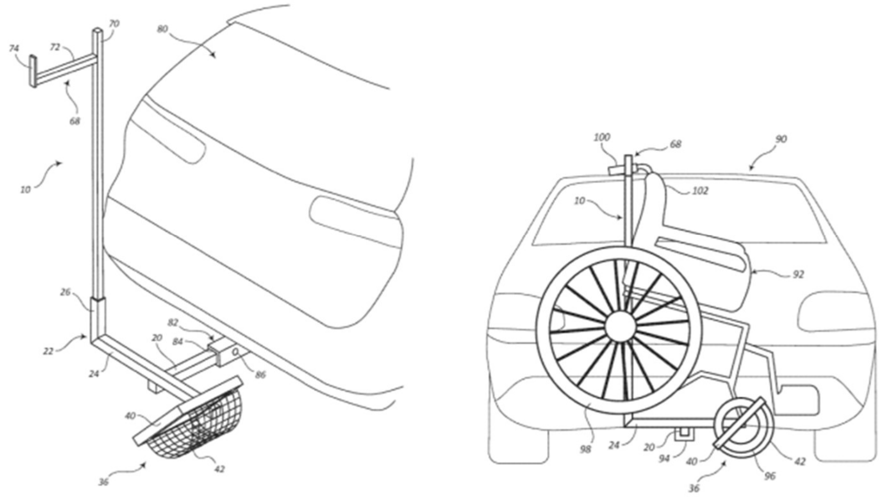


Figure 14- Patent Nº. 5 - US 20200022852. “Carrier assembly for a wheeled mobility device”

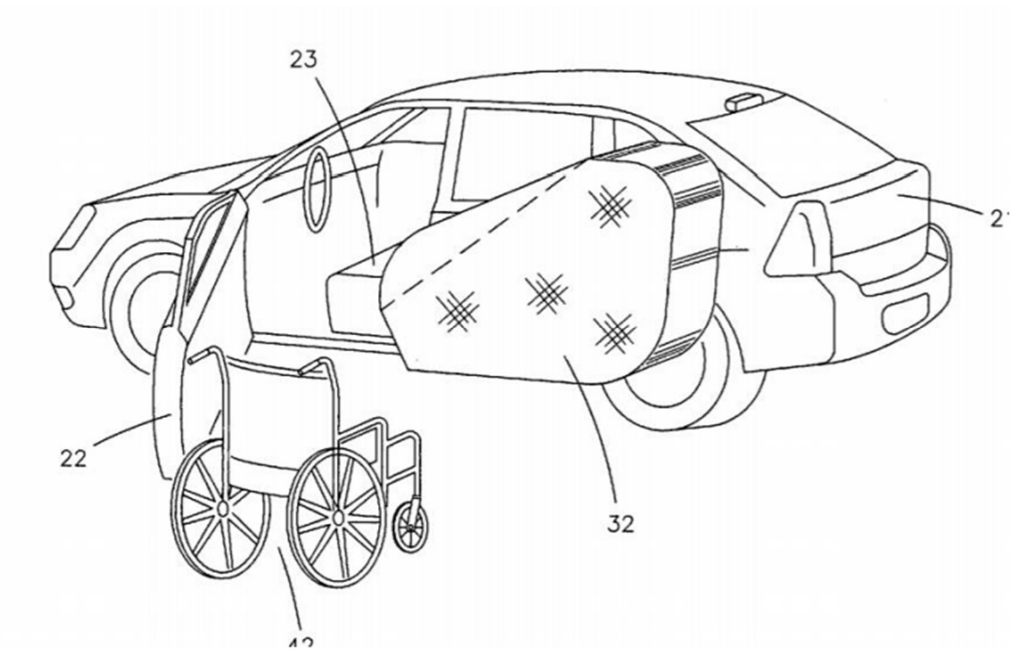


Figure 15- Patent Nº. 6 - US 2006/0027619 A1. “Driver accessible wheelchair carrier”

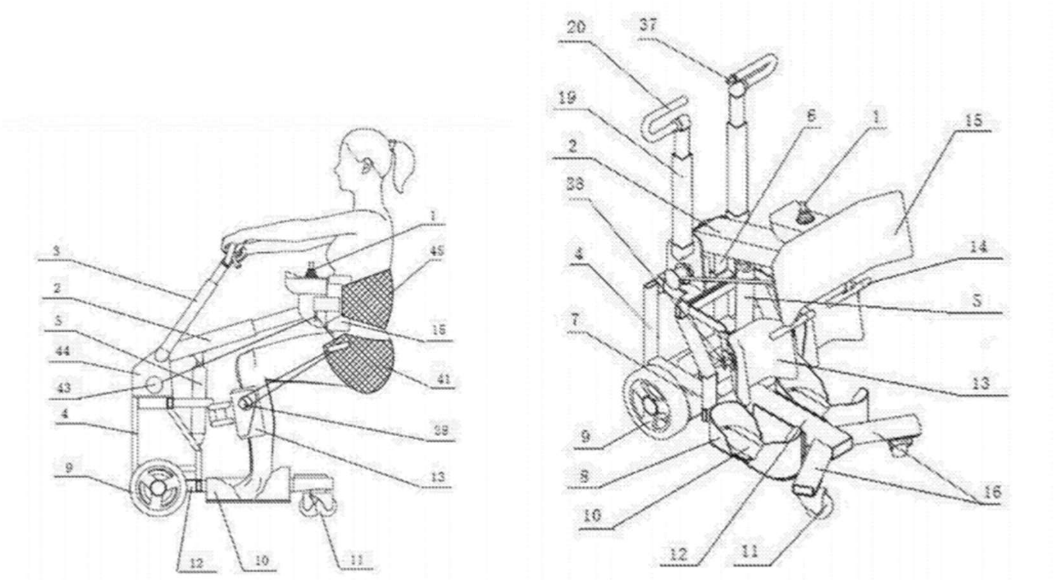


Figure 16- Patent №.7 -CN106236422B. “A kind of standing rehabilitation wheelchair car”

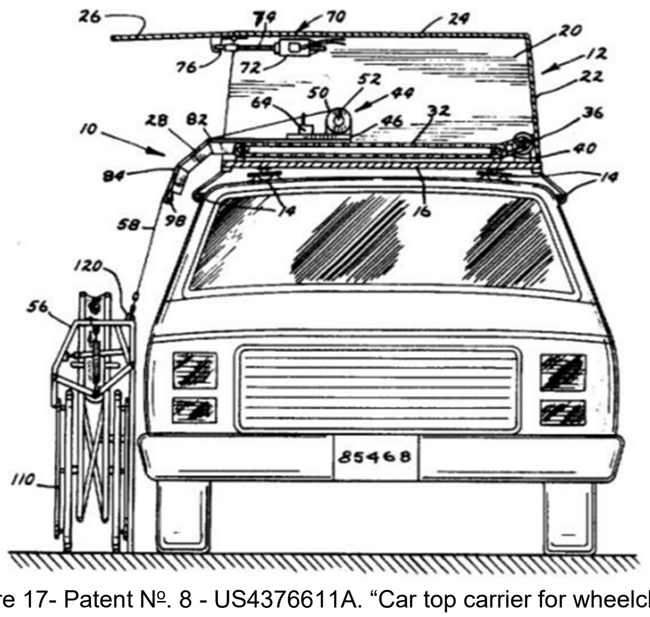


Figure 17- Patent №. 8 - US4376611A. “Car top carrier for wheelchair”

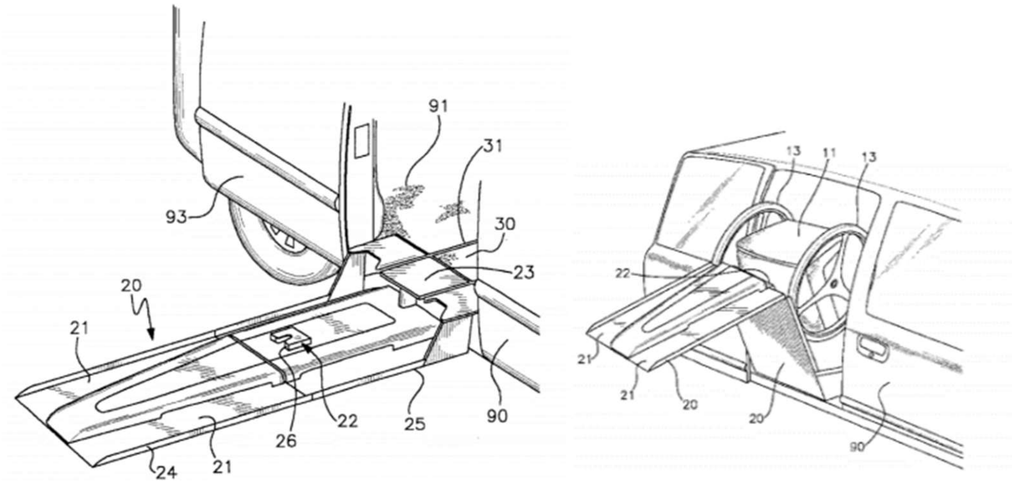


Figure 18- Patent Nº 9 - US 6729829 b2. “Wheelchair vehicle access system”

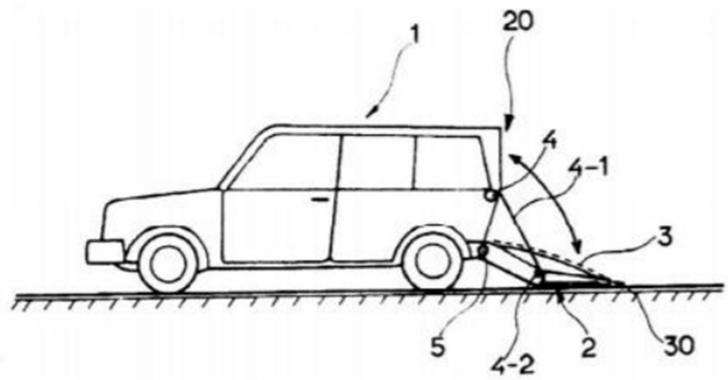


Figure 19- Patent Nº. 10- KR200153955Y1. “Motor vehicle structure adapted for disabled person using a wheelchair”

In general, after analyzing the patents, it can be concluded that despite many interesting alternatives, none of them has the characteristics to fulfill the central objectives of this project: to bring accessibility to a large target audience, with different socioeconomic parameters, implying the value of cost, ease of obtaining parts, assembly and ensuring the complete autonomous accessibility of the individual and it is in these details that the differentials of the project in question are found.

3.2. Project Data

First, it is necessary to think about how to move the wheelchair in the car, that is, the accommodation of the wheelchair. For it to be adaptable to different types of cars, it seeks to use a property that they all have in common: a sturdy chassis that is usually made of a sheet steel monocoque. The entire project of attaching the wheelchair to the roof of the car is based on the principle that such a structure must be housed in a place that supports the weight and that can allow changes according to current traffic regulations, respecting dimensions, among other rules.

As for the structure responsible for the locomotion of the wheelchair user to the car seat, it is necessary to do something that brings safety and comfort to the user and that, mainly, allows him to operate the equipment alone. There are two systems responsible for effecting movement: the motor to lift the wheelchair up from the ceiling through a steel cable and later, with the release of this motor, a spring serves as an actuator that, together with gravity, allows ejecting the wheelchair support down. The other is a hydraulic system with double-acting actuators responsible for moving the seat with a linear movement, projecting it out of the car and later retracting it.

To better visualize the concept of the project, some hand-drawn sketches, figure 20 and figure 21, were developed that allow us to understand how the driver's chair would be ejected and how the wheelchair would be lifted in figure 22.

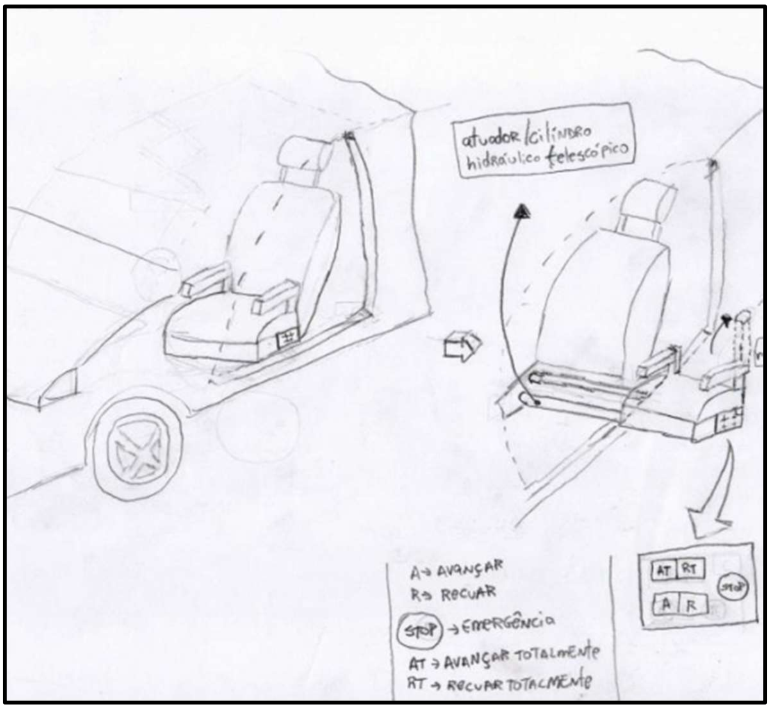


Figure 20- Hand-drawn sketch: driver's chair ejection

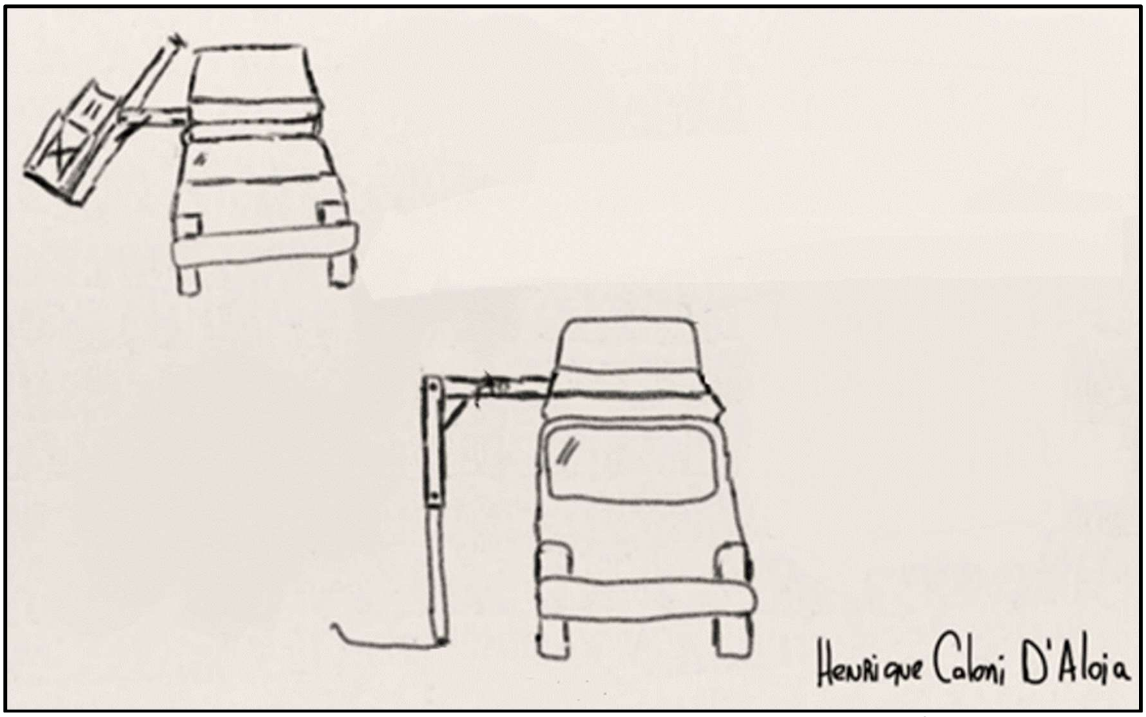


Figure 21- Rand-drawn sketch illustrating how the wheelchair will be lifted

From the sketches developed so far, it is known that we must build a system to collect the wheelchair user so that he/she can do this activity alone, that the structure is low cost and low weight. Even if we are using the car's chassis, we do not like to use equipment with a very high weight, it would affect other car functions such as higher fuel consumption and equipment installation. To this purpose, a system was made as minimalist as possible, also meeting the need to cheapen the project so that it can be supplied to a wide range of the public in need. Another important point is to verify the possibility of implementing the project in different styles of cars of different sizes, since they all have rigid chassis structures that can be used. Regarding the actuation system of the car seat, it was decided to make a hydraulic system of actuation after the sketch instead of the pneumatic system, not only because of the forces required, but also to take advantage of the tools of possible application in the car's own system, since it already has other types of system through hydraulic actuation, such as the braking system itself. The actuation system needs to rely on the electromechanical movement command system and needs an emergency button that deactivates the force of the actuators. Such a scheme is represented in the hydraulic system figure 23 next to the sketch figure 24 and figure 25.

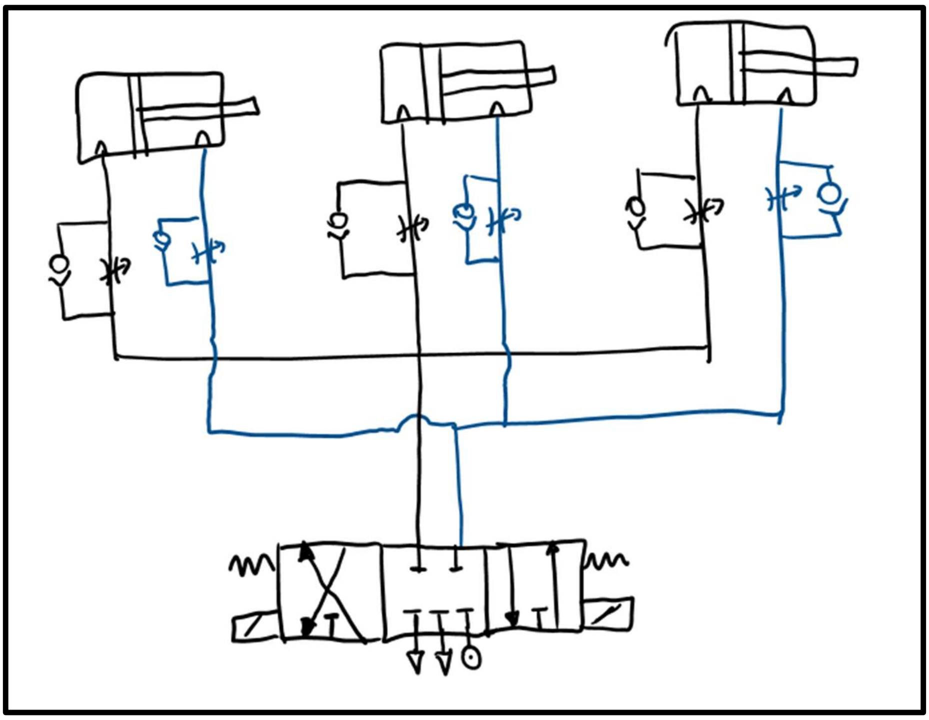


Figure 22- Representation of the hydraulic system

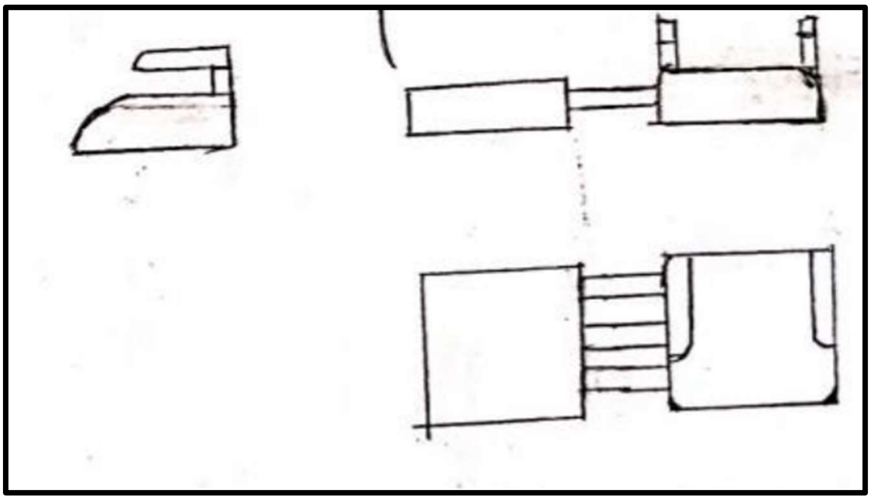


Figure 23- Technical drawing sketch 1

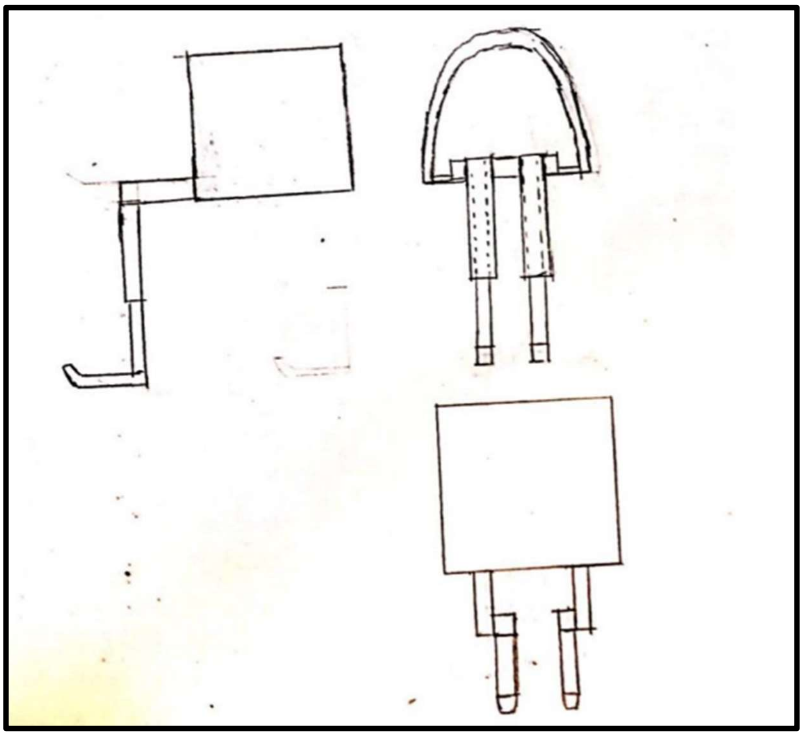


Figure 24- Technical drawing sketch 2

3.3. Real Problem Definition

According to the Wheelchair foundation, [22] it was estimated that in 03/2016 in a population of 7,091,500,000 people:

- In the 34 developed countries it is estimated that 1% or 10,000,000 people require a wheelchair.
- In the 156 developing countries it is estimated that at least 2% or 121,800,000 people require a wheelchair
- Overall, of the 7,091,500,000 people in the world, approximately 131,800,000 or 1.85% require a wheelchair

However, despite these people being able to get a reasonable locomotion to move in adapted places and in short distances with their wheelchairs, most users find it very difficult to use private means of transport such as cars for several reasons, to which they highlight up:

1. The high price to get a car adapted to their special needs
2. The difficulty of using the adapted car autonomously, always requiring the help or support of a third person to store the wheelchair or to help the wheelchair user get into the car. Many need to pay a caregiver or have a family member or friend always willing to help them for their needs and, therefore, many give up their freedom due to such difficulties.

Therefore, it is understood that there is a need to develop a project that improves the conditions due to the demand that these people with special needs have. Therefore, the objective of the project is to make a set of structures that allow the adaptability of a wheelchair user and his wheelchair in a car. We need mobility to be done autonomously by the wheelchair user, without the need for help from other people. In addition, we seek to obtain equipment that is easy to apply, cheap and easy to use, thus being able to take advantage of the usual structures of cars found on the market, without the need for the restricted use of trailers or large cars. In order to understand which aspects we need to improve and features that we should develop, a bibliographic review of the state of the art on the subject is necessary.
In the figure 10 below, we can see a flowchart of some important aspects to be considered during the project to identify problems and seek to present solutions effectively.

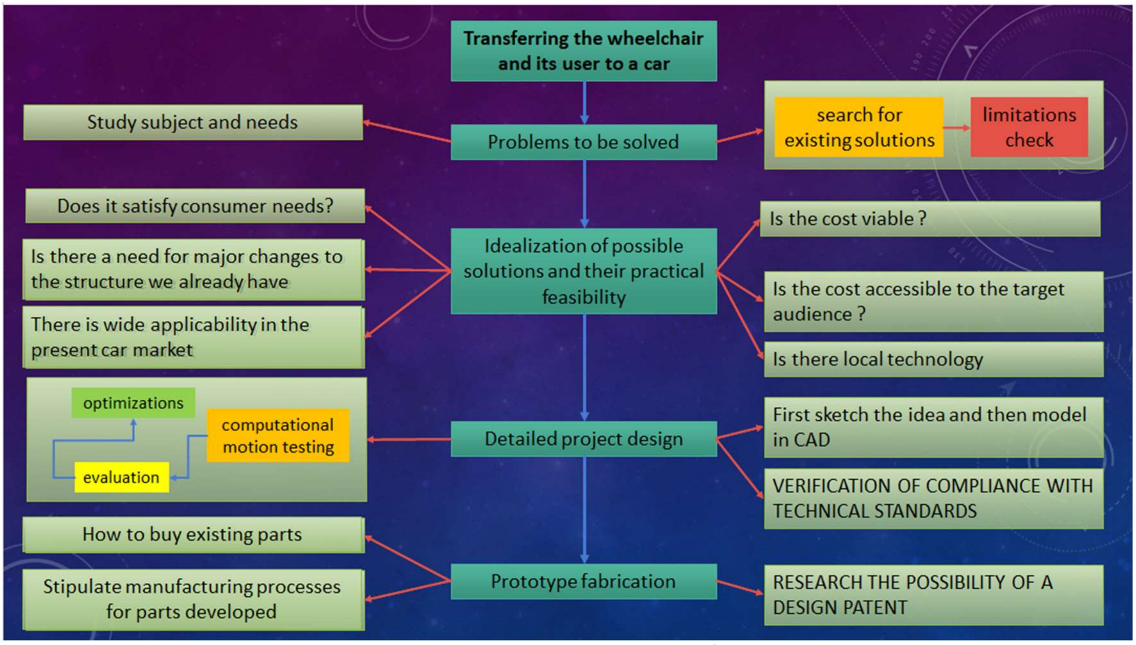


Figure 25- Wheelchair chair project flowchart

3.4. Possible Stakeholders in the Wheelchair Problem

Currently, as we could see when evaluating the patents already developed with a similar objective to the project in question, we realize that there are several projects involving companies with designers, car assemblers and several other employees involved in the assembly of the equipment, in the production and manufacture of the parts. Furthermore, it is evident that the main stakeholders in the product would be those directly benefited by it, that is, the wheelchair user. As we could see, there are about 132,000,000 people who need to get around with a wheelchair, a population much larger than that of several countries. However, not all of this population can afford to pay for an extremely expensive project, projects that involve the complete modification of a car, and an inclusive product would have greater viability. We know, at the same time, that in many countries there are policies that oblige the government to make such products available or make them viable, reducing fees and taxes, to make the cost more accessible. Despite this, governments need and must wisely manage their economic expenses and a product that meets the population's needs with a lower cost and impact is undoubtedly interesting.

In addition to the social and economic aspects, we must not forget the environmental aspect of the project. The project seeks to reconcile necessary mechanical properties with the materials and implementations that seek to reduce the carbon footprint and environmental impacts due to the end of life, recycling feasibility. At table 6 it's possible to see some of the possible stakeholders in our specific project.

Table 6- Possible stakeholders in the wheelchair problem [6]

Local or National Government	Material suppliers	Customers (existing and potential)
The public or local community	**Lobbyists and interest-groups**	**Employees**
Investors, shareholders	**Health and planning authorities**	**The scientific community**

3.5. Wheelchair Project: General Description

From the sketches developed so far, it is known that the idea of the apparatus is to allow the wheelchair user to have free mobility to get in and out of the car by himself. We know too that the structure must have a low cost and low weight. Even if we are using the car's chassis, it is not feasible to use equipment with a very high weight, this would affect other functions of the car such as higher fuel consumption and equipment installation. By that, a minimalist system was made, also meeting the need to cheapen the project, so that, it can be supplied to a wide range of the public in need. Another important point is to verify the possibility of implementing the project in different types of cars with different sizes, since they all have rigid chassis structures that can be used.

Regarding the actuation system of the car seat, it was decided to make a hydraulic actuation system alternatively to the pneumatic system, not only because of the forces required, but also to take advantage of the tools of possible application in the car system itself since it already has other types of systems through hydraulic actuation, such as the braking system itself. The actuation system needs to rely on the electromechanical movement command system and needs an emergency button that deactivates the force of the actuators. Such a scheme is represented in the hydraulic system next to the sketch, in figure 23.

Initial concept

All the development of the work, with all the sketches, research, helped to form the project concept. All stages considered what was desired as a final product, what were the expectations of its usefulness, what role it had to fulfill, adapted to different contexts, among other needs.
The concept was first carried out by hand (figure 26) showing some ideas that were maintained throughout the project such as the linear actuation system of the chair together with its security system, the coupling of the wheelchair catcher on top of the car along with its set of arms.

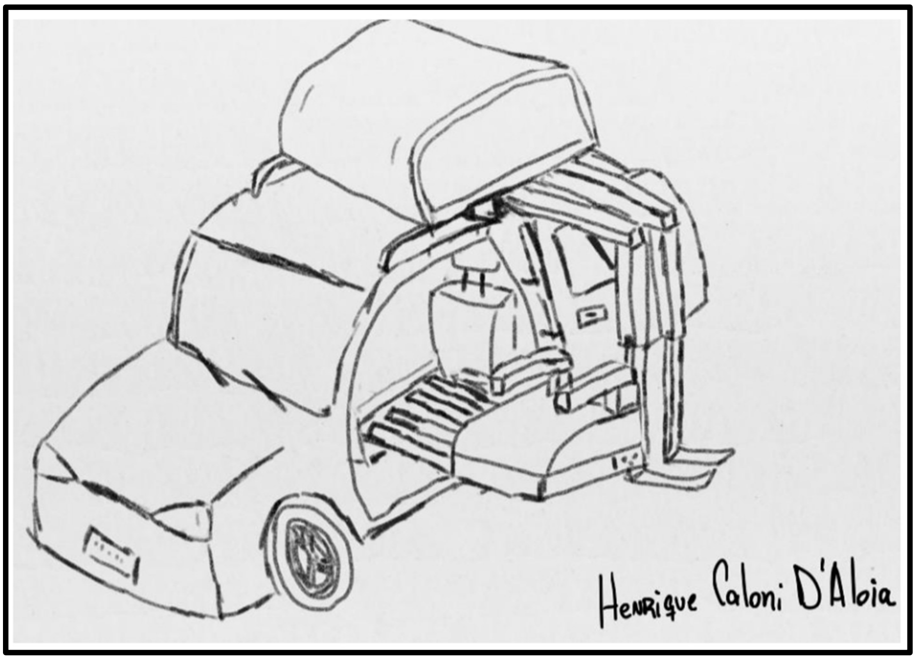


Figure 26- Complete structure sketch

Then, a 3D CAD concept was carried out in the “SOLIDWORKS” software, which considered the following aspects: the motor, an arm system to couple the wheelchair, the place where the wheelchair should be housed, the system of actuation of the driver's chair to transport him. It is interesting to note that at this stage there is the digitized evolution of the concept, however, as will be seen in the next phases – it was not completely adopted, requiring the adaptation of some details that made the project unfeasible. By that, we can verify the importance of this step in the formulation of the final concept, as it allows us to visualize in a practical way the changes that need to be made and, mainly, it allows us to work with a system that facilitates adaptation according to the needs of the designer.

Figure 27- Digital sketch of the wheelchair transport system and safety panel

Figure 27 shows the initial concept of the seat and the actuator control panel.

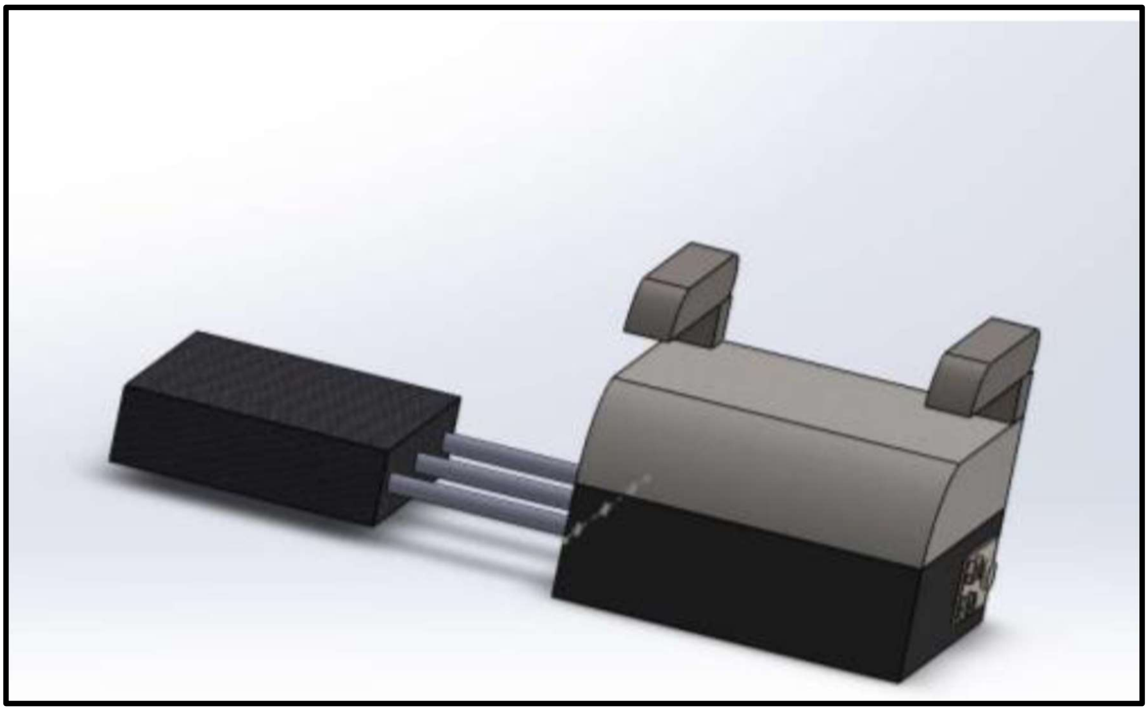


Figure 28 - Digital sketch of the wheelchair transport system: view with actuators

Figure 28 allows us to see the initial concept of the seat with the actuators together.

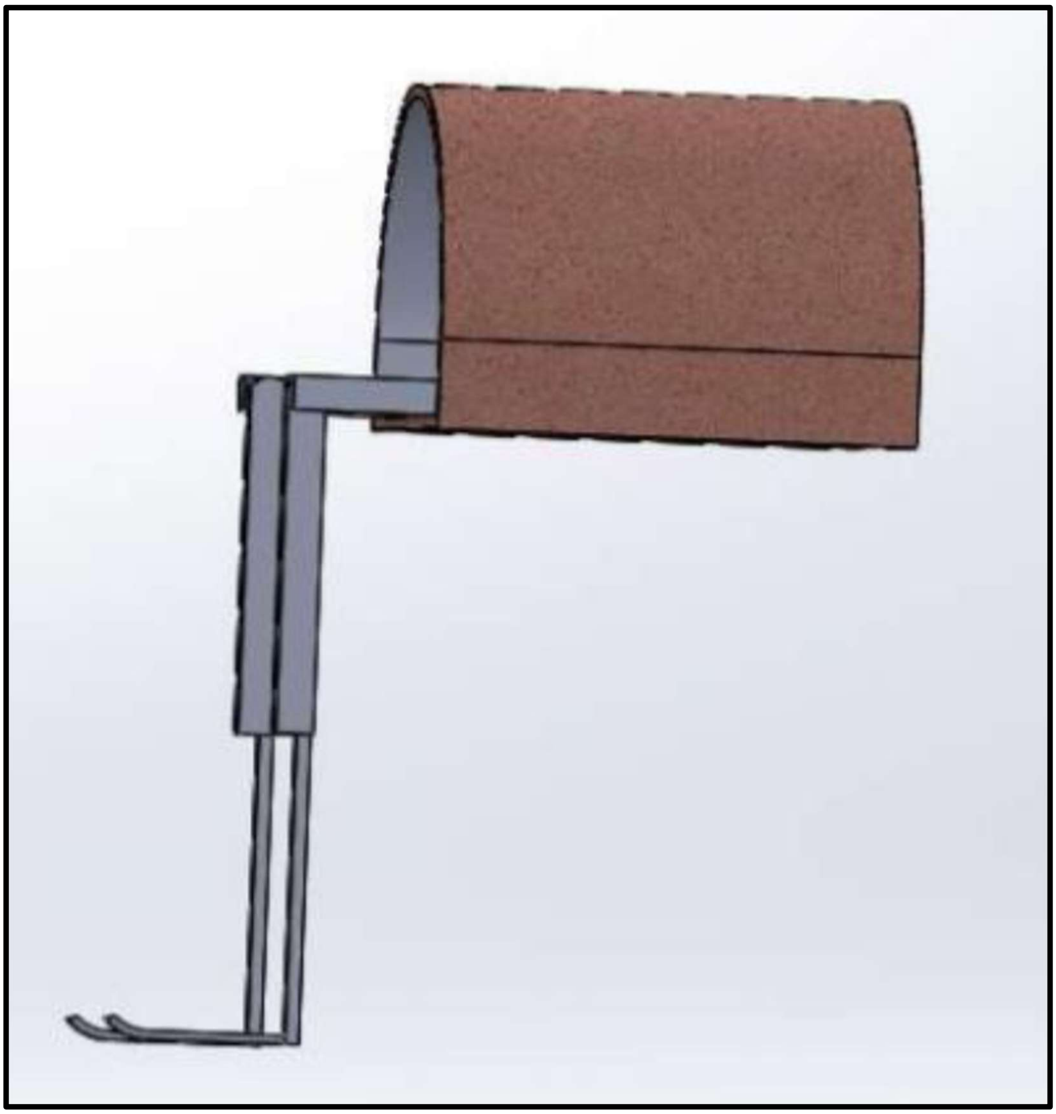


Figure 29- System for housing the wheelchair seen from the side isometric

Figure 29 and figure 30 represent the system for housing the wheelchair that is placed over the car. As told before the figures 27, 28, 29 and 30 are steps of an important process of the design in a project, those images are just the initial idea that help us to build the final concept.

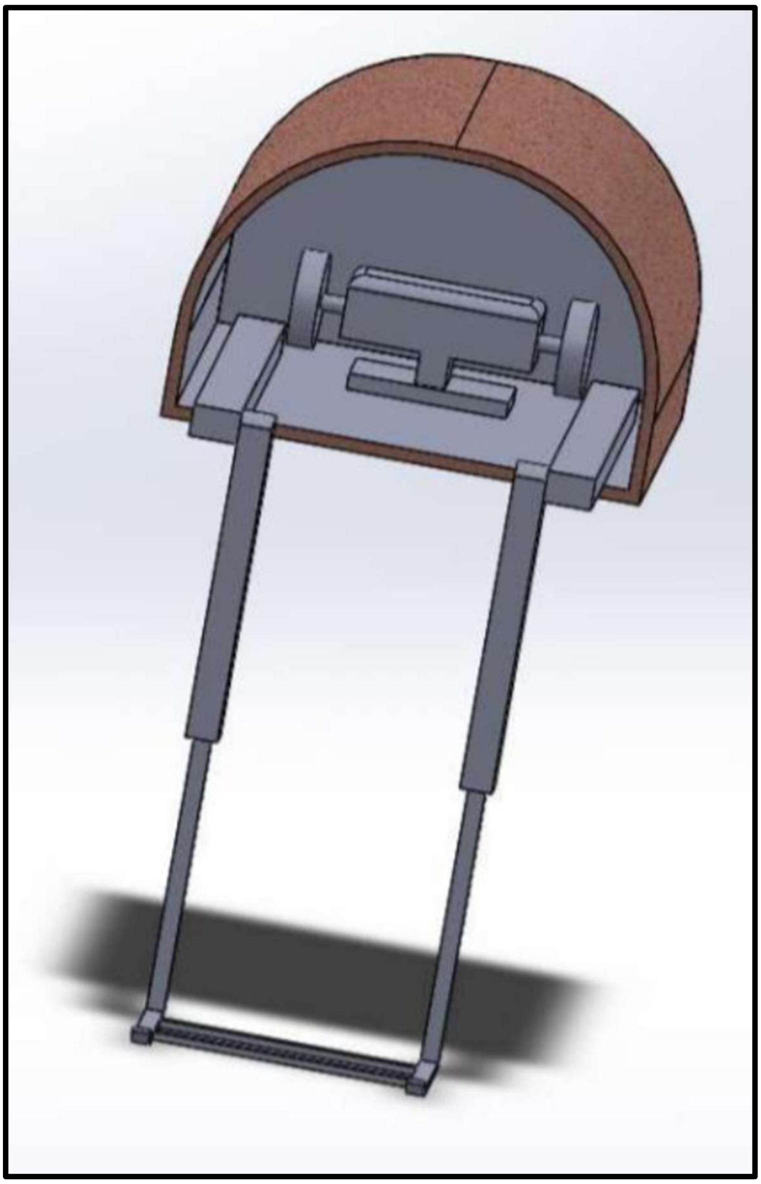


Figure 30- System for housing the wheelchair isometric front view

It can be seen from the images above that no cable traction or spring compression system was carried out, the concept still needed to be matured, but the chassis of it was successfully formed. Finally, as a final step, the CAD 3D concept of the final project was formulated, considering all the particularities necessary for its operation. It should also be noted that the entire designed system was properly dimensioned as can be seen in the next section of the work. Something that greatly facilitated the constant work of modifications and adaptation of the project was the work from “assembly”, which allows to work each piece individually and then put it together to form what I call a system. As an example, I put here a photo of how the junction was carried out to couple the parts in a set in the system to collect the wheelchair:

Figure 31- 3D CAD drawing assembly tree

Figure 31 shows us how the process was built. All the components of the CAD design was made part by part and then after assembled all together.

With this strategy it's possible to select and work with each component individually, whether screws, bearings, parts made by themselves, as shown in Figure 32, for example:

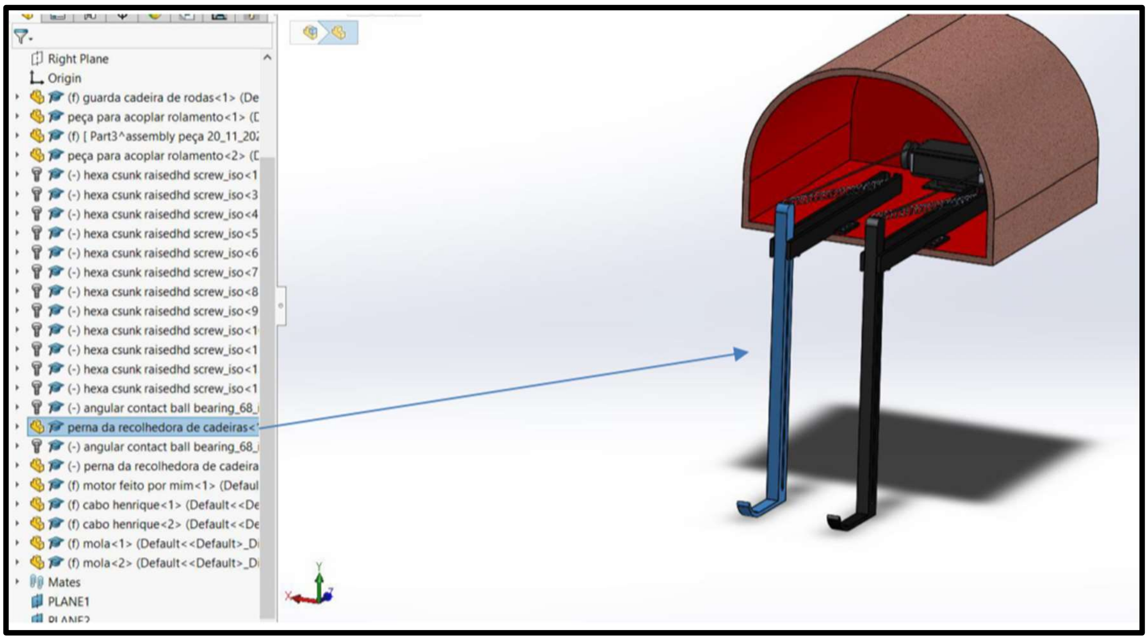


Figure 32- Assembly structure made from the parts

Therefore, the result of each set and subset is verified:

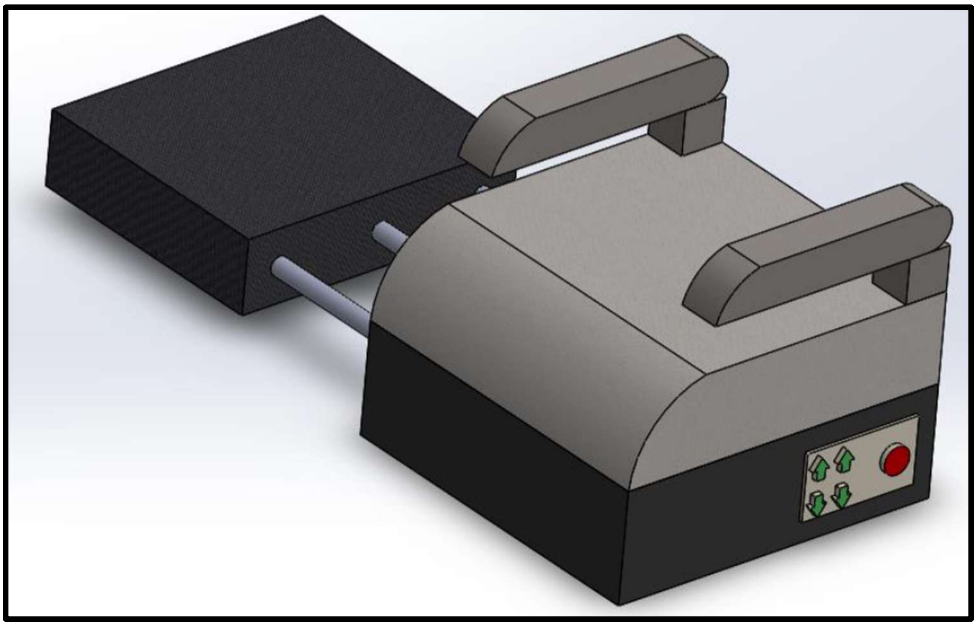


Figure 33- Final transfer system from wheelchair to car

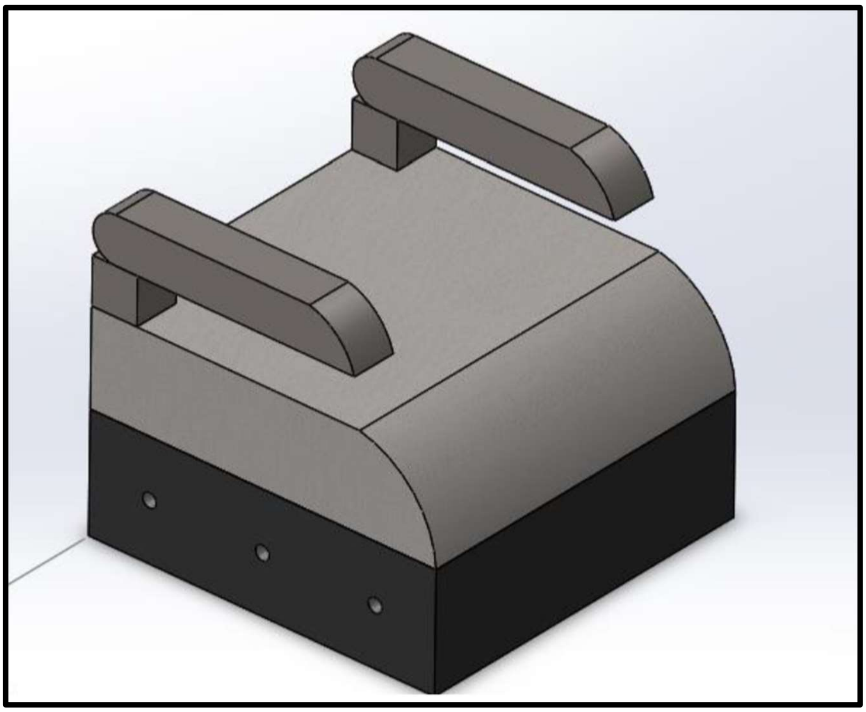


Figure 34- Chair view without actuators

Figures 33 and 34 are the components that illustrate the car seat design that is coupled with the actuators, so it can be ejected from inside the car.

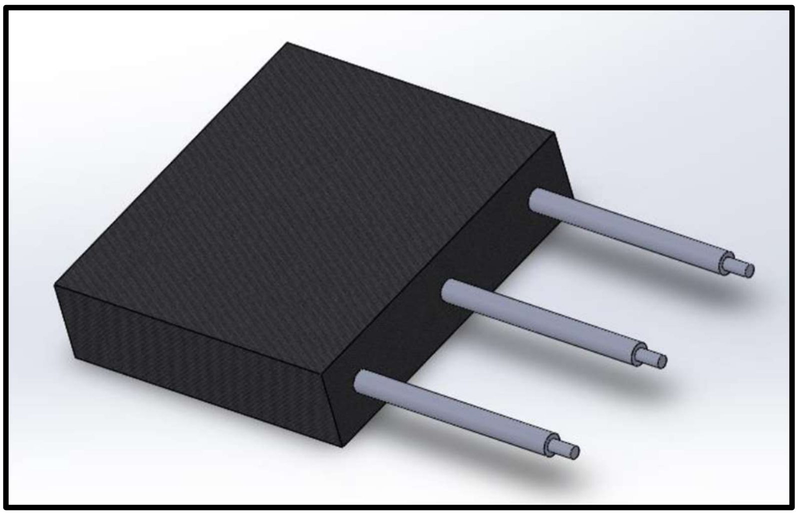


Figure 35- Chair hydraulic actuators support

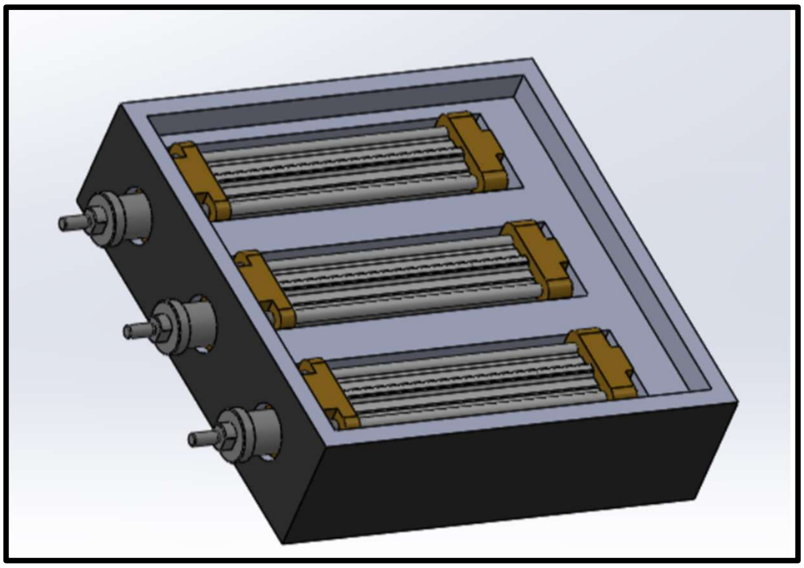


Figure 36- Arrangement of hydraulic actuators on the support

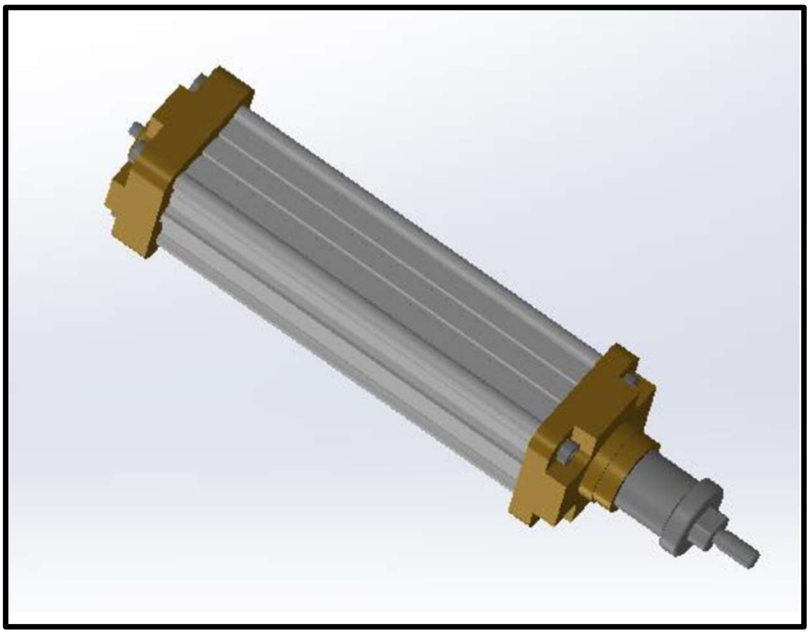


Figure 37- Hydraulic actuator

Figures 35, 36 and 37 are the final concept of the actuation system. We have the hydraulic actuators figure 37 that are located at a support that can be seen in the figure 36 and 37.

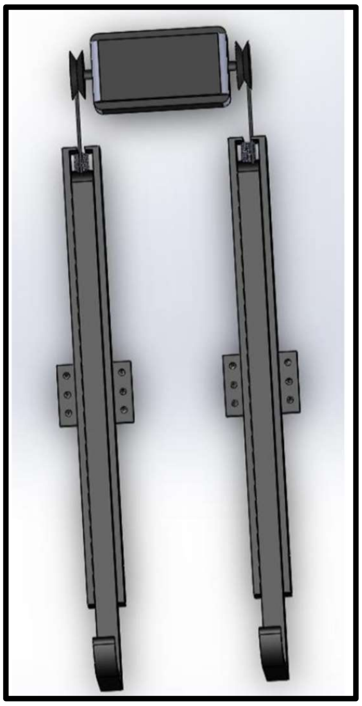


Figure 38- Arm system with motor, spring and attached cables

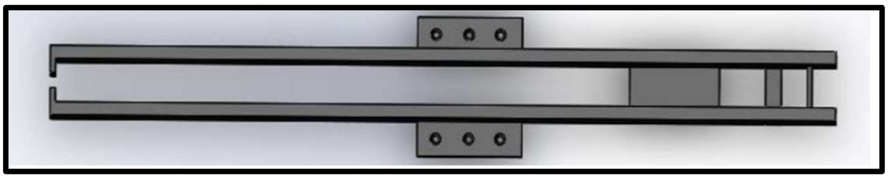


Figure 39- Base to guide linear movement and spring coupling

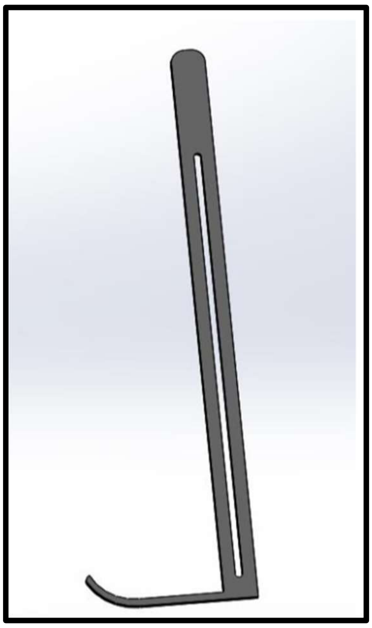


Figure 40- Arm for attaching a wheelchair

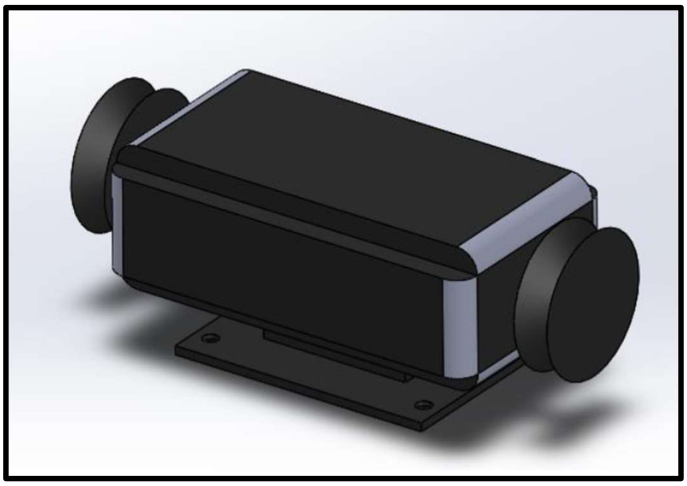


Figure 41- Motor with two coupled pulley systems

In figures 38, 39, 40 and 41 we have some of the moving components that are needed to lift the wheelchair.

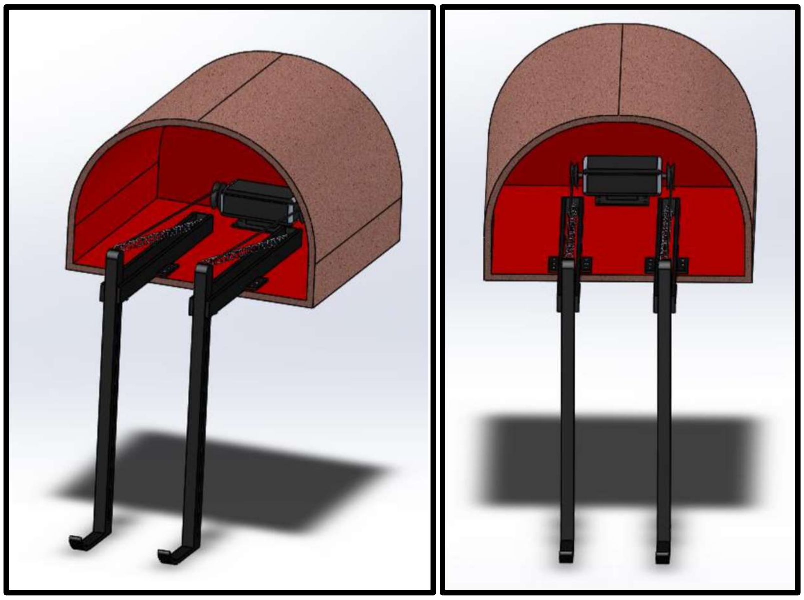


Figure 42- Wheelchair transport system

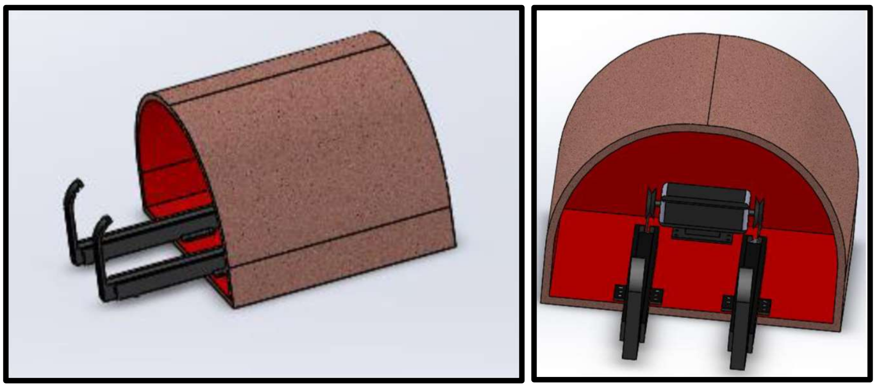


Figure 43- Wheelchair transport system folded arms system

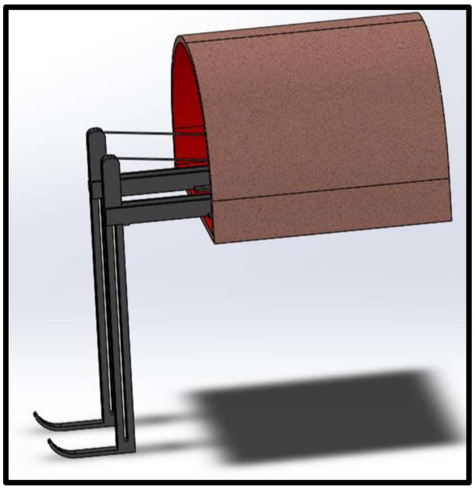


Figure 44- Wheelchair pick-up assembly side view

Finally, in the figures 42, 43 and 44 we can see the set of attached parts forming the component that is housed on top of the car roof. It is interesting to pay attention, as well, in figure 45, to the similarity of the isometric drawing made by hand to the final result, taking into account the changes and adaptations:

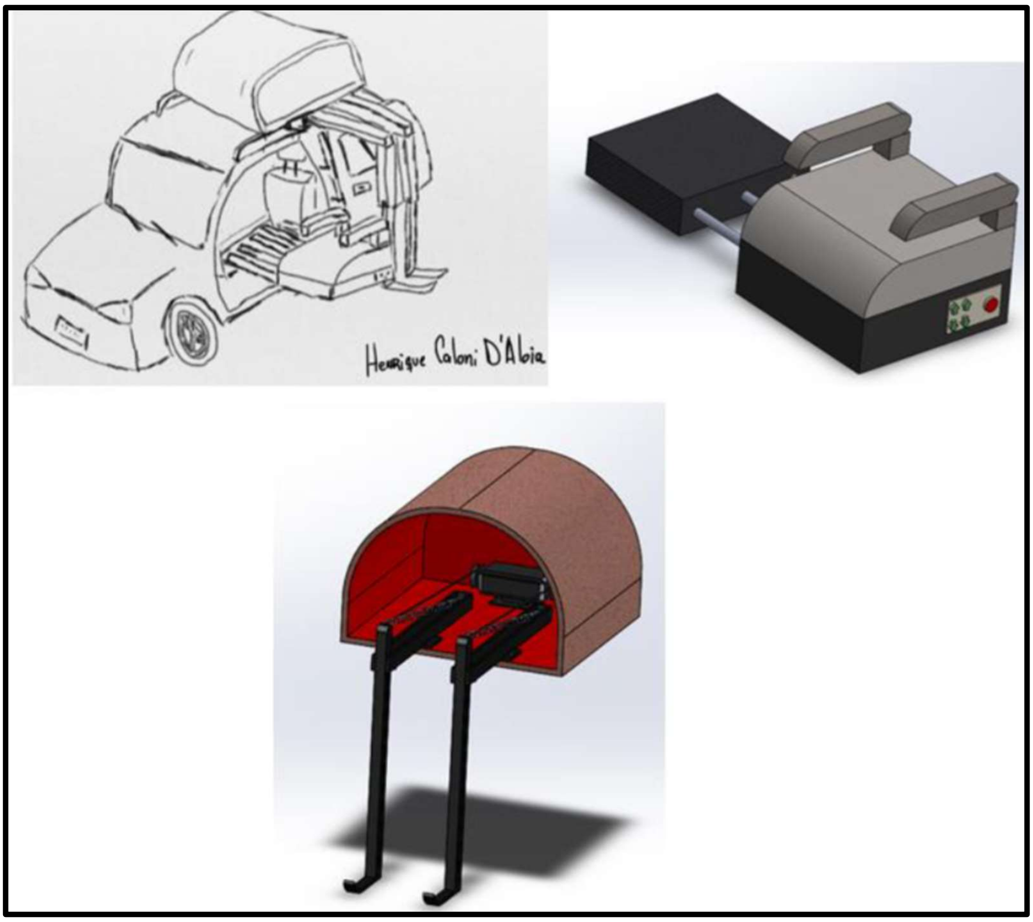


Figure 45- Comparison between initial isometric drawing made by hand and final result in 3D CAD

3.7. Calculation Log

The calculation memorial consists of an analysis made to verify which materials should be used in the project, which efforts they will be submitted and, for that, to dimension them in a coherent way with its objective. The main components of the project were verified and dimensioned, which, among others, are subject to the action of loads, or need to perform a certain force and even transmit this force. Considering that the verification and dimensioning calculations of the cables, elastic springs, motor, arm that lifts the wheelchair, screwed metallic arm, actuators of the driver's collection system were carried out.

3.7.1. Structure Material Selection

All the material of the structure and its assembly was defined according to the decision matrix, in which the important factors in the project were ordered, later classified according to their level of importance, thus adapting the best option to the project. The table 7 shows a grade scale of the importance of some characteristics that can be seen at table 8 (Structure selection). These rating criteria is specified at table 9.

Table 7- Grade scale

	grade scale
1	bad
2	
3	medium
4	
5	good

Table 8- Structure selection

Variant V(i)	structure selection
1	commercial aluminum profile
2	commercial steel structure
3	cast iron structure
4	welded structure
5	bolted structure

Table 9- Rating criteria

Rating Criteria		
Rating criteria	Criteria	Importance factor W(i)
1	Cost	4
2	Ease of assembly	2
3	Ease of manufacture	2
4	Static and dynamic stiffness	5
5	Durability	4
6	Adaptability	3
7	Safety	5
8	Low environmental impact	5
9	Ease of use	4

Table 10- Decision matrix

Decision matrix (Global value calculation)													
Criteria number	Criteria	Importance factor W(i)	Variant V(1)		Variant V(2)		Variant V(3)		Variant V(4)		Variant V(5)	
			v(1)	v(1)*wi	v(2)	v(2)*wi	v(3)	v(3)*wi	v(4)	v(4)*wi	v(5)	v(5)*wi
1	Cost	4	4	16	4	16	5	20	2	8	3	12
2	Ease of assembly	2	4	8	3	6	3	6	2	4	5	10
3	Ease of manufacture	2	5	10	4	8	3	6	2	4	4	8
4	Static and dynamic	5	3	15	5	25	4	20	4	20	3	15
5	Durability	4	4	16	4	16	4	16	4	16	4	16
6	Adaptability	3	4	12	3	9	2	6	2	6	5	15
7	Safety	5	4	20	4	20	4	20	3	15	3	15
8	Low environmental impact	5	5	25	4	20	3	15	1	5	2	10
9	Ease of use	4	4	16	4	16	4	16	3	12	5	20
	Global Value		138		136		125		90		121	

It can be verified that in the analysis of materials by the decision matrix, table 10, the best materials classified for a project like this had their use in the end. The commercial aluminum profile is used in the wheelchair's folding arms and in the support that couples the hydraulic actuators. Commercial steel frame is used on the hydraulic actuator rod in the frame bolted to the car roof. The cast iron it is used in the cylinders of hydraulic actuators. We can see below the dimensioning of each component separately.

3.7.2. Hydraulic Actuator

The calculation of the hydraulic actuator will be done to adopt a step-by-step process, something that is not actually necessary with the support of the software that we have at our disposal today. This will happen, because in the calculation elements that will come later, such a detailed analysis will not be done, since the “step-by-step” procedure will already be demonstrated in this section. As a way of guaranteeing the stability of the system, initially, 3 hydraulic actuators bolted to the user's seat. The rods of the 3 actuators will have the role of reaching their maximum length so that the driver's seat can be projected out of the car, allowing the wheelchair user to pass from his wheelchair for the driver's seat. It can be seen at figure 46 and 47.

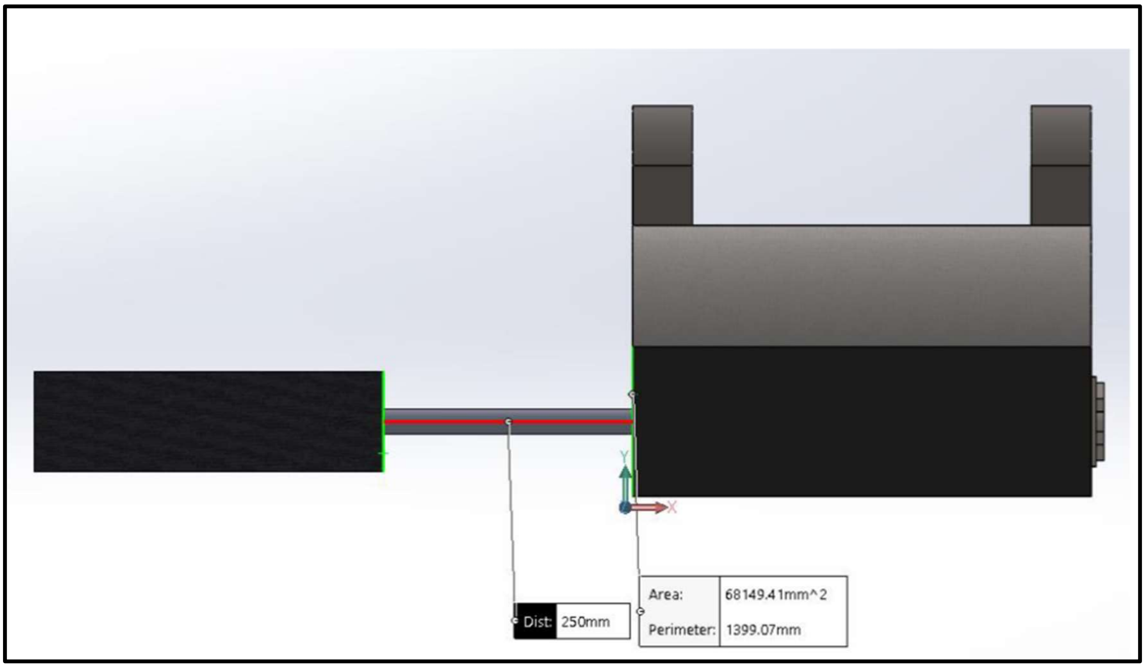


Figure 46- Rod length

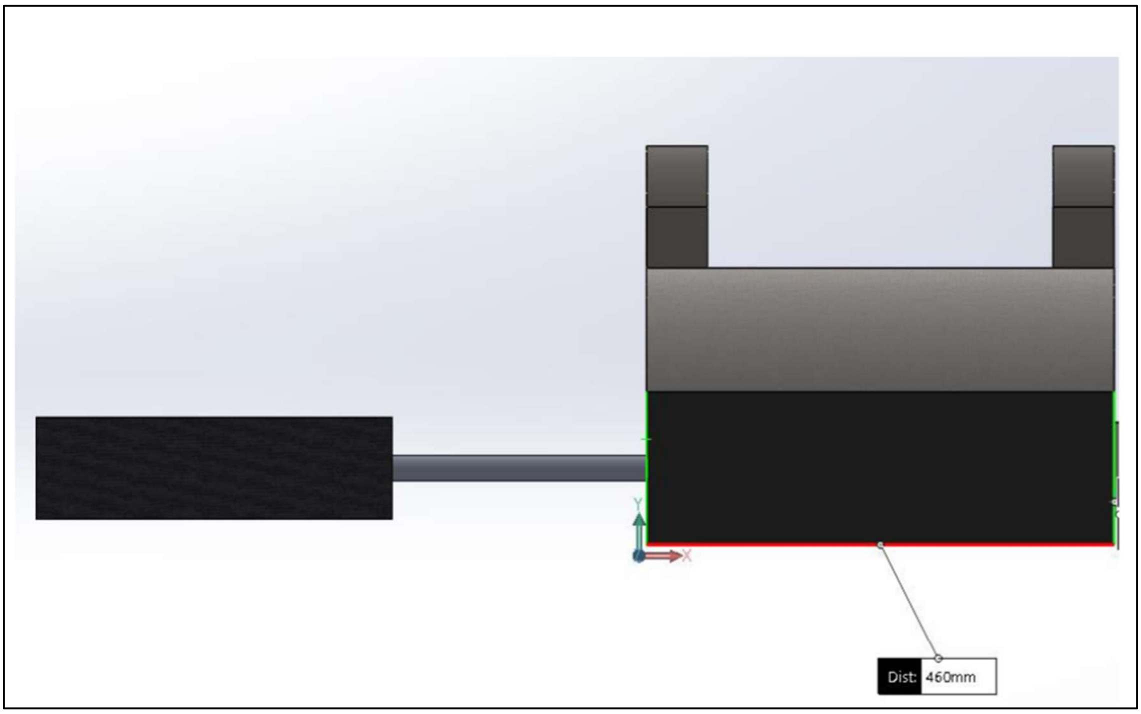


Figure 47 – Seat length

To perform the calculation of the system above in order to have a structure that can withstand the loads and fulfill the due role, it is first necessary to analyze the efforts present and which was carried out on the work floor to obtain an approximation:

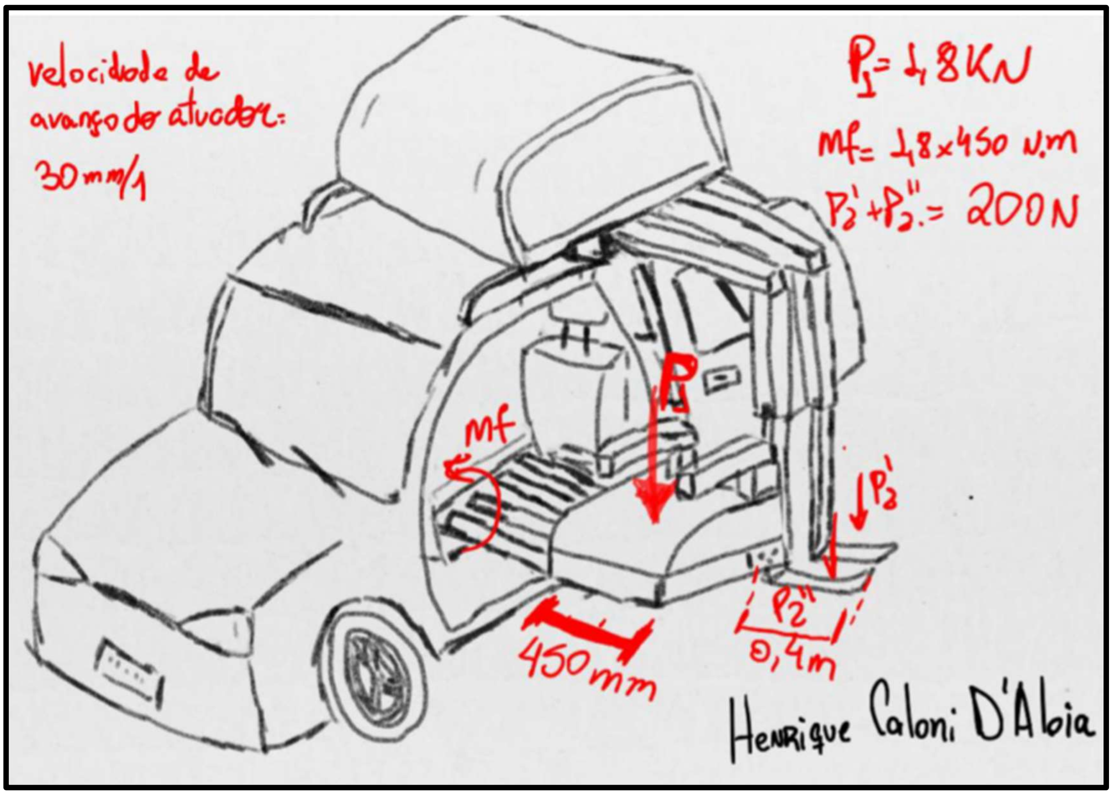


Figure 48- Outline of effort analysis

We can conclude from figure 48 that the actuators will need to withstand a bending moment due to a load arising from the weight of the user on the passenger seat. For security measures, we will design with an expected mass of 200 kg, equivalent to a weight of 1,960 N, considering that usually the system will not be subjected to this type of effort and that the average mass of an adult is 75kg, we are dealing with a safety index of 2.67. For a weight of 1,960N approaching its center of mass at the center of the driver's seat, we would have a bending moment generated from the equation:

$$MF = P \times d \tag{1}$$

Where "MF" is the bending moment of the section, "P" the weight, and "d" the distance.
The distance considered is the rod length plus half of the seat length. We are considering half of the seat length because as we have the weight (considered as a force uniformly distributed in a regular retangular shape) which has its center of mass at the indicated location in figure 48. Bearing in mind that the bending moment will have its critical value when the rod is completely out and its length is maximum, not counting any other type of support in addition to the partial embedding of the piston, which only allows linear movements, we are in a situation of a free-embedded bar structure to be stressed for a moment. So, we have 3 equally spaced rods the load can be approximated by calculating the bending moment in 1 rod section per 1/3 of the original load. Finally, the maximum bending moment is given by:

$$MF = \left(\frac{200}{3} \times 9{,}81\right) \times \left(250 + \frac{460}{2}\right) \quad (2)$$

$$MF = 313.920\ N.mm \quad (3)$$

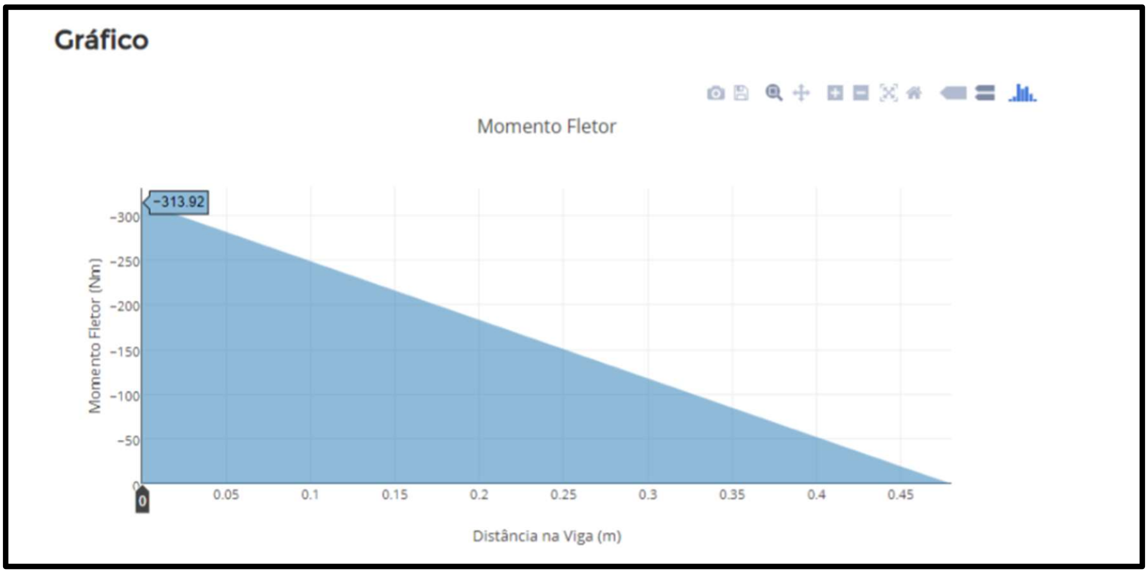


Figure 49- Bending moment graphic

The stress at the critical section can be determined by:

$$\sigma = \frac{MF \times r}{I} \quad (4)$$

Where MF is the bending moment, r the radius at the center, and I the moment of inertia of the section.

$$I = \frac{\pi r^4}{4} = 19\ 174{,}76\ mm^4 \quad (5)$$

and the profile of efforts in the section will be as follows:

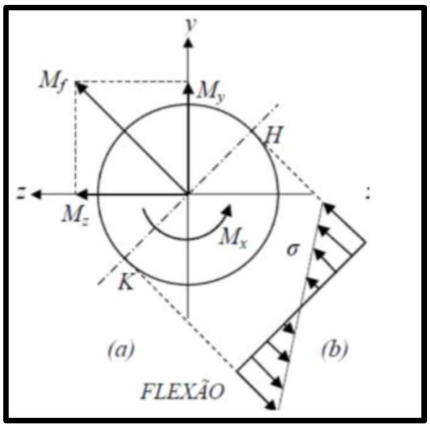


Figure 50- Stress profile of a circular beam in bending [33]

The critical stress:

$$\sigma = \frac{313\,920 \times 12{,}5}{19\,174{,}76} = 204{,}64\ \mathrm{N \cdot mm^{-2}} \quad (6)$$

$$\sigma = 204{,}64\ \mathrm{MPa} \quad (7)$$

Table 11- Mechanical properties SAE steels [33]

MATERIAL	TENSÃO DE RESISTÊNCIA (MPa)			TENSÃO DE ESCOAMENTO NA TRAÇÃO (MPa)	ALONG. (%)
	σ_{tr}	σ_{cr}	τ_{cr}	σ_{te}	ε
SAE-1010	350	350	260	130	33
SAE-1015	385	385	290	175	30
SAE-1020	420	420	320	193	26
SAE-1025	465	465	350	210	22
SAE-1030	500	500	375	230	20
SAE-1040	580	580	435	262	18
SAE-1050	650	650	490	360	15
SAE-1070	700	700	525	420	9
SAE-2330	740	740	550	630	20
SAE-2340	700	700	525	485	25
SAE-3120	630	630	475	530	22
SAE-3130	680	680	510	590	20
SAE-3140	750	750	560	650	17
SAE-4130	690	690	520	575	20
SAE-4140	760	760	570	650	17
SAE-4320	840	840	630	650	19
SAE-4340	860	860	650	740	15
SAE-5120	610	610	460	490	23
SAE-5140	740	740	550	620	18
SAE-8620	620	620	465	560	18
SAE-8640	750	750	560	630	14
AISI-301	770	770	580	280	55
AISI-302	630	630	470	248	55
AISI-310	690	690	515	315	45
AISI-410	490	490	370	264	30
Fo.Fo.	120 à 240	600 à 850	--	--	--
Cobre	225	225	168	70	45
Latão	342	342	255	120	57
Bronze	280	280	210	--	50
Alumínio	180	180	135	70	22

From table 11, it is possible to place any SAE steel in order to obtain the best expected result, while still having a good safety margin. For this, we will choose SAE4130 steel to obtain a good compromise between tensile strengths. Regarding the calculation of the force needed to be done by the hydraulic system, we need to make a force analysis acting on the actuator, figure 51 and figure 52.

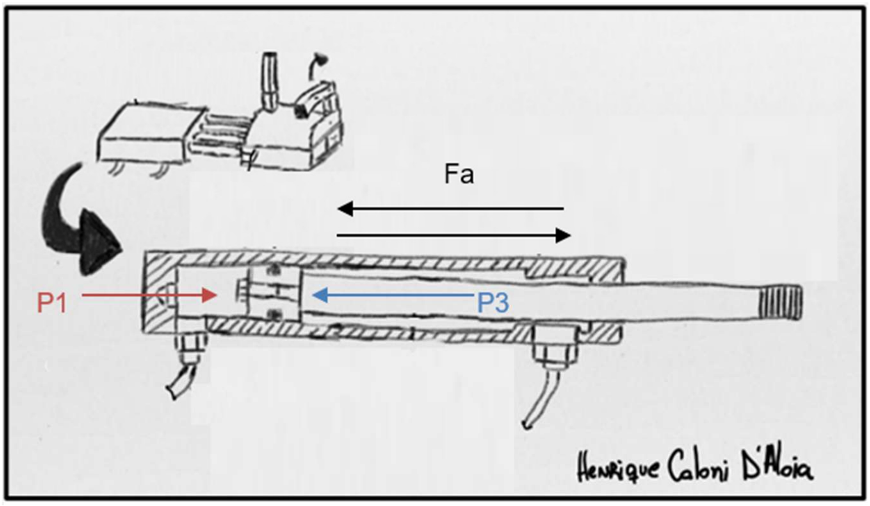


Figure 51- Present forces in the actuators

It is considered a force of static friction that needs to be overcome because of the weight of 654N (calculation of 1 rod).

$$Fa = \mu N \tag{8}$$

Table 12- Average friction coefficients for typical materials [34]

Materials in contact	Conditions	Static Friction Coefficient	Kinetic Friction Coefficient
rubber/ steel	dry	0,6 – 0,9	0,3 - 0,6
rubber/ asphalt	dry	0,7 – 0,9	0,5 – 0,8
rubber/ asphalt	wet	--	0,25 – 0,75
rubber/ rubber	dry	--	1,16

By the table 12 adopting μ=0,9 for rubber/steel contact. The force to be overcome is

$$\mathrm{Fa} = 0{,}9 \times 654 = 588{,}8\ \mathrm{N} \tag{9}$$

Taking into account the relationships of a cylinder:

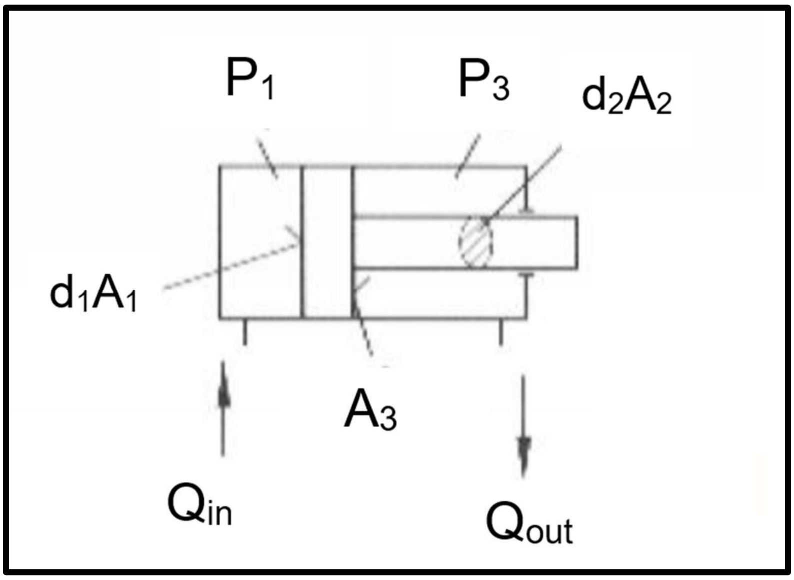


Figure 52- Structure and parts of an actuator [35]

The force required for the forward motion is:

$$\mathrm{FF} = \mathrm{P}_1 \times \mathrm{A}_1 \tag{10}$$

The force required for the return movement is:

$$\mathrm{FR} = \mathrm{P}_3 \times (\mathrm{A}_3 - \mathrm{A}_2) \tag{11}$$

As we have D_1=D_3= 60 mm and D_2= 25 mm.

$$\mathrm{FR} = \mathrm{FR} = \mathrm{Fa} = 588{,}8\ \mathrm{N} \tag{12}$$

By that we can get the necessary pressures:

$$\mathrm{P}_3 = 1{,}2\ \mathrm{MPa} \tag{13}$$

$$\mathrm{P}_1 = 0{,}4\ \mathrm{MPa} \tag{14}$$

Alternatively with the finite element analysis I obtained the following results- figure 53 and figure 54- which are very close and confirm the analytical calculation. When analyzing the results in finite elements, we can see in figure 53 that, by Von Mises stress analysis, the maximum tensile and compressive stresses. We can see, as well, that the maximum tensile stress is present on the actuators surface. The point that this tensile occur is where the bending movement is prevented. What is analyzed here can be clearly seen in figure 49 (when observing the maximum reaction) and in figure 50 illustrating in which zone of the radius the maximum tensile stress would be present. In figure 54 we can see which parts of the set have moved the most due to the applied force. It was expected that the maximum displacement would be at the farthest point of where the bending motion is constraining, as we can see in the image.

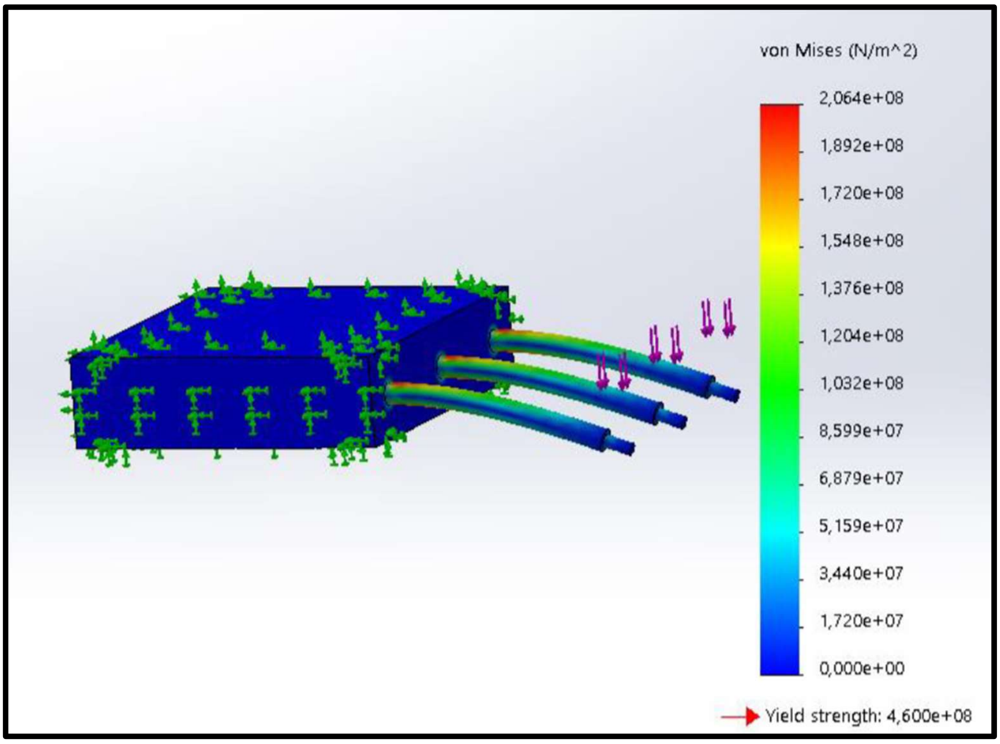


Figure 53- Analysis of the tensions of the hydraulic actuator rods from the von Mises yield criterion

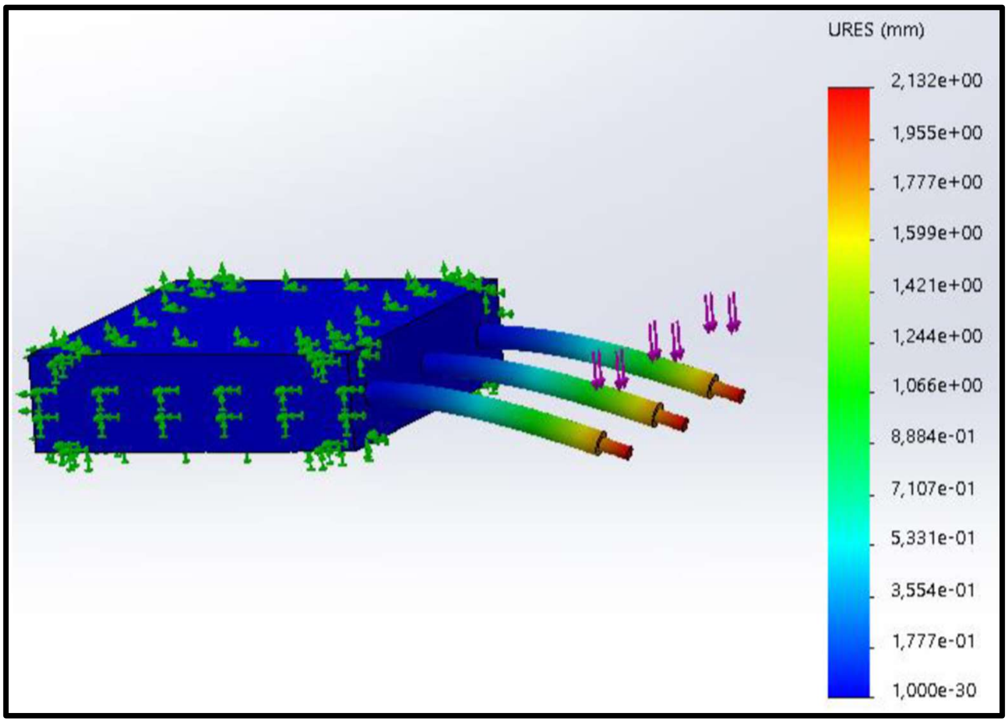


Figure 54- Analysis of the deformation of the hydraulic actuator rods

3.7.3. Wheelchair Anchor System

Considering the need to transport the wheelchair through the physical strength of its user, wheelchairs are usually made of light materials and on average do not exceed 15 kg, therefore, for the scope the work done below will be considered that mass.
First of the following system analysis at figure 55.

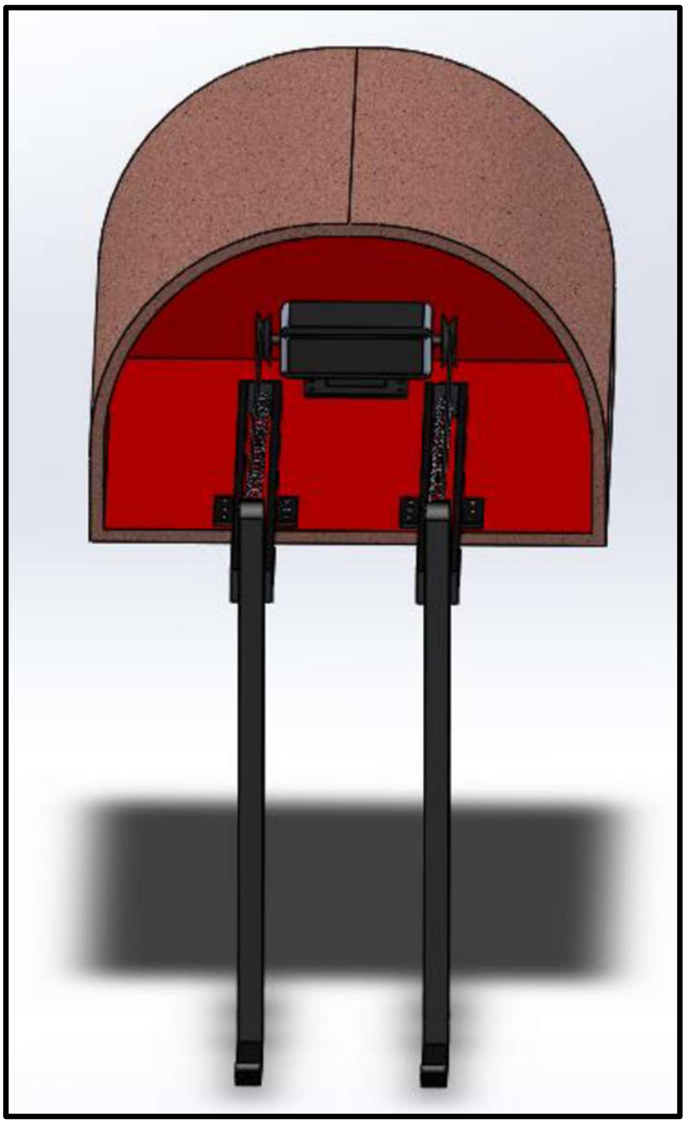


Figure 55- Front view wheelchair pick-up system

We have that the traction to be carried out by the steel cables results from the moment to overcome the weight of the chair together with the weight of the metallic arm made of aluminum alloy.
The aluminum alloy chosen considered the desired characteristics and that is why the 2024 series 2 alloy was chosen. From [36]: “These aluminum alloys have limited weldability, however some alloys in this series have superior machinability. The 2024 series is the most popular and most common alloy used in aircraft construction.”

In an analysis considering the density of the alloy we have that the mass of each leg is 28.4 kg as shown in the figure 56:

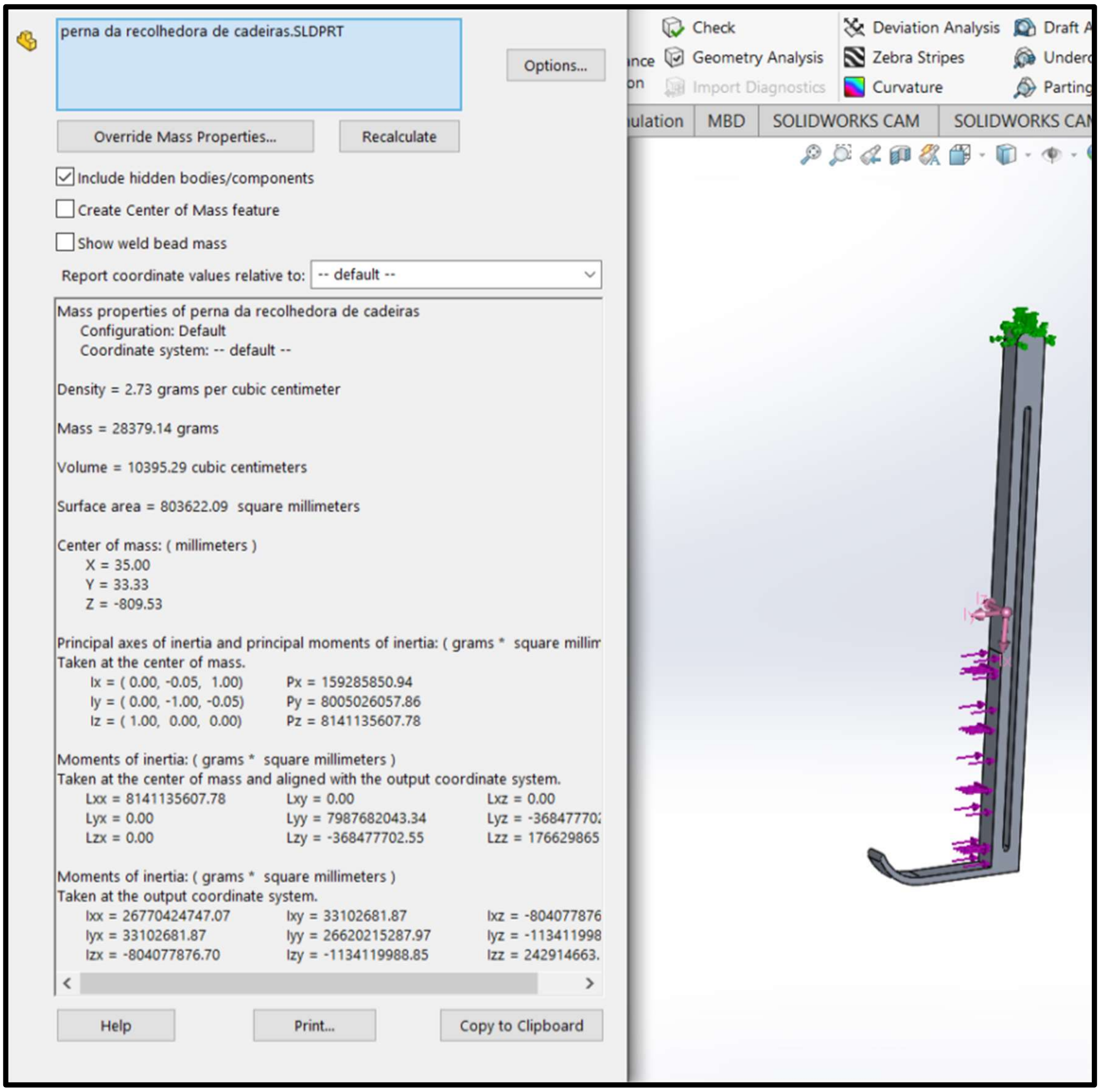


Figure 56- Wheelchair mass collector arm

Considering the weight of the chair evenly distributed on each arm, we have that the balance of moments shows that the traction is maximum when the arm is at an angle of 45º with the horizontal, having a balance of moments around the end of the marked slot in the figure 57:

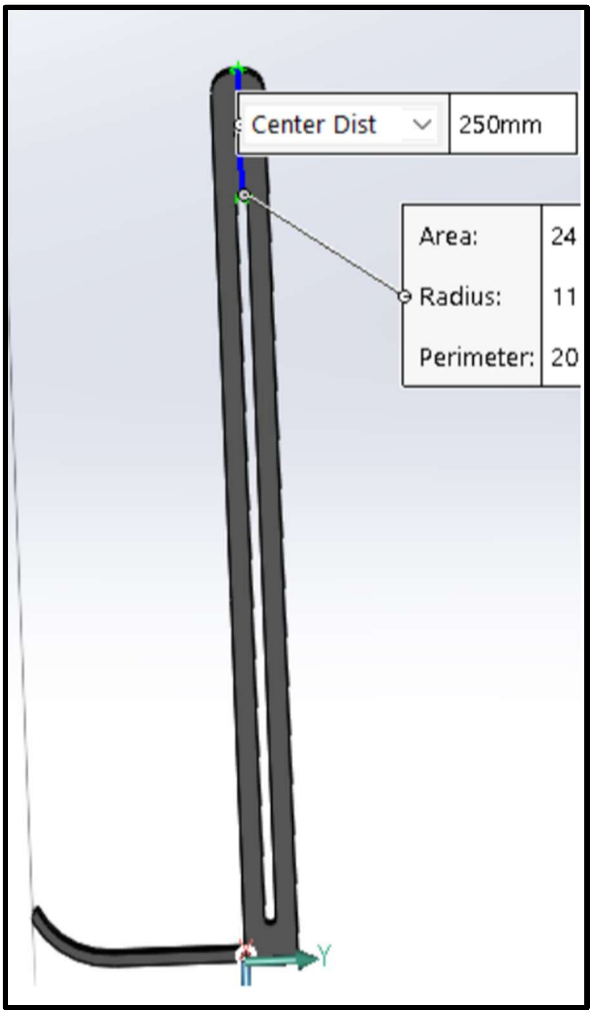


Figure 57- Rotation center

Having as extreme condition the weight of the wheelchair located at the opposite end of the bar (where the y axis of the figure is) and the weight of the bar at the center of mass, the moment equilibrium is given by:

$$250 \times T \times \cos\left(\frac{\pi}{4}\right) = \left(\frac{P_c}{2}\right) \times 1450 \sin\left(\frac{\pi}{4}\right) + P_b \cdot 600 \sin\left(\frac{\pi}{4}\right) \quad (15)$$

Finally, a material check will be made by finite elements of the wheelchair arm:

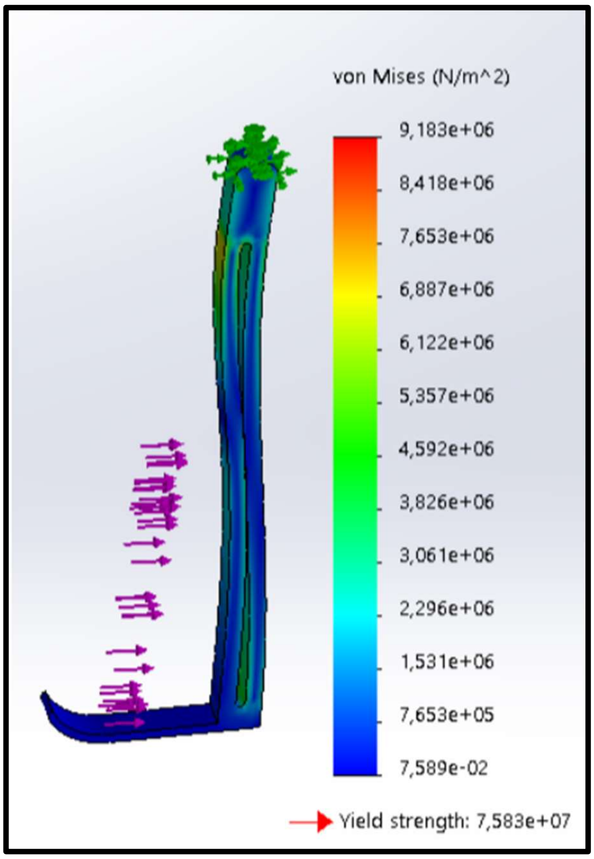


Figure 58- Finite element verification wheelchair lift arm

From figure 58 we can see that the point where the maximum stress will occur is at the limit of the slot through which the bearing moves. When analyzing, we see that the result makes sense for some reasons such as: (1) the change of geometry in the zone, a place susceptible to stress concentration, in addition we can observe that (2) we have in such zone the place where the bending moment is maximum due to the maximum distance from the load zone where bending movement is restricted.

3.7.4. Spring

The spring applied to the system needs to have the force - when releasing the steel cable lock coupled to the motor- to return the system with the chair down, that is, you need to push the system until the center of gravity does the rest on its own.

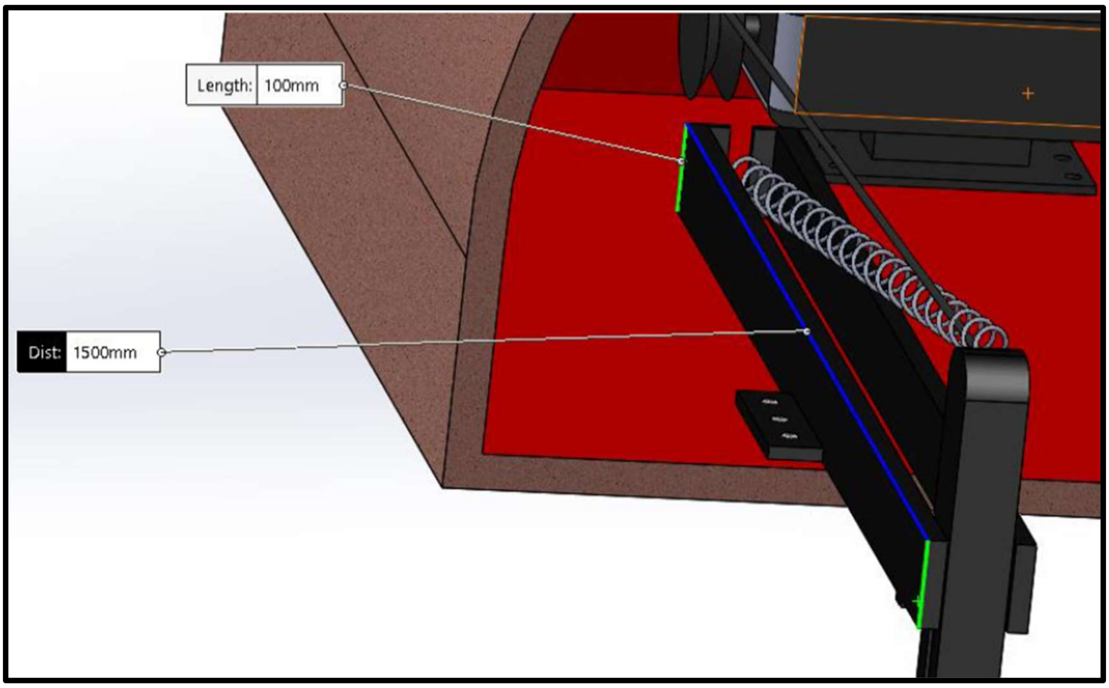


Figure 59- Total distance from the bar to be coupled to the spring

Considering higher values of friction between steel and aluminum and the average values of coefficient of friction at table 13 , as the system will be supported by a bearing, it will greatly reduce the forces required.

Table 13- Average values of coefficient of friction [40]

Surface Material	μ_e	μ_c
Steel/ Steel	0,74	0,57
Aluminum/ Steel	0,61	0,47
Wood/ Wood	0,25 - 0,50	0,20
Glass/ Glass	0,94	0,40
Metal/ Metal (Oiled)	0,15	0,06
Ice/ Ice	0,1	0,03

To overcome the friction force, a force of:

$$\mathrm{F_s} = (7{,}5 \times 9{,}81 + 28 \times 9{,}81) \times 0{,}61 = 212\ \mathrm{N} \qquad (16)$$

Considering a spring with a length of 1000 mm as seen in figure 59, at the end of its compression it will be around 150 [mm], verifying a need for a spring constant of at least 250 [N/m].

3.7.5. Fixed Arm

Since this element is only required by a bending moment, its maximum bending moment will be when the system is in the configuration of figure 60 in which each screwed arm will have to support the moment of the wheelchair and the arm that has just been scaled. We have the configuration in finite element analysis:

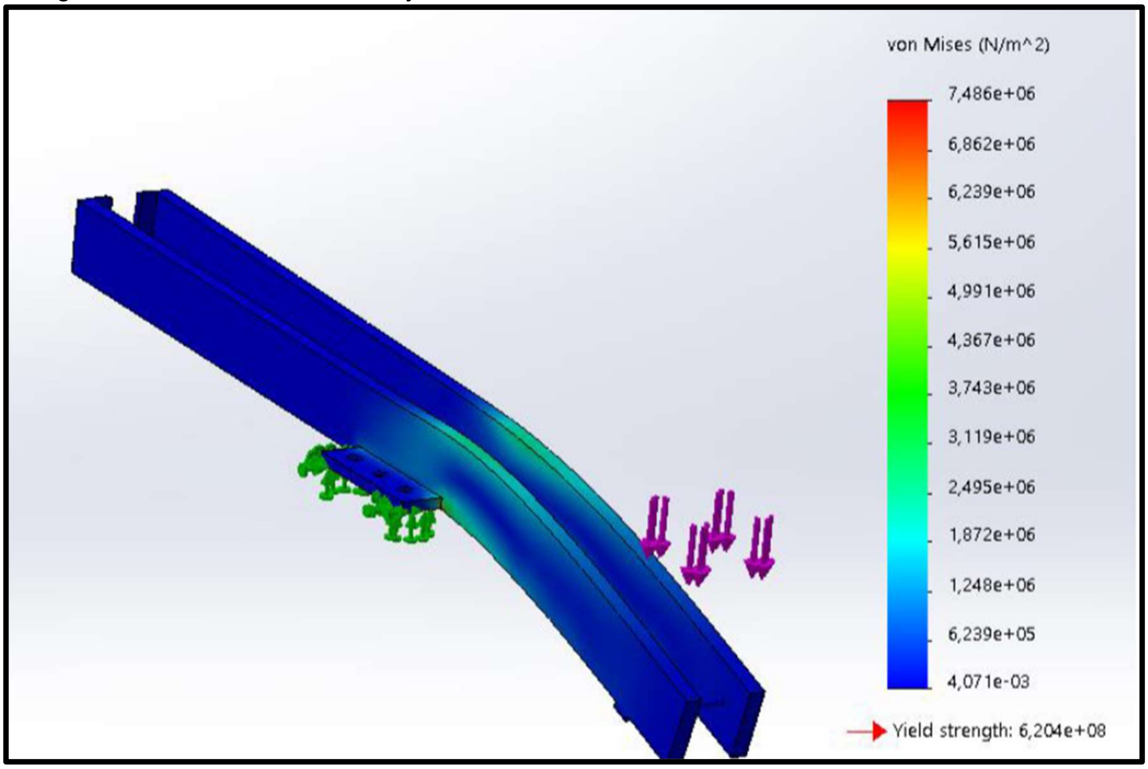


Figure 60- Yield analysis by von Mises in the bolted structure

Very similar to what we have seen so far, we have the main force present, the bending moment, which causes the maximum stress in the recessing zone near the screws, which was also expected due to the maximum bending moment in the zone.

3.7.6. Motor

For the dimensioning of the motor, a maximum speed of retraction of the chair of 0.5 [m/s] was selected, considering the calculation involved in the traction performed by the steel cables T=1086 [N], it was possible to plan an engine to perform such a task, it can be seen at table 14.

Table 14- Engine requirements

Engine Rotation [rpm]	106
Engine Power [W]	542,95
Engine Power [cv]	73,55
Engine Torque [N.m]	97,74
Engine Torque [in.lbs]	865,07

To analyze a supplier that met the objectives of the project in question, I found the manufacturer "Parker". Through the complete catalog of engines and products that the supplier makes available, we can illustrate the choice of a suitable engine for the present use, figure 61.

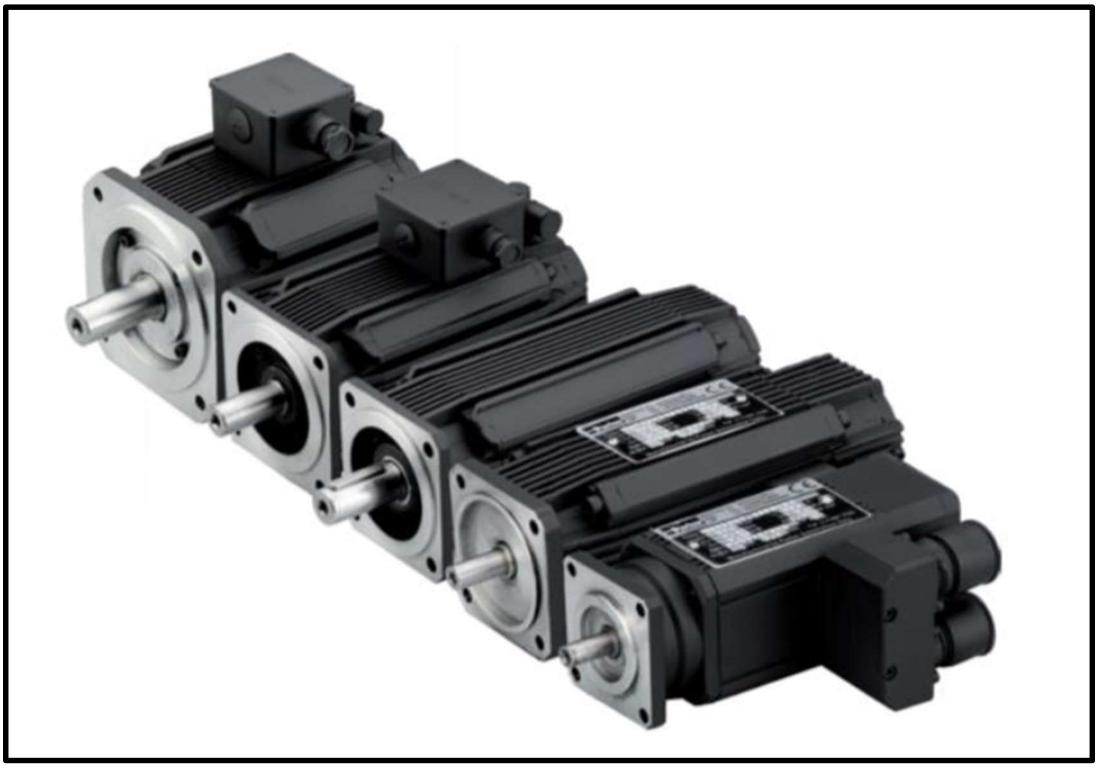


Figure 61- Engine models [37]

The manufacturer has a series of motors for different torques, speeds and different needs, taking as an example the series "MH / MB Motors, Size 265 - 75...270 Nm" which would clearly meet the power needs, as seen in figures 62 and 63.

MH / MB Motors, Size 265 - 75...270 Nm

400 VAC

Model	Size	Stall		Nominal			Peak	Inertia		Ke (2)(3)	Kt (2)(3)
		Torque (1)	Current	Torque (1)	Speed	Current	Torque(1)	No brake	With brake		
		T_{065} (T_{105}) [Nm]	I_{105} [A]	T_{n105} [Nm]	n [min⁻¹]	I_{n105} [A]	T_{max} [Nm]	J [kgmm²]	J [kgmm²]	Ke [Vs]	Kt [Nm/A$_{rms}$]
M_ 265 10 75			17.8	94	1000	17.6				3.08	5.33
M_ 265 20 75		75 (95)	35.6	92	2000	34.5	240	22000	30100	1.54	2.67
M_ 265 30 75			55.3	87	3000	48,8				1.03	1.78
M_ 265 10 150			32.8	175	1000	32.8				3.08	5.33
M_ 265 20 150		145 (175)	73.7	170	2000	71.6	480	36000	44100	1.37	2.37
M_ 265 30 150	265		98.1	144	3000	80.7				1.03	1.78
M_ 265 10 220			47.8	254	1000	47.6				3.08	5.33
M_ 265 20 220		205 (255)	95.6	231	2000	86.6	695	49000	61960	1.54	2.67
M_ 265 30 220			143	185	3000	104				1.03	1.78
M_ 265 10 285			69.5	325	1000	68.5				2.74	4.75
M_ 265 20 285		270 (330)	139	288	2000	121	900	63000	75960	1.37	2.37
M_ 265 30 285			185	215	3000	151				1.03	1.78

(1) Data referred to motor suspend in horizontal position in free still air, 20 °C ambient temperature
(2) Data measured at 20 °C. When "hot" consider 5 % derating
(3) Tolerance data ±10 %

Figure 62- Parker motors da série "MH / MB Motors, Size 265 - 75...270 Nm" [37]

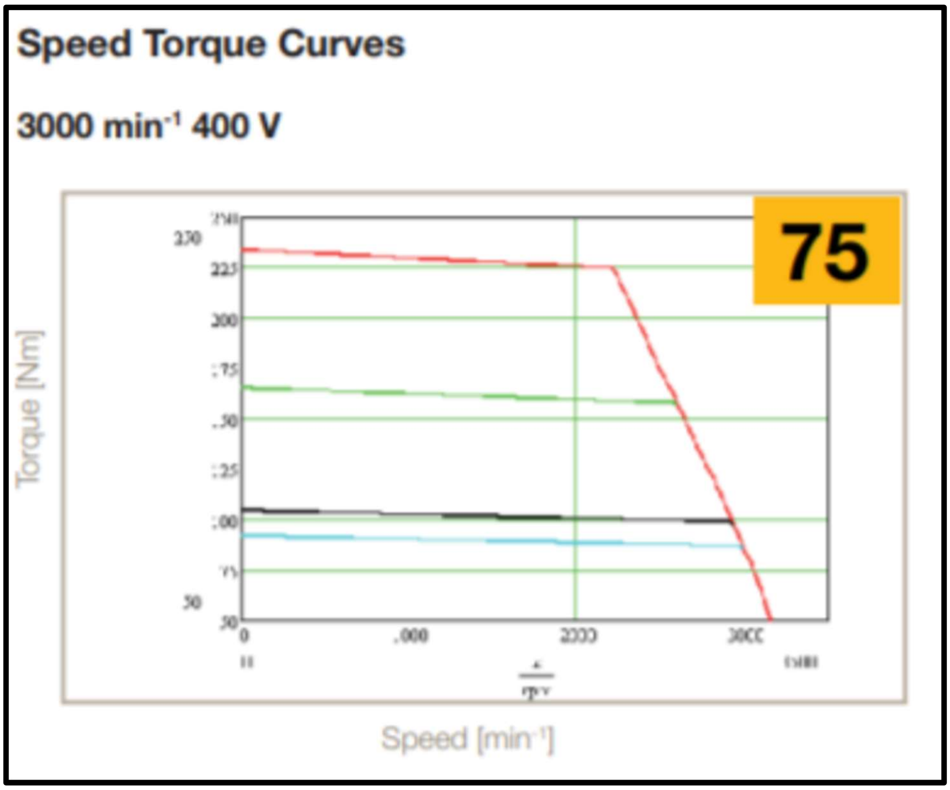
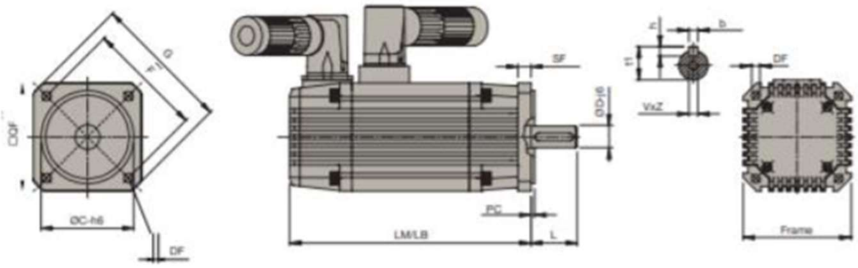


Figure 63- Torque speed curves [37]

Dimensions



Motor - Size		LM/LB	Weight	DxL	bxh	t1	VxZ	C	F	DF	G	SF	PC	QF	Order code QF
70	0,5	158/214	2	11x23 14x30	4x4 5x5	12.5 16	M4x10 M4x12.5	60	75	6	90	8.5	2.5	70	5
	01	188/244	2.8												
	1,5	218/274	3.5												
	02	248/304	4.3												
	2,5	278/334	5.1												
105	02	186/250	5	19x40 24x50	6x6 8x7	21.5 27	M6x16 M8x19	95	115	9.5	140	10	3.5	105	5
	04	229/293	7					95	115	9.5	140	10	3.5	105	4
	06	273/337	9					80	115	9.5	140	10	3.5	105	9
	08	317/381	11					110	115	9.5	140	10	3.5	105	6
145	04	200/274	8	19x40 24x50 28x60	6x6 8x7	21.5 27 31	M6x16 M8x19 M10x22	130	165	11.5	200	12	3.5	145	5
	08	231/305	12												
	15	292/366	18					130	165	11.5	200	12	3.5	145	4
	22	354/428	23												
	28	416/490	28												
205	15	239/338	20	38x80 42x110	10x8 12x8	41 45	M12x32 M16x40	180	215	14	250	18	4	205	5
	28	273/372	29												
	50	342/441	44												
	70	411/510	59												
	90	480/579	74												
265	75	340/475	89	48X110	14x9	51.5	M16x40	250	300	19	342	35	4	264	5
	150	447/582	126												
	220	554/689	164												
	285	661/796	203												

LM: Motor length without brake with resolver
LB: Motor length with brake with resolver
DxL: Shaft
bxh: Key
t1: Overall shaft height
VxZ: Shaft hole depth
mm for dimensions, kg for weight

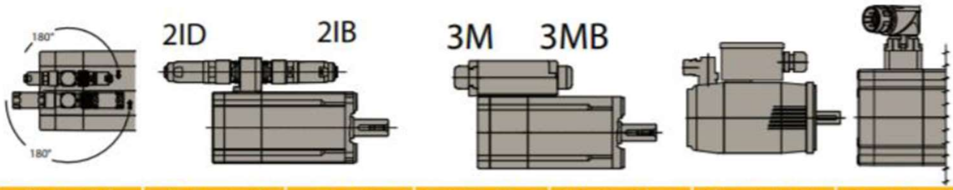
C: Center
F: Distance between center of holes clamp
DF: Fixing holes
G: Dimension in diagonal
SF: Flange thickness
PC: Centering depht
QF: Flange square

Figure 64- Engine dimensions [37]

It is possible to ask the manufacturer for changes due to your need for use, within several specification options are for example the adaptation of connectors / couplings as we can see at figure 64 and figure 65.

Layout and connectors

M_ motors are available with different combinations of connectors and layout, depending of size of motor and the application



	2x Parallel upright connectors 2I	2x Forward facing connectors 2IB	2x Rear facing connectors 2ID	Terminal box rear facing 3M	Terminal box forward facing 3MB	Terminal box forward facing 3I	Hiperface DSL® connetor IZ
MH_70	✓	-	-	-	-	-	-
MH_105	✓	-	-	-	-	-	-
MH_145	-	-	-	-	-	✓	✓
MH_205	-	-	-	-	-	✓	✓
MH_265	-	-	-	✓	-	-	-
MB_70	✓	-	-	✓	✓	-	-
MB_105	✓	-	-	✓	✓	-	-
MB_145	✓	-	-	✓	✓	✓	✓
MB_205	-	-	-	✓	✓	✓	✓
MB_265	-	-	-	✓	-	-	-
ME_70	✓	-	-	-	-	-	-
ME_105	✓	-	-	-	-	-	-
ME_145	✓	-	-	-	-	✓	✓
ME_205	-	-	-	-	-	✓	✓
ME_265	-	-	-	✓	-	-	-

- Not possible
✓ Possible without increment
Δ Possible with increment motor length

Figure 65- Adaptive layout and connectors [37]

3.8. Manufacturing and Assembly

In the following figures are shown some characteristics referring to the fabrication of the components of the structures of the projects that were stipulated from the ideals already mentioned a few times before: weight, resistance, cost, etc. Each particularity: assembly, manufacture and material were thought out individually so that it could fulfill its role in the final project. In general, the subsystems are interconnected by bolted connections, figure 66 and 67.

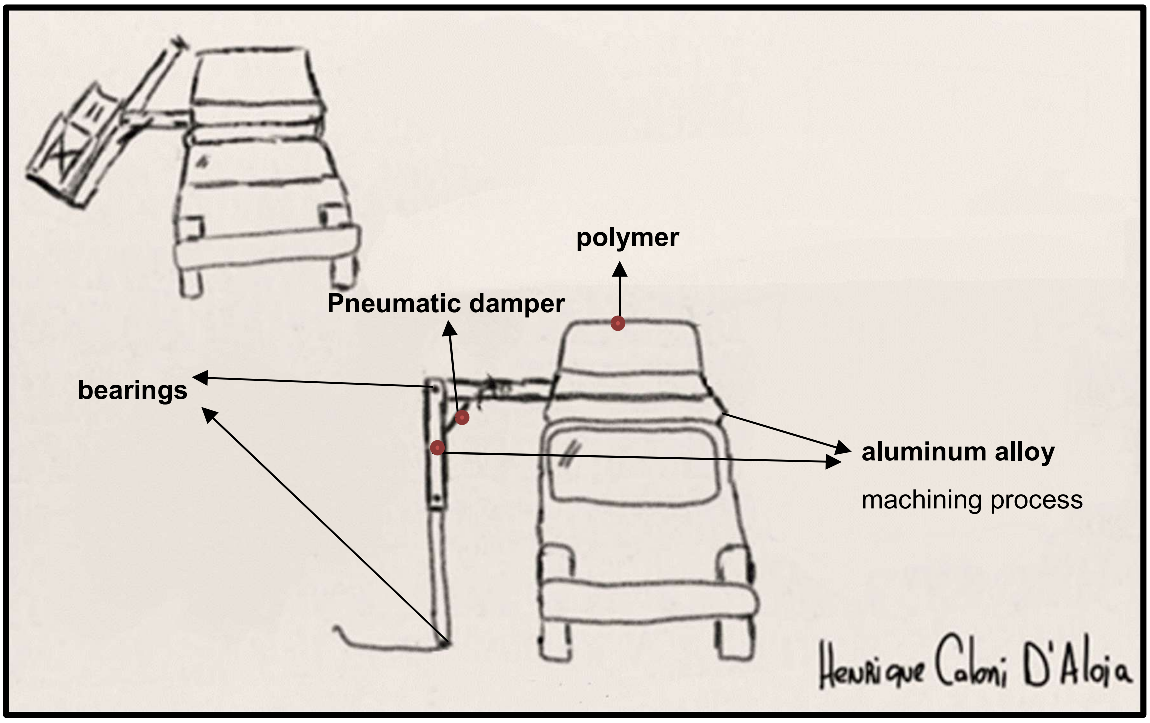


Figure 66- "Wheelchair pick-up" materials

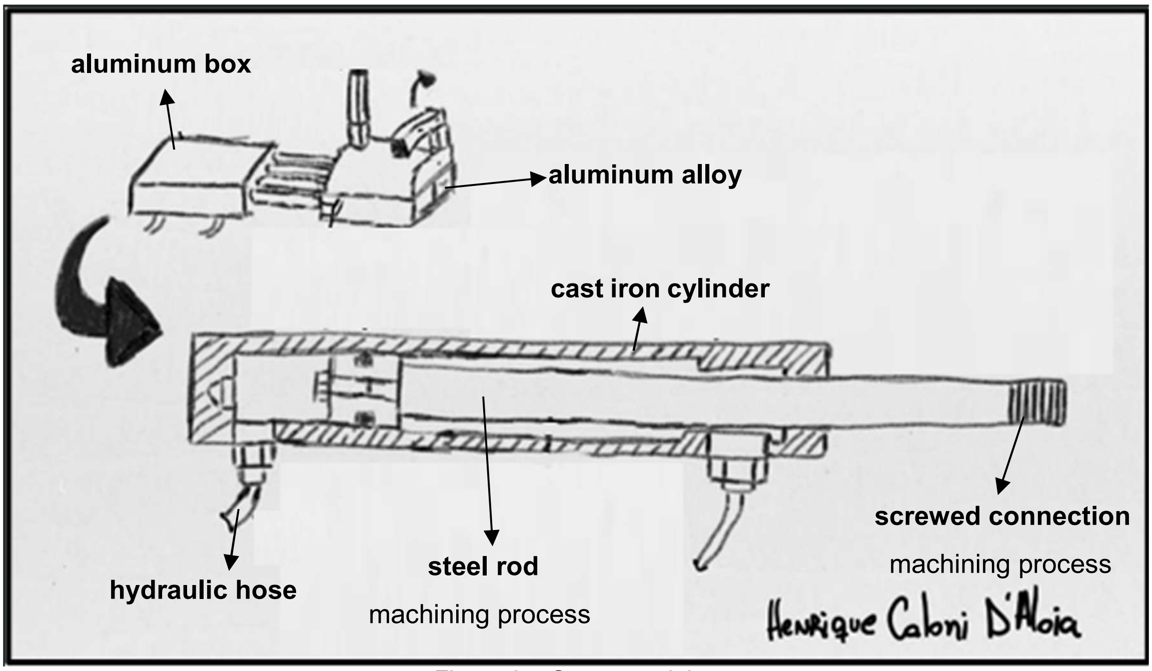


Figure 67- Seat materials

3.9. Product Operation and Maintenance Overview

Separating the product into two parts and analyzing each one in its particularity: with regard to the wheelchair pick-up, for its operation, it is only necessary to know the use of electronic equipment, such as a remote control of an engine. As for product maintenance, it is necessary to overhaul the engine over time, always guarantee the lubrication of the moving parts, avoiding great wear, as well as the exchange and revision of the cables that carry out the traction to collect the system with the wheelchair and of the spring that acts to release the wheelchair. It is also important to check for possible damage to the part to which the chair is attached, as this is constantly being requested by bending moments. In the case of the hydraulic actuator, again for its operation it is only necessary to have knowledge of the use of electrical systems and to recognize the function of the forward, retract and emergency buttons. Regarding maintenance, it is necessary to constantly change the car's oil, which must already be done regardless of the implementation of the product and check the integrity of the actuators which are also constantly suffering bending moments.

3.10. Operational Safety Considerations

The system that is in direct contact with the operator has the main requirements safety: it is constantly fixed (the way the hydraulic system was designed), thus allowing it to be immobile in the position it is in and allowing greater firmness so that the operator can lean and feel secure while transferring the wheelchair. The bench has side arm supports, where the user can achieve safety in the use of the product, having something to lean on during its movement, it has an emergency button that causes the release of the actuators, to allow its free movement in case of any problem.

3.11. Product Discontinuation

Bearing in mind that a large part of the product is made of aluminum and aluminum alloys material recycling is very feasible through steps commonly used in the industry through their separation, cleaning and casting as we can see at figure 68.

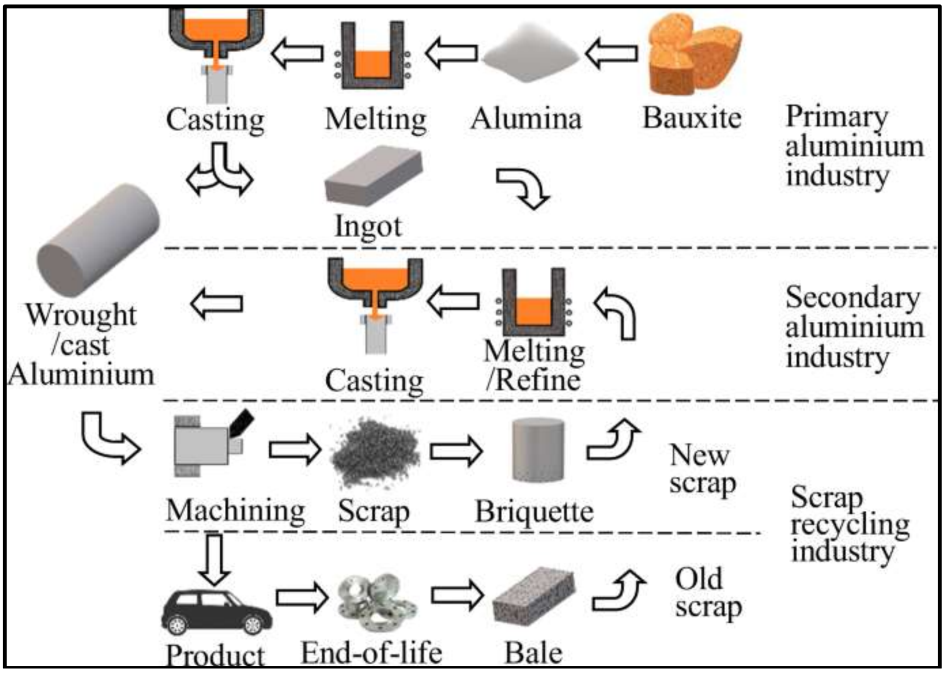


Figure 68- Aluminum recycling cycle [38]

As for the steel cables and steel actuators, as well as the cast iron housing of the actuator, they have adequate recycling ways and without harm to the environment and which are constantly used in the industry, from, in general, the processing, melting, purification and subsequent solidification of the products, (each alloy of steel or cast iron through its thermal, chemical treatment may undergo variations in the processes) as can be verified in figure 69.

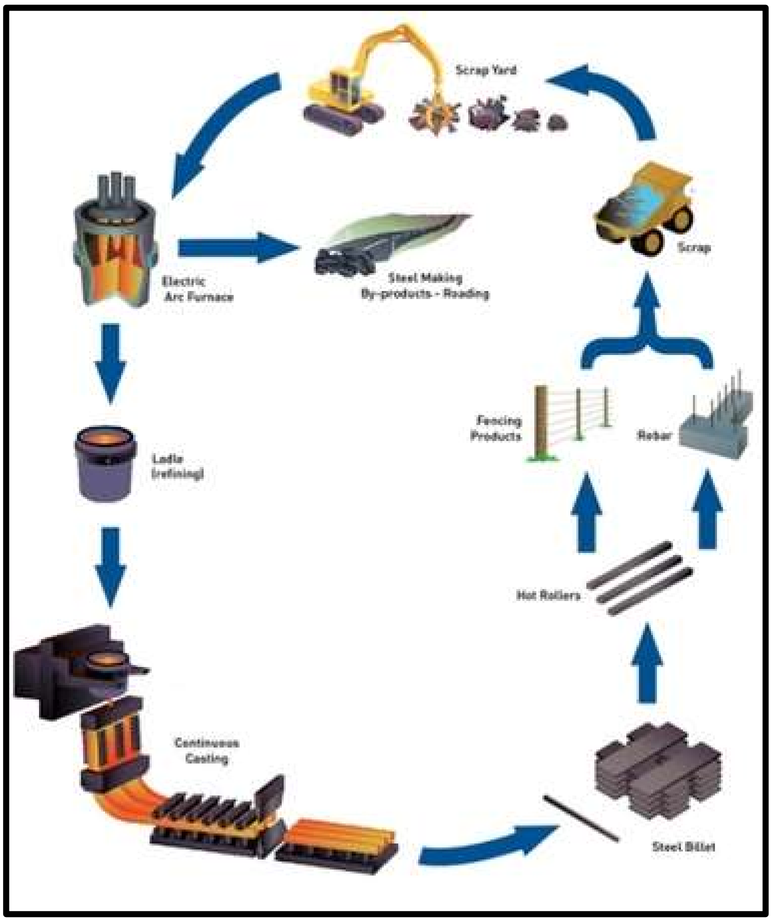


Figure 69 - Iron and steel recycling [39]

As for the seat on which the driver will sit, they have the same conventional seat materials: leather. Leather, in turn, has several alternatives for recycling, such as the transformation of leather into natural fertilizers, grinding for use with tires, recycled paper, etc. Which would bring a good end of life to the product.

Some answers regarding the project and concerns about social responsibility can be seen below in table 15 in the same format already presented by table 4.

Table 15-Social responsibility concerns- check list

Materials	Is the material supply-chain secure?	YES
	Are any of the materials listed as "critical"? If so, why?	NO
	Given the scale of the articulation, will the demand for critical materials stress the supply chain?	NO
	Where are the materials sourced? What is the human-rights record of the country of origin?	Aluminum steel and iron are materials of great world scope, there are no territorial restrictions for their

		obtainment, despite they be more abundant in some regions
	How much transport is involved in material sourcing and manufacture?	Production is summarized in ordering the raw material, further machining the materials, assembling parts and distributing the parts to the market.
	Are materials used efficiently?	From the project design, de idea is to use the essential amount of material and any type of waste in production to be reused in the recycling processes of these materials
Environment	The carbon footprint is less than current practice? Does the articulation provide its function with less dissipation of material resources than current practice?	Considering that the project was formulated with the aim of achieving a very high recycling rate and with a great adaptability of the car structure, the idea is to reduce the carbon footprint as much as possible.
	Can the materials of the product be recycled? Does a recycling infrastructure exist?	As we have seen, the materials chosen for the project, in addition to meeting the mechanical requirements, have a high recycling rate. Recycling processes for these materials already exist and are widely used.
	Do the materials, manufacture, use or disposal of the articulation pose any threat to the bio-sphere?	The steel and iron: if they don't go through a proper recycling process, can damage the biosphere a lot, on the other hand this does not happen with leather. That's why it's important to have the lowest rate of waste and the highest rate of recycling possible.
Society	Will the articulation, if implemented, create jobs?	YES

	Are plans in place to invest some of this wealth in the local community? If it creates wealth, will it be shared equitably? Does it contribute to human well-being, national and personal self-esteem and pride? es it increase self-sufficiency and resilience? Is the design inclusive, or does it exclude some members of society?	The interesting thing about the project is that in addition to generating work, wealth and being interesting for companies, the project also represents a great importance for the government in its role of providing support to the needy population in view of the low cost of the project when compared to others existing. The society point of view is one of the key features of the project
Economics	What is the cost-benefit balance of the articulation?	A project that, in addition to being cheap, can be used for the purpose of companies and the government to achieve their economic and social goals.
	What subsidies or credits exist to support articulations seen as sustainable?	In many countries, as an example of Brazil, the government provides fiscal incentives for hiring companies that use sustainable and social projects, which always adds a commercial advantage.
Legislation	What legislation or regulatory measures are relevant to the implementation of the articulation? What legislation or regulation bears on the production, use and disposal of the materials of the articulation?	We need to check all legislation regarding the use of materials such as iron, aluminum, steel (the rules regarding the recycling and disposal of those materials). It's important too to check the traffic legislations of each country taking into account the cars modifications
Energy	Does the articulation use energy over its life? What is the source of power?	All energy that will be used must come from the car, which can come from combustion or, in the case of electric cars, from the car battery.

Chapter 4. Wheelchair Project: Reflection and Conclusion

The main objective by creating a project in the mechanical engineering -which link the areas of economic, social and ecological interest- was successfully achieved. We can see how we can apply a methodology in order to find solutions for the industry that solve multiple problems without creating new ones.

Certainly, with greater study efforts in the project area, there would be paths to obtain more suitable materials for the specific production location considering the local legislation, the materials extraction and manufacturing conditions. In addition, there are certainly optimizations in terms of the design of the structure to improve aerodynamics and thus reduce the energy impact. Another point that can always be seen is regarding the choice of material and the tradeoff between mechanical properties and weight which helps to increase fuel consumption.

On the topic: project scale. If a project like this is implemented in the social objectives of the country government, there would certainly be a significant impact. The project was carried out with characteristics that make this purpose possible: the project is simple, inexpensive and feasible to be widely used.

And finally, as already discussed, it will undoubtedly be necessary to verify that the project complies with all traffic legislation, through the changes that would be made to the vehicle.

References

[1] P. M. Banerjee; V. Shastri, SOCIAL RESPONSIBILITY and ENVIRONMENTAL SUSTAINABILITY in BUSINESS, 1st ed. New Delhi: Response Books, 2010.

[2] GAES. "CRS". Green Alternative Energy Assets. https://www.gaea.bg/about-GAEA/corporate-social-responsibility.html (Accessed March 28, 2022);

[3] S.Writer "A Brief History of Corporate Social responsibility (CSR)". Thomas. https://www.thomasnet.com/insights/history-of-corporate-social-responsibility/(Acessed March, 28, 2022);

[4] J. M. Smith, J. C Lucena. "Social responsibility in Engineering Education and Practice: Alignments, Mismatches, and Future Directions", American Society for Engineering Education, 2018

[5] ASME PRESS, "Unwritten Laws of ... Ethics and Change in Engineering Unwritten Laws of ... Ethics and Change in Engineering", The American Society of Mechanical Engineers (ASME), 2015

[6] Michael F. Ashby, "Materials and Sustainable Development". Cambridge University and Granta Design, Cambridge, UK, Coral Universitat politecnica de Catalunya, Spain, 2016

[7] European Commission. "Critical raw materials". EUROPA.EU. https://ec.europa.eu/growth/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en. (Accessed April. 05, 2022).

[8] Social Accountability International, "Responsabilidade Social 8000 Norma Internacional", SAI, UK, 4th edition, 2014. Available: https://sa-intl.org/wp-content/uploads/2020/01/SA8000-2014_Portuguese.pdf

[9] SETHI, S. P.; ROVENPOR, J. L. The Role of NGOs in Ameliorating Sweatshop-like Conditions in the Global Supply Chain: The Case of Fair Labor Association (FLA), and Social Accountability International (SAI). Business and Society Review v. 121, n. 1, p. 5–36, 2016.

[10] KARKOTLI, Gilson Rihan. RESPONSABILIDADE SOCIAL: uma estratégia empreendedora. Tese (Doutorado em Engenharia de Produção) – Pós-Graduação em Engenharia de Produção, UFSC, Florianópolis. 2004

[11] V. M. R Ponte, M.C. Oliveira. A Busca da Qualidade na Responsabilidade Social e Ética e na Divulgação e Auditoria de Relatórios Sociais: A Estrutura AA1000 e a Souza Cruz, Available: http://www.anpad.org.br/admin/pdf/enanpad2002-cab-1026.pdf

[12] Um olhar sustentável sobre o mundo empresarial. “A AA1000- a ferramenta de gestão de stakeholders”. http://www.sustentabilidadecorporativa.com/2010/03/aa1000-ferramenta-de-gestao-de.html (Accessed April. 18, 2022).

[13] DNV “ISO 14001 - Sistema de Gestão Ambiental” . dnv.com.br. https://www.dnv.com.br/services/iso-14001-sistema-de-gestao-ambiental-74433. (Accessed April. 18, 2022).

[14] GHISELLINI, A.; THURSTON, D. L. Decision traps in ISO 14001 implementation process: Case study results from Illinois certified companies, 2005.

[15] ORECCHINI, F. The ISO 14001 certification of a machine-process. Journal of Cleaner Production, v.8, n.1, p. 61 -68, Feb. 2000.

[16] COUTINHO . “RESPONSABILIDADE SOCIAL EM PROJETOS DE CONSTRUÇÃO CIVIL”. Tese (Mestre em Ciências na Área de concentração: Engenharia de Construção Civil e Urbana.) – Mestrado em Engenharia Civil, Escola Politécnica da Universidade de São Paulo, São Paulo, 2019

[17] BSI, “Introdução à OHSAS 18001 - Gestão de Saúde e Segurança Ocupacional” BSI.COM, https://www.bsigroup.com/pt-BR/ISO-45001-Saude-e-Seguranca-Ocupacional/Introducao-a-OHSAS-18001/(Acessed April 18, 2022)

[18] NADAE, J. “Sistemas de gestão integrados como indutor para a sustentabilidade: uma análise do impacto no desempenho das organizações baseado no Triple Bottom Line”. 2016. Tese (Doutorado em Engenharia de Produção) - Escola Politécnica, Universidade de São Paulo, São Paulo, 2016.

[19] INMETRO “ISO 26000 ” inmetro.org.br http://www.inmetro.gov.br/qualidade/responsabilidade_social/iso26000.asp (ac essed april 18, 2022).

[20] Synthesis Engineering Services inc. " What is the Cost Of Change?." Synthesis Engineering Services. https://www.synthx.com/engineering-change-request/ (accessed April, 20, 2022).

[21] "How many Earths? How many countries?" EARTH OVERSHOOT DAY. https://www.overshootday.org/how-many-earths-or-countries-do-we-

need/#:~:text=Here's%20how%20we%20calculate%20that,if%20everyone%20lived%20like%20Americans. ((accessed April, 20, 2022).

[22] WHEELCHAIRFOUNDATION. “Wheelchair Needs In The World” wheelchairfoundation.org. https://www.wheelchairfoundation.org/fth/analysis-of-wheelchair-need/ (accessed May. 08, 2022).

[23] “Vehicle Conversion assembly and Method of Converting a Vehicle”, by J. WATTERS. (2004, Dec.23).US2004/0256827A1[Online].Available:ttps://patentimages.storage.googleapis.com/d3/74/e3/c78cdd3ea3c915/US20040256827A1.pdf

[24] Vehicle Wheelchair Lift. By SCHLOSSER, Kraig James, KITCHIN, Steven Lee. (2017, Mar,28). US 9603759 B2 [Online]. Available: https://patentimages.storage.googleapis.com/5d/b6/3d/347b65fedc6911/US9603759.pdf

[25] Wheelchair vehicle access system, by ZIMMER, Paul H. (2004, May,04. US 6729829 B2 [Online]. Available: https://patentimages.storage.googleapis.com/54/73/4d/c3282c40641230/US6729829.pdf

[26] “Motor Vehicle structure adapted for disabled person using a wheelchair”, by,황철. (1996,Dec.01) KR200153955Y1[Online]. Available: https://patentimages.storage.googleapis.com/1f/20/22/51128ef0679b06/KR200153955Y1.pdf

[27] “Sistema para baixar, levantar e guardar cadeiras de rodas no teto de automóveis", by Hummel, R. (1996, OCT.22) PI9605326-7A2 [Online]. Available: https://www.escavador.com/patentes/513426/sistema-para-baixar-levantar-e-guardar-cadeiras-de-rodas-no-teto-de-automoveis

[28] “Carrier Assembly for a Wheeled Mobility Device”, by S. HOLMES.(2020, Jan 23) US 20200022852[Online].Available:https://patents.google.com/patent/US20200022852A1/en?oq=US+20200022852+

[29] “Driver Accessible Wheelchair Carrier”, by W. WALTHER. (2006, Feb 09). US 2006/0027619 A1[Online].Available:https://patents.google.com/patent/US20060027619A1/en?oq=US+2006%2f0027619+A1+

[30] “Car Top Carrier for Wheelchair”, by B. KOOP.(1983, Mar 15) US4376611A [Online]. Available: https://patents.google.com/patent/US4376611A/en?oq=US4376611A

[31] “Cadeira de rodas com adaptação automotiva”, by SAKO s. d. BR 102013023589-0 A2 [Online]. Available:https://hugepdf.com/queue/propriedade-industrial-revista-rpi-9_pdf?queue_id=-1

[32] “A kind of standing rehabilitation wheelchair car”, by 汪开灿。.(2012, Dec 12). CN106236422B[Online].Available:https://patents.google.com/patent/CN106236422B/en?oq=CN106236422B

[33] P. CAMANHO. Mecânica dos sólidos. “Apostila resistência dos materiais IFSP.” Porto, Porto: Faculdade de Engenharia da Universidade do Porto.

[34] C.C.BERGLER. “Força de fricção”. Available: https://slideplayer.com.br/slide/5103104/. (Accessed April 18, 2022).
[35] R. AGUIAR, “Sistemas óleo hidráulicos ISEL DEM.”. Available: https://pt.slideshare.net/jose180272/3-oleohidraulica-cilindros. (Accessed May. 08, 2022).

[36] GRAUS DE ALUMÍNIO. “Total Matéria”, 2015. Availble:https://www.totalmateria.com/page.aspx?ID=GrausdeAluminio&LN=PT. (Accessed April 18, 2022).

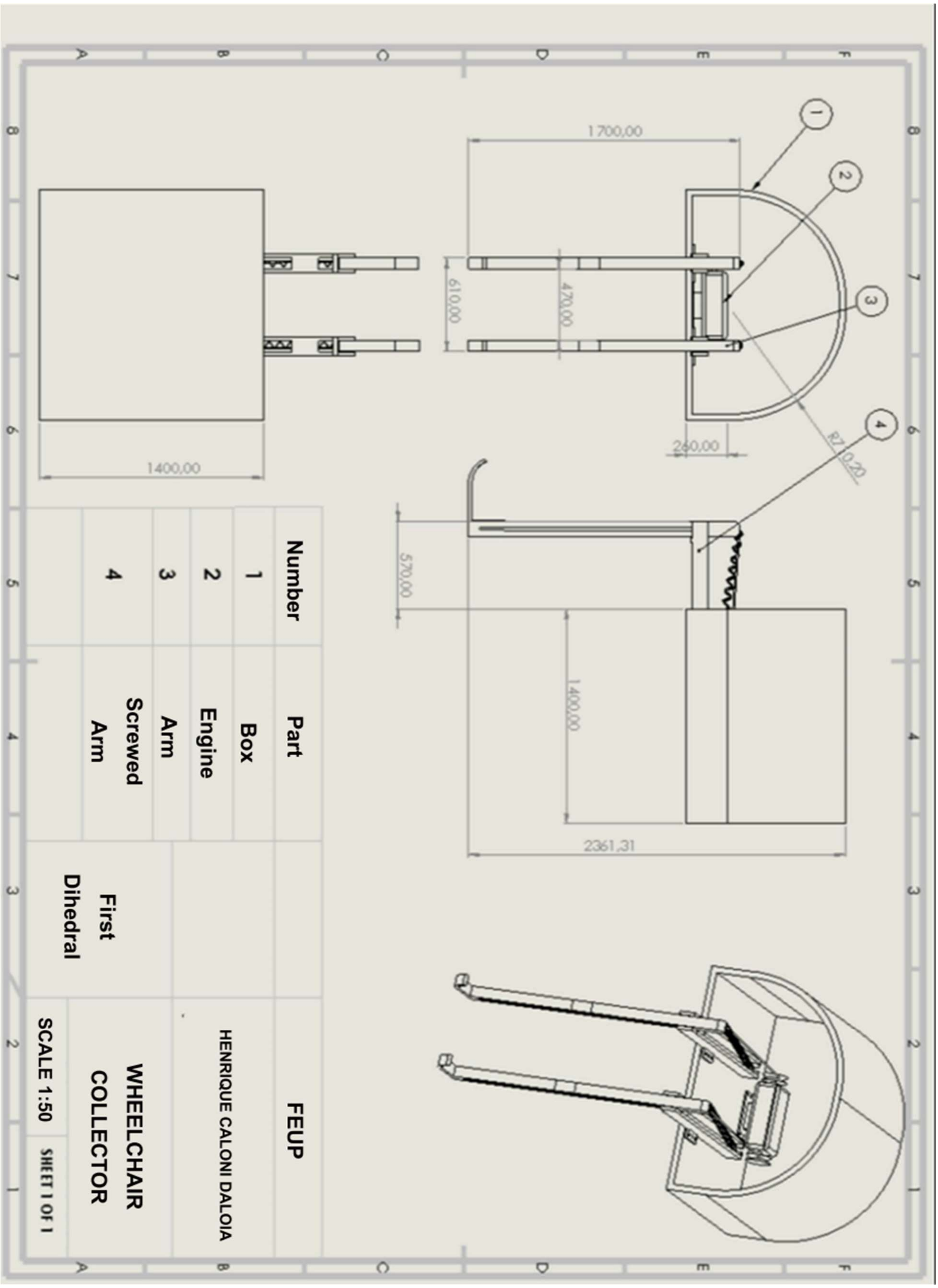
[37] P. HANNIFIN. “Parker's Hydraulic Pump And Power Systems”. Accessed: https://www.mhhydraulics.com/en/brands/parker-hannifin.html (accessed May. 08 , 2022).

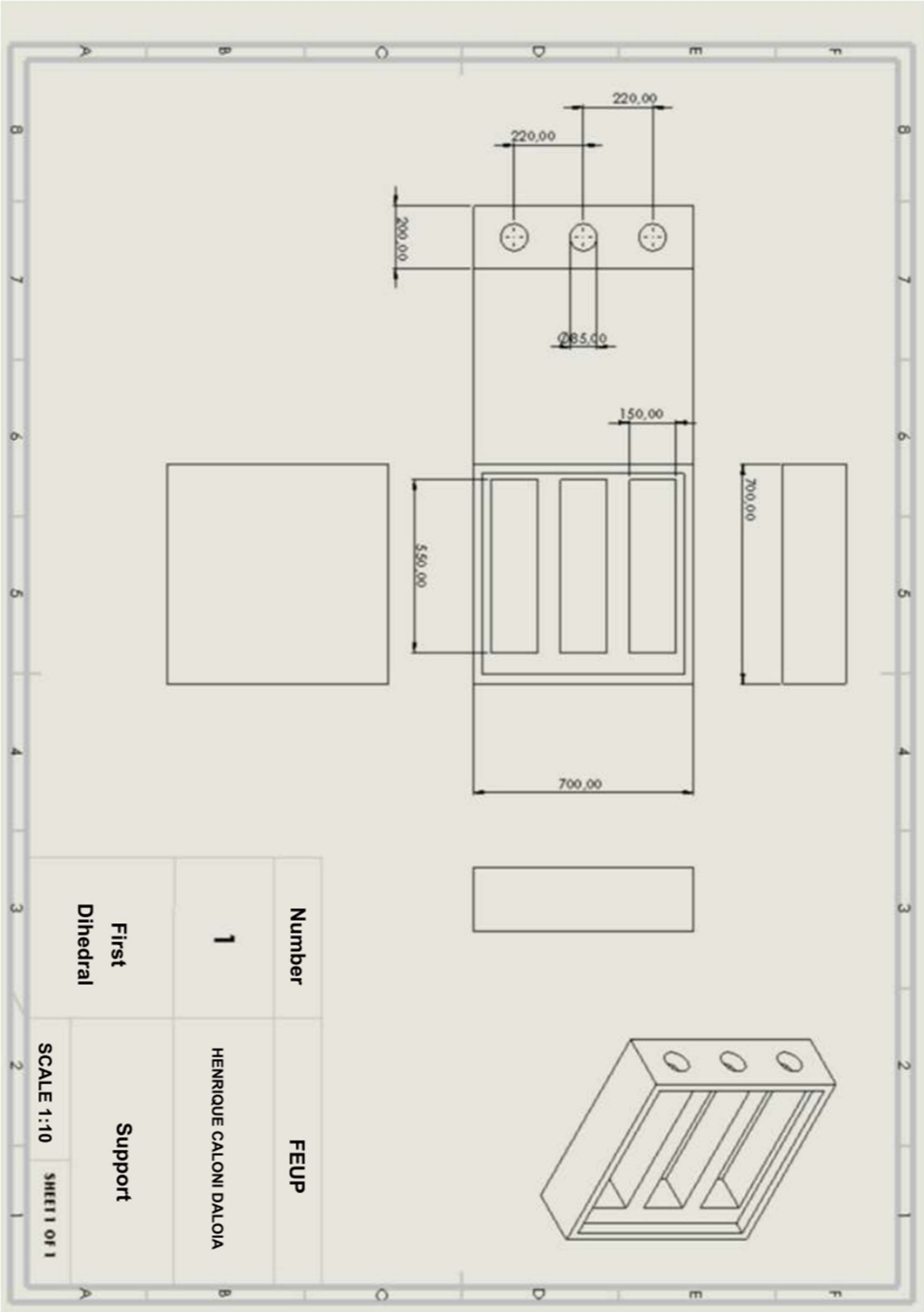
[38] Wagiman, A., Mustapa, M.S., Asmawi, R. et al. “A review on direct hot extrusion technique in recycling of aluminium chips”. Int J Adv Manuf Technol 106, 641–653 (2020). Available: https://doi.org/10.1007/s00170-019-04629-7.(Accessed May. 13, 2022).

[39] W. GETBLOGO. “Why you should recycle scrap metals”. Available: https://getblogo.com/why-you-should-recycle-scrap-metals/. (Accessed May. 23, 2022).

[40] C.M. MOTA. “BIOMECÂNICA, CINÉTICA LINEAR”. Universidade Federal de Santa Maria-Laboratório de Biomecânica. Available: https://slideplayer.com.br/amp/328308/. (Accessed May. 08 , 2022).

Attachments

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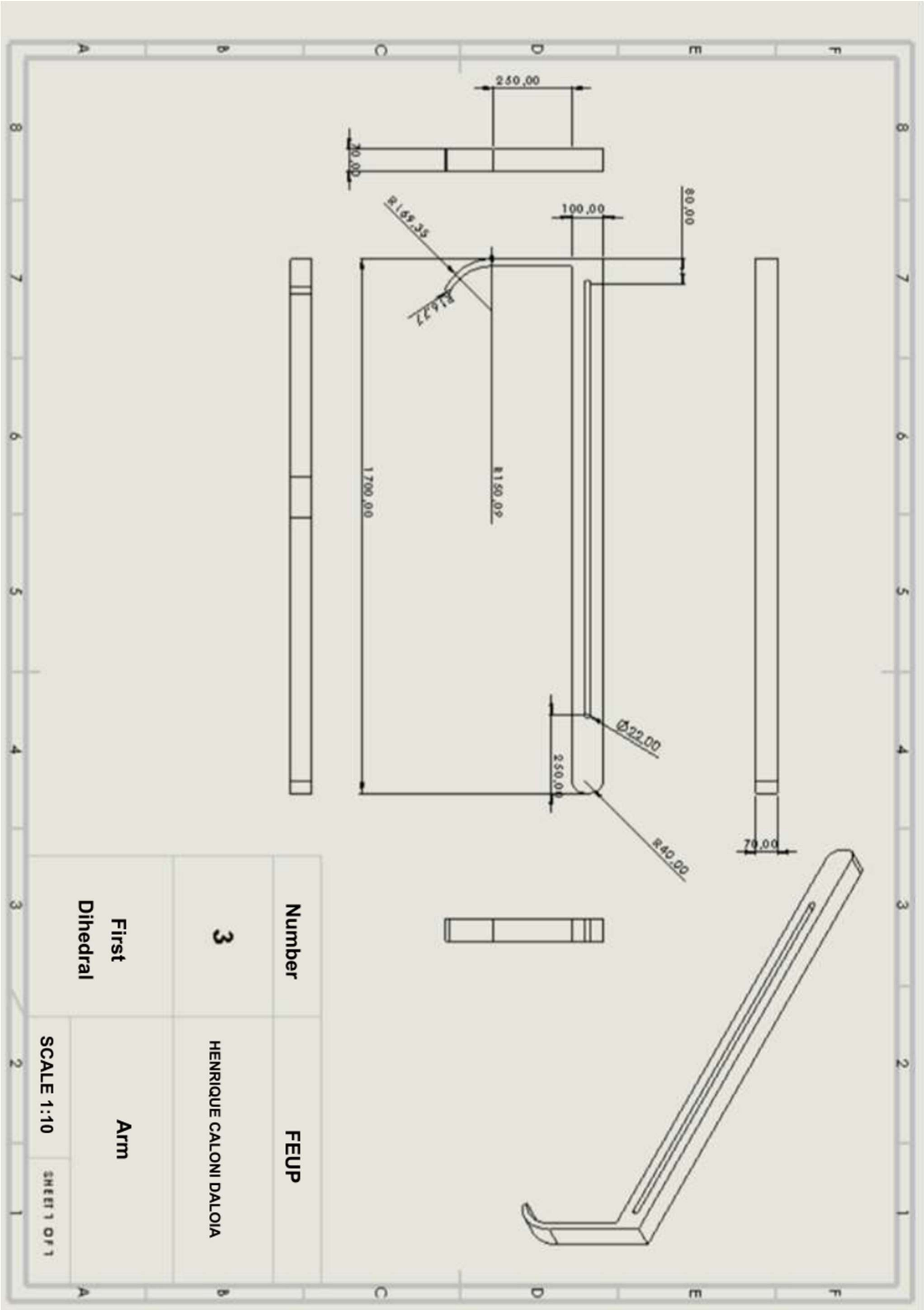

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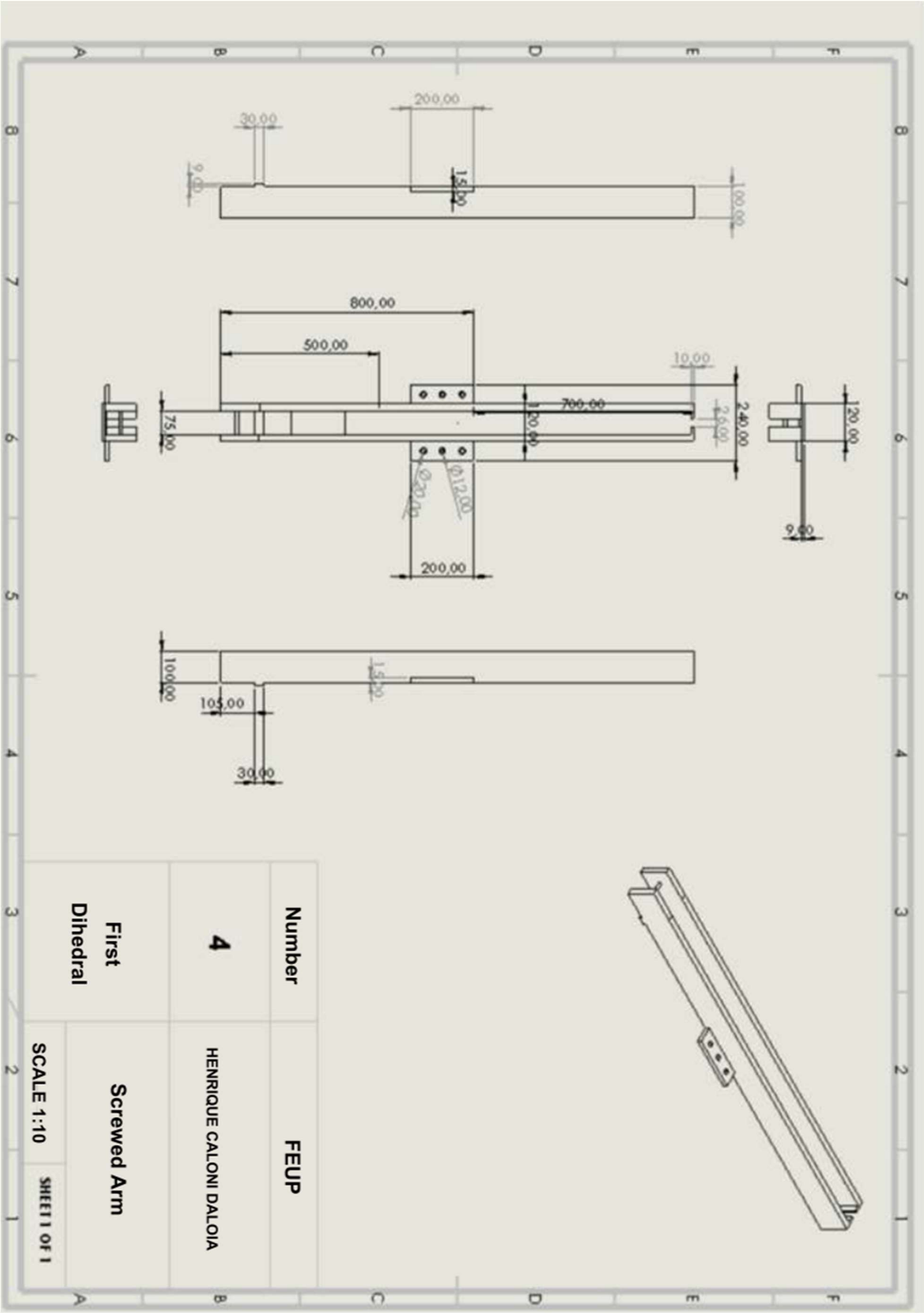
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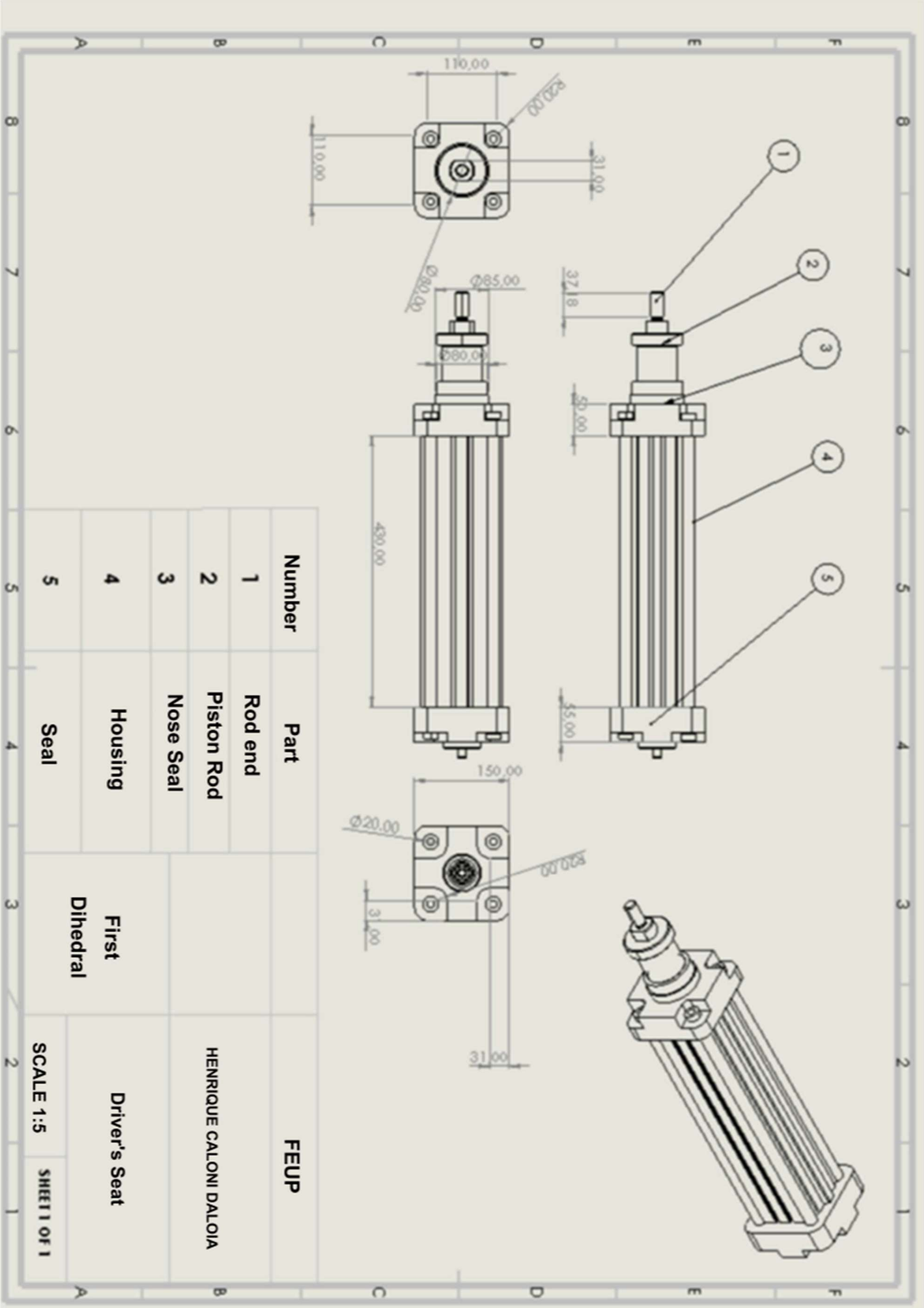

Number
Part
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Rod end
2
Piston Rod
3
Nose Seal
4
Housing
5
Seal
First Dihedral
FEUP
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Driver's Seat
SCALE 1:5
SHEET 1 OF 1
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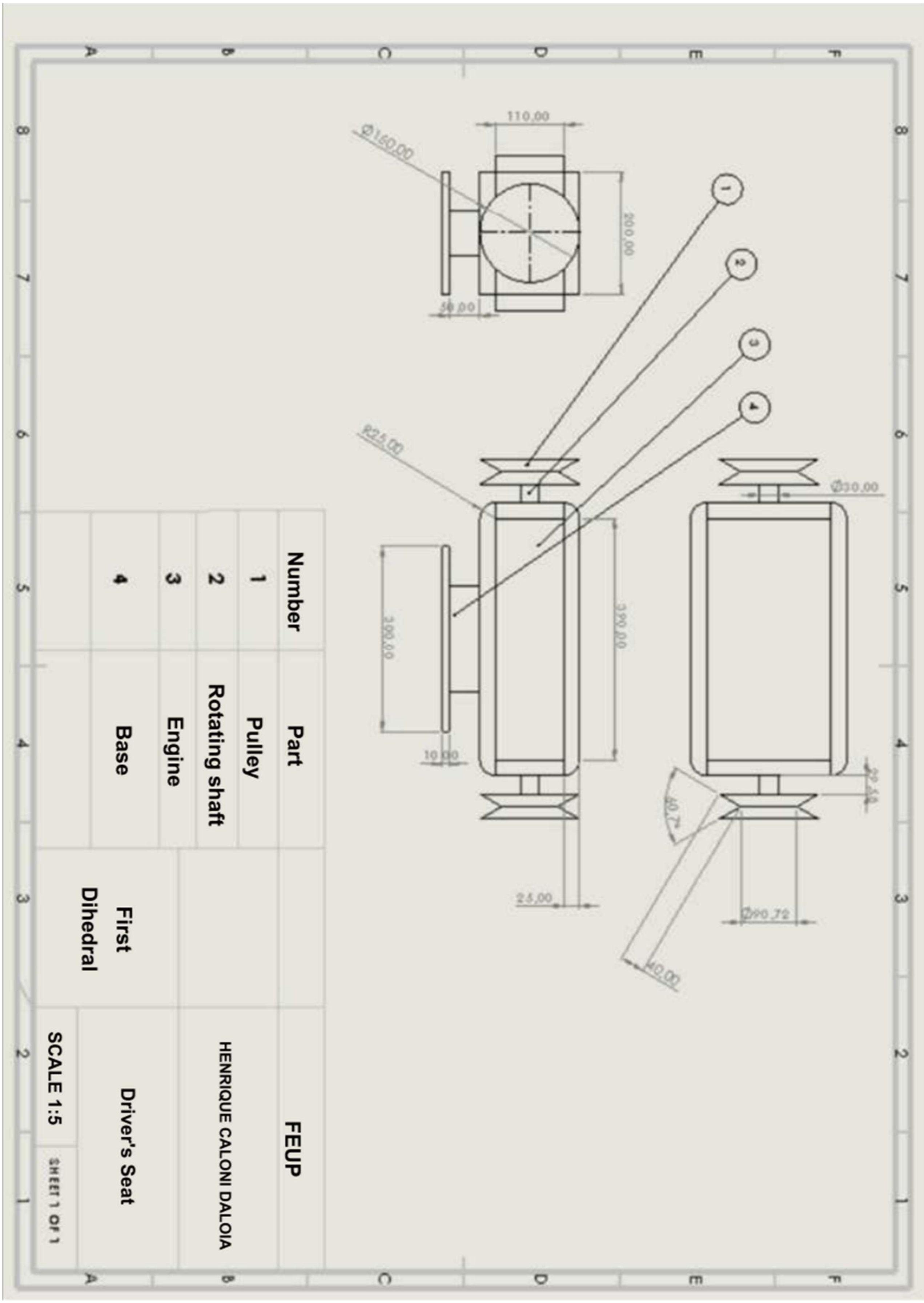
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2
3
4
Part
Pulley
Rotating shaft
Engine
Base
First Dihedral
FEUP
HENRIQUE CALONI DALOIA
Driver's Seat
SCALE 1:5
SHEET 1 OF 1
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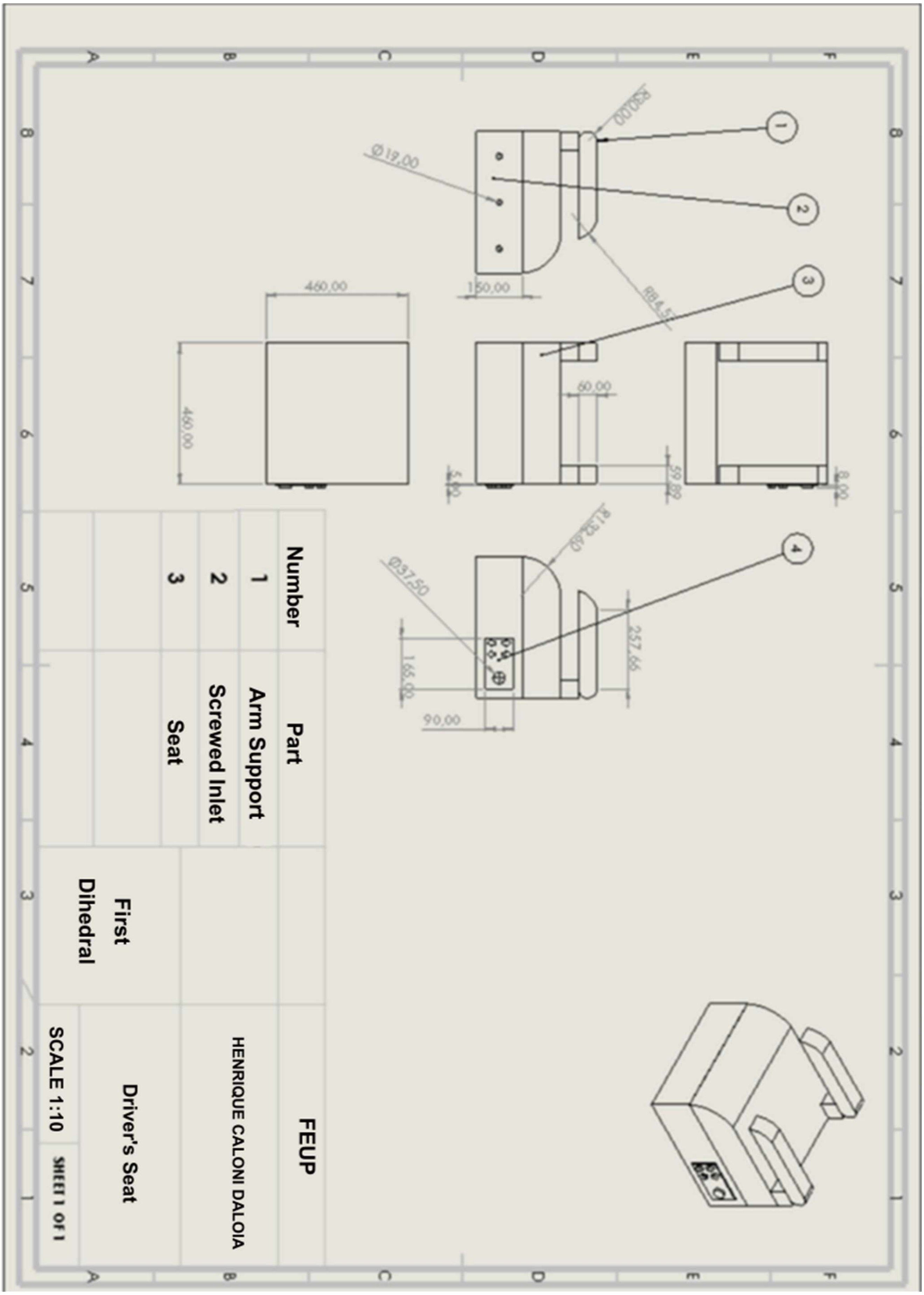
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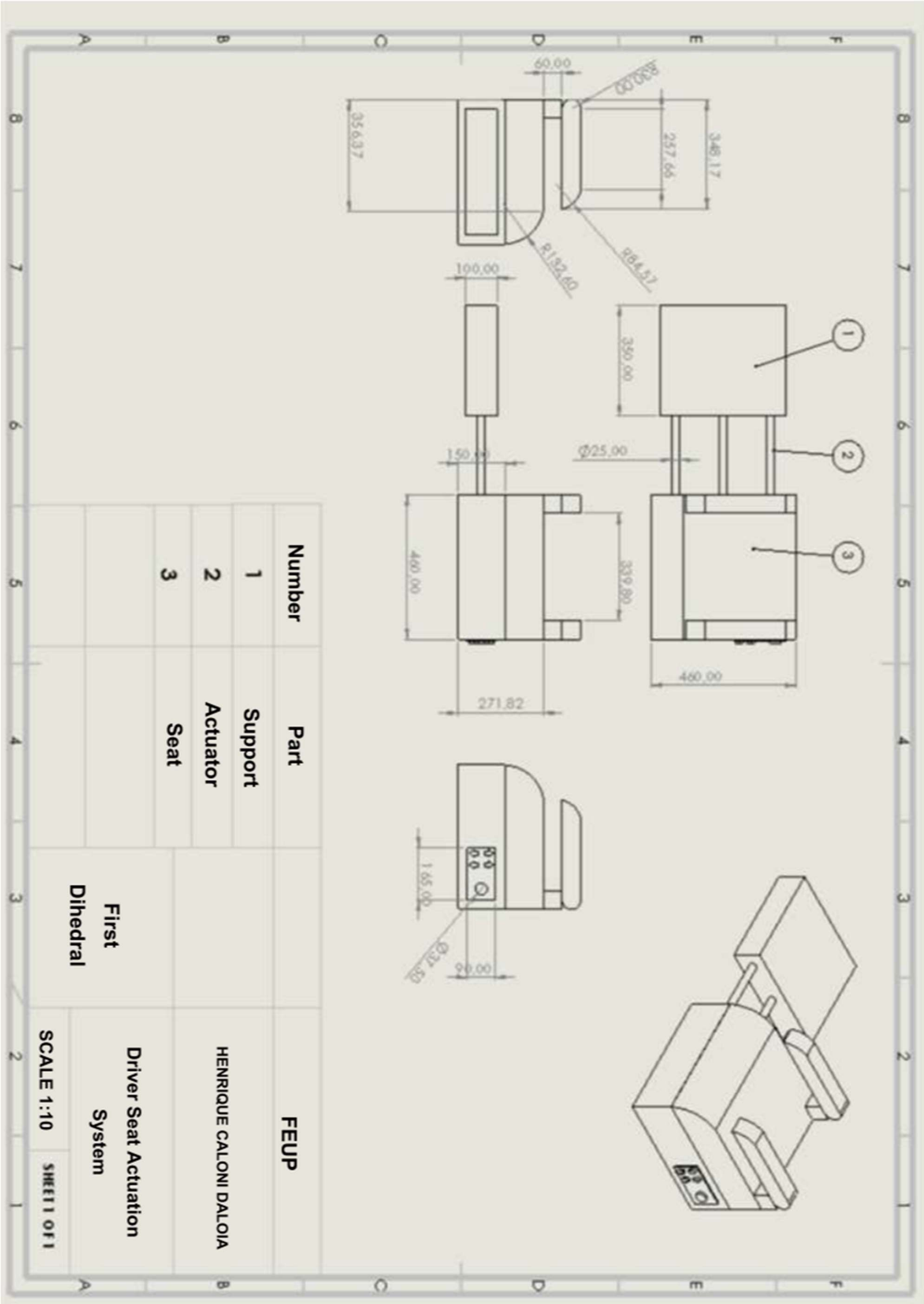

Number
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Driver Seat Actuation System
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SHEET 1 OF 1