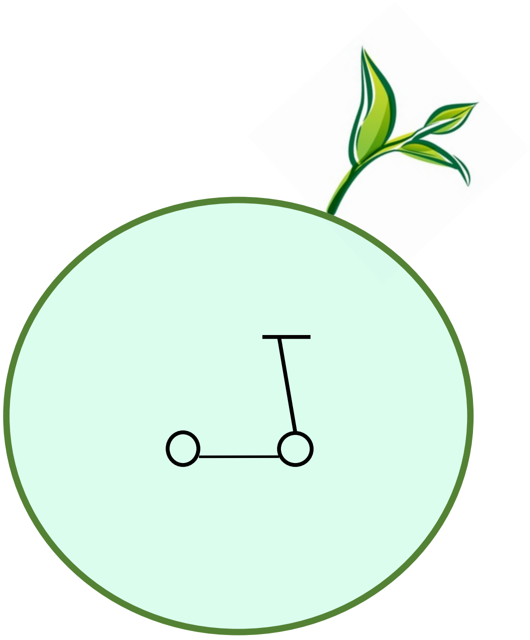
EcoPat



Student Arnau Gabarró Martin

Mentor Philippe Duquenne

Institut National Polytechnique de Toulouse
ENSIACET

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1. Introduction

1.1 Aims and description of the project

This Project aims to design a service based in an eco-friendly mean of transport, electric kick-scooters, devoted to private and public domain. The starting point of this study will be the Toulouse-Labège Campus of INPT.

The main goals of the project, in decreasing order of importance, are the following:

- Sizing of the whole system (number of stations, number of patinettes) depending on the number of users, the number of buildings, the average flows and distances between these buildings.
- Design of the charge stations.
- Design of the electric kick-scooter bodywork.
- Describe the operation of the whole service.
- Seize the economic effort needed and elaborate a Business Plan accordingly.
- Take into account the economic key figures of the whole system CapEx & OpEx.
- Appreciate the key figures ruling the extension of this context to a wider study case.

The last target points out the need for abstraction and for a theoretical approach all along this study, beginning with a literature overview.

1.2 Why should any company or structure invest in this kind of system?

This system must not be seen as a business, but as a service offering eco-friendly mobility to the users of a given domain; this service may be seen as an additional comfort offered to employees. One of the outcomes of this study will be to size the economic effort required by such a service.

We will consider that the main benefits expected from such a system will be the employees' and visitors' comfort and the optimization of people transportation.

Main reasons to invest in electric Patinettes

After this quick glimpse into social and environmental considerations, the main reasons to invest in an electric kick-scooter service are detailed below:

✓ Helps to reduce the Air Pollution levels

This system will attract car users who get stuck every day in traffic jams or simply who find it truly difficult to park in the city. This will led the air pollution levels to drop, so all the inhabitants of the city will benefit from this system.

✓ Helps combat the Climate Change

With less fossil fuel burners running through the city, the levels of greenhouse gas emissions (the main cause of the Climate Change) will drop.

✓ Creates more motivational and eco-responsible jobs

In the process of creating and establishing the system, it is estimated that thousands of jobs will be created. Even once the system has been established, there will be maintaining workers and employees needed to keep running the service in good conditions.

✓ Helps the users to save money in means of transport

Gasoline prices and taxes are constantly rising, and taking into account the planet limited resources of that matter, they will not stop rising. Moreover, there are additional maintaining charges to pay when you own a vehicle.

With the EcoPattinete system the user will not be affected by this kind of money problems. In addition, in order to use this service little money will be required from the user. That leaves the user with a relevant amount of money saved each year.

✓ Improve the level of well-being of the city inhabitants

The EcoPatinette service will bring the society with an efficient and optimized way of transport that will, by all means, ease their daily lives, which is translated in a well-being level improvement.

2. Literature survey

2.1 History of the Kick-scooter[1]

At this point of the project, the kick-scooter history will be fully explained in order to know the evolution and the problems that have been solved, mainly regarding the non-electric kick-scooter.

2.1.1 Definition of the Kick-scooter

The so called kick scooter, push scooter or scooter is a human-powered land vehicle with a handlebar, deck and wheels that is propelled by a rider pushing off the ground. The most common scooters today are made of aluminium, titanium and steel. Some kick scooters that are made for children have 3 or 4 wheels and are made of plastic or do not fold.

Motorized scooters, historically powered by gas engines, and more recently electric motors, are self-propelled kick scooters capable of speeds of around 30 km/h.

2.1.2 Early scooters

It is a real fact that kick-scooters have been handmade in industrial urban areas in Europe and the U.S. for at least 100 years, often as play items made for children to roam the streets. One common home-made version is made by attaching roller skate wheel sets to a wood board and finally adding some kind of handlebar (see *Figure 2.1*)

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[1] https://en.wikipedia.org/wiki/Kick_scooter#cite_note-6

https://thegioitienganhvietnam.wordpress.com/history-about-kick-scooter/

Figure 2.1 *Wooden scooter model (around 100 years ago).*

After a quick search in the German "*Bundesarchiv*"[2] for "roller" reveals both homemade and manufactured children's scooters used and even raced in Paris, Berlin and Leipzig in 1930, 1948 and 1951. After all, they did not defer much from modern designs.

2.1.3 Honda Kick 'n Go

In 1974 the Honda company made the Kick 'n Go, a scooter driven by a pedal on a lever. As it can be seen in *Figure 2.2*, unlike the early kick-scooters, the Kick 'n Go was powered by kicking a pedal who at the same time powered the wheel by means of a chain. Moreover, since it was a vehicle especially made for children, an extra wheel was added at the front in order to provide more stability. The front section actually pivoted to the left and right allowing the user to lean their weight to whichever direction they needed to go.

While it seemed to be as much effort to "kick" as a regular scooter, the novelty of it caught on and it became popular nevertheless.

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[2] *http://www.bild.bundesarchiv.de*

Figure 2.2 *Kick 'n Go from Honda (1974).*

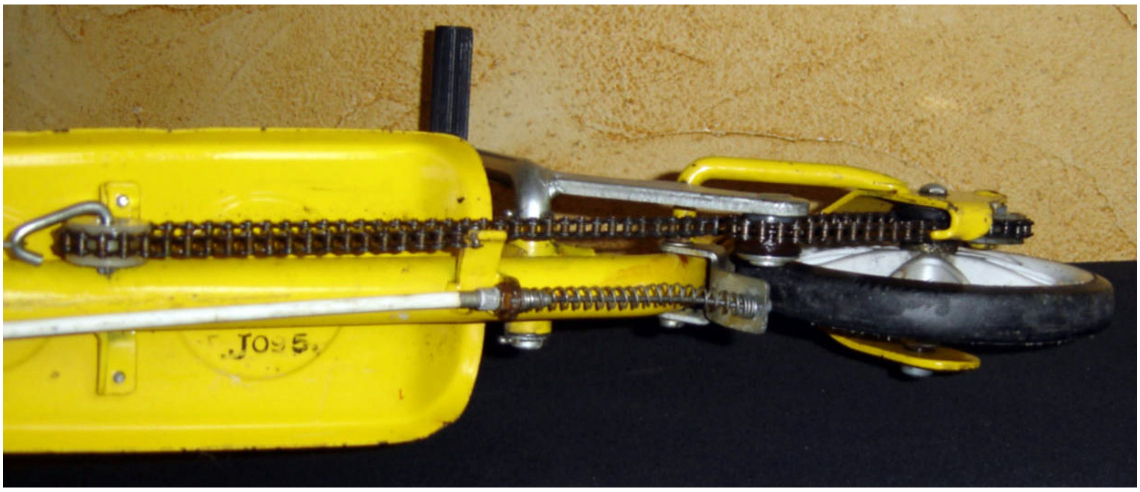

Figure 2.3 *Kick 'n Go mechanical propulsion overview (rear wheel from below).*

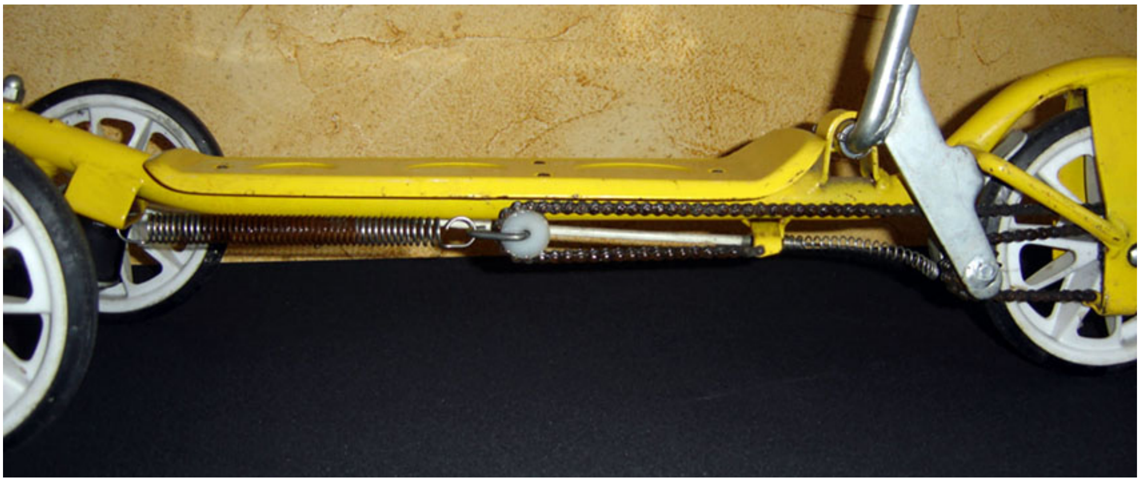

Figure 2.4 *Kick 'n Go mechanical propulsion overview (from the left side).*

Figure 2.5 *Kick 'n Go advertisement commercial (1974).*[3]

The dreaded 45 kg (100lb) weight limit sticker proved to be a downer for most older kids or young teenagers who wanted to try them. To combat this, Honda released a Kick 'N Go 2 (US Only) in 1976 for teenagers alongside a Kick 'N Go Senior (GOGO7) for adults.

After a successful launch of the Kick 'N Go 2 and Senior models, Honda was in development of the Kick 'N Go VII in 1976, a much larger and more adult oriented version. During its prime, the unthinkable happened when 2 kids died in an accident associated with the Kick 'N Go in the spring of '76. Honda executives quickly responded with pulling the sales of the product and ceasing production all together. Acquisitions soon surfaced that Honda had created a dangerous product for kids.

2.1.4 Kick-scooters with pneumatic tires

Even maybe it is difficult to believe, before bicycles became popular among children, steel scooters with two small bicycle wheels had been the most useful vehicles for them.

Around 1987, many BMX manufacturers produced kick scooters with pneumatic tires, with a handlebar structure really similar to the BMX's (see *Figure 2.6*)

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[3] *http://hondaroots.com/2015/01/21/honda-kick-n-go-scooter/*

Figure 2.6 *GT Zoot Scoot 14 (1987).*[4]

Those manufacturers discontinued their scooters, but some scooter manufacturers were established after years, and still develop similar scooters today. Some are used in dense urban areas for utility purposes, being faster than a folding scooter and more convenient than a utility bicycle. Some are made for off-road use and are described as Mountain Scooters. Besides commuting, sports competition and off-road use, large wheel scooters are used for dog scootering where single or team dogs such as huskies pull a scooter and rider in the same way that a sled is pulled across snow. Besides, some Amish are not allowed to ride bicycles, so they ride scooters instead.

Figure 2.7 *Amish using pneumatic-wheeled kick-scooters.*[5]

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[4] https://bmxmuseum.com/bikes/gt_bicycles/28678

[5] https://magdalenaperks.wordpress.com/2011/05/15/amish-scooters-again/

2.1.5 Kickbike

The kick bike is a larger variation of the model just presented in the last point. The development of the kickbike in Finland in 1994 changed the way kick-scooters are viewed.

The Kickbike has a large standard size bicycle front wheel and a much smaller rear wheel, allowing a much faster ride. The Kickbike is regarded as the leading dog scooter in the world (see *Figure 2.9*)

Figure 2.8 *Example of a Kickbike from Kickbike.*[6]

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[6] *https://kickbike.com*

Figure 2.9 *Example of a Kickbike pulled by dogs.*

2.1.6 Folding scooters

Finally, in 1996, the famous foldable aluminium scooter with inline skates wheels was created by Wim Ouboter of Micro Mobility Systems in Switzerland. The scooter was sold as "Micro Skate Scooter", "Razor" and "JDBUG/JDRAZOR MS-130A".

After the Razor was introduced to Japan in 1999, many youngsters in Tokyo began to use it as a portable transporter and then it became famous around the world. Moreover, this small kick-scooters still became popular toys for children.

Figure 2.10 *JD Razor kick-scooter developed by Micro mobility Systems and manufactured by JD Corporation.*[7]

From this last model, the kick-scooter did not make relevant changes in its main structure. Some of their parts have been reinforced and redesigned to practice what it is called "Stunt scootering", using the kick-scooter to perform tricks and even compete in official extreme sports competitions. However, the kick-scooters used to perform "Stunt scootering" are not foldable.

2.1.7 Electric scooters[8]

Even though the born date of electric kick-scooters is a bit blurry, it is known that they have surpassed gas engined scooters in popularity since the year 2000. This was mainly due to a number of instances, stemming from accidents on petrol powered scooters.

The electric scooter will revolutionise public transport around the world. In fact, nowadays we can already see how more and more people are using electric kick-scooters to carry out their city displacements. The cost to run these scooters is very little, in comparison to a petrol model. Not to mention the cost to the

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[7] https://web.archive.org/web/20100831235000/http://www.razor.co.jp/item.php?action=dt&no=10010&category=1

[8] https://www.myproscooter.com/history-of-the-motorized-scooter/

environment, by running these small electric modes of transport, around major cities.

They are quiet, quick and can be limited to a maximum speed of 30 km/h. Much safer than the previous gas models.

The several parts of the electric kick-scooter will be fully discussed and studied in the following points.

2.2 Types of electric kick-scooters nowadays

At this point, the most efficient and most recent adult electric kick-scooters will be presented and detailed. Since the service that is going to be designed in this project is thought to be for teenagers and adults (14+), the focus is only going to be set in adult kick-scooters.

It is true that one of the objectives of this project is to design a kick-scooter from scratch, but it is truly important to first carry out a market analysis to see what kind of electric kick-scooters exist nowadays and which is the price in what they have to offer.

2.2.1 Nineboot ES1[9]

The Nineboot ES1 is the first kick-scooter model of a series of 2 scooters from Segway so far. To make easier the explanation, a chart with the main technical characteristics will be shown (see *Table 2.1*).

Concept	Technical information
Wheels	Front wheel: Solid rubber
	Rear wheel: Solid rubber
Output power	250 W
Max distance range	25 km
Max speed	20 km/h
Max weight	100 kg
Max ascending range	5,71 ° (10%)
Frame material	

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[9] https://www.youtube.com/watch?v=F7ubaNOQOtY

http://fr-fr.segway.com/products/ninebot-by-segway-kickscooter-es1

Resistance	IP54 (dust and splash resistance)	
Brake system	Front: Electronic	
	Rear: Physical (friction)	
Shock absorber	Front	
Battery	Li-Ion	Energy= 187 Wh
		Charging time= 3,5 h
Weight	11,3 kg	
PRICE	**499 €**	

Table 2.1 *Nineboot ES1 specifications.*

Figure 2.11 *Nineboot ES1 by Segway.*

2.2.2 Nineboot ES2[10]

Most recently a more powerful version of Nineboot ES1 has come to the market, the Nineboot ES2. The main differences between the two of them is the power, the maximum speed and an additional shock absorber at the rear. Here below are the detailed specifications.

Concept	Technical information
Wheels	Front wheel: Solid rubber
	Rear wheel: Solid rubber

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[10] https://www.youtube.com/watch?v=oj62G_1r278

http://fr-fr.segway.com/products/ninebot-by-segway-kickscooter-es2

Output power	300 W	
Max distance range	25 km	
Max speed	25 km/h	
Max weight	100 kg	
Max ascending range	5,71 ° (10%)	
Frame material		
Resistance	IP54 (dust and splash resistance)	
Brake system	Front: Electronic	
	Rear: Physical (friction)	
Shock absorber	Front and rear	
Battery	Li-Ion	Energy= 187 Wh
		Charging time= 3,5 h
Weight	12,5 kg	
PRICE	599 €	

Table 2.2 *Nineboot ES2 specifications.*

Figure 2.12 *Nineboot ES2 by Segway.*

2.2.3 Xiomi M365[11]

Xiaomi has produced his own electric scooter as well, called M365.

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[11] https://www.youtube.com/watch?v=BCVQ976stKE

http://www.mi.com/us/mi-electric-scooter/specs/

<table>
<tr><th>Concept</th><th colspan="2">Technical information</th></tr>
<tr><td rowspan="2">Wheels</td><td colspan="2">Front wheel: Inflated rubber tire</td></tr>
<tr><td colspan="2">Rear wheel: Inflated rubber tire</td></tr>
<tr><td>Output power</td><td colspan="2">250 W</td></tr>
<tr><td>Max distance range</td><td colspan="2">25 km</td></tr>
<tr><td>Max speed</td><td colspan="2">25 km/h</td></tr>
<tr><td>Max weight</td><td colspan="2">100 kg</td></tr>
<tr><td>Max ascending range</td><td colspan="2">8 ° (14%)</td></tr>
<tr><td>Frame material</td><td colspan="2"></td></tr>
<tr><td>Resistance</td><td colspan="2">IP54 (dust and splash resistance)</td></tr>
<tr><td rowspan="2">Brake system</td><td colspan="2">Front: Electronic</td></tr>
<tr><td colspan="2">Rear: Mechanical (Brake lever - Discs)</td></tr>
<tr><td>Shock absorber</td><td colspan="2">Front and rear</td></tr>
<tr><td rowspan="2">Battery</td><td rowspan="2">Li-Ion</td><td>Energy= 192 Wh</td></tr>
<tr><td>Charging time= 5 h</td></tr>
<tr><td>Weight</td><td colspan="2">12,2 kg</td></tr>
<tr><td>PRICE</td><td colspan="2">450 €</td></tr>
</table>

Table 2.3 *Xiaomi M365 specifications.*

Figure 2.13 *Xiomi M365.*

2.2.4 Zoom Stryder[12]

Concept	Technical information	
Wheels	Front wheel: Solid rubber	
	Rear wheel: Solid rubber	
Output power	500 W	
Max distance range	28 km	
Max speed	30 km/h	
Max weight	100 kg	
Max ascending range	14,04 ° (25%)	
Frame material		
Resistance	IP54 (dust and splash resistance)	
Brake system	Front: Electronic	
	Rear: Physical (friction)	
Shock absorber	Front and rear	
Battery	Li-Ion	Energy= 215 Wh
		Charging time= 2 h
Weight	10,9 kg	
PRICE	600 €	

Table 2.4 *Zoom stryder specifications.*

Figure 2.14 *Zoom stryder.*

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[12] https://www.youtube.com/watch?v=e6phdEF67fM

https://www.ridezoom.co/es/

2.2.5 Inmotion L8F[13]

Concept	Technical information
Wheels	Front wheel: Solid rubber
	Rear wheel: Inflated rubber tire
Output power	350 W
Max distance range	30 km
Max speed	30 km/h
Max weight	100 kg
Max ascending range	15 ° (26,8%)
Frame material	
Resistance	IP54 (dust and splash resistance)
Brake system	Front: Electronic
	Rear: Physical (friction)
Shock absorber	Front and rear
Battery	Li-Ion Energy= 313 Wh Charging time= 5 h
Weight	11,7 kg
PRICE	690 €

Table 2.5 *Inmotion L8F specifications.*

Figure 2.15 *Inmotion L8F.*

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[13] http://www.inmotion-france.fr/L8.php

2.2.6 Overall comparison

Concept	**Xiaomi M365**	**Nineboot ES1**	**Nineboot ES2**	**Zoom Stryder**	**Inmotion L8F**
Wheels	Front wheel: Inflated rubber tire	Front wheel: Solid rubber	Front wheel: Solid rubber	Front wheel: Solid rubber	Front wheel: Solid rubber
	Rear wheel: Inflated rubber tire	Rear wheel: Solid rubber	Rear wheel: Solid rubber	Rear wheel: Solid rubber	Rear wheel: Inflated rubber tire
Nominal power	250 W	250 W	300 W	500 W	350 W
Max distance range	25 km	25 km	25 km	28 km	30 km
Max speed	25 km/h	20 km/h	25 km/h	30 km/h	30 km/h
Max weight	100 kg	100 kg	100 kg	100 kg	100 kg
Max ascending range	8 °	5,71 °	5,71 °	14 °	15 °
Resistance	IP54 (dust and splash resistance)	IP54 (dust and splash resistance)	IP54 (dust and splash resistance)	IP54 (dust and splash resistance)	IP54 (dust and splash resistance)
Brake system	Front: Electronic	Front: Electronic	Front: Electronic	Front: Electronic	Front: Electronic
	Rear: Mechanical (Brake lever)	Rear: Physical (friction)	Rear: Physical (friction)	Rear: Physical (friction)	Rear: Physical (friction)
Shock absorber	Front and rear	Front	Front and rear	Front and rear	Front and rear
Battery (Li-Ion)	Energy= 192 Wh	Energy= 187 Wh	Energy= 187 Wh	Energy= 215 Wh	Energy= 313 Wh
	Charging time= 5 h	Charging time= 3,5 h	Charging time= 3,5 h	Charging time= 2 h	Charging time= 5 h
Weight	12,2 kg	11,3 kg	12,5 kg	10,9 kg	11,7 kg
PRICE	**450 €**	**499 €**	**599 €**	**600 €**	**690 €**

2.3 Parts of an electric kick-scooter

2.3.1 Batteries

Clearly, without a battery, even the best adult electric kick-scooters will not travel very far. As the source of power, the batteries are a key component and directly affect the reliability and general functionality of any electric vehicle. There are several types and technologies available, some older than others. Here are the main types of batteries existing nowadays, from the oldest to the youngest.

- Sealed Lead Acid Battery (SLA)
- Nickel Metal Hydride Battery (NiMH)
- Lithium Ion Battery (Li-ion, LFP, LiPo)
- Graphene Batteries (*Still in research phase*)

Sealed Lead Acid Battery (SLA)

These types of batteries have been in the market now for many years. They are the standard type of battery that you will find in any car or truck. Since they can generate a very high current required for starting an engine, the auto industry has been relying on them for years.

Because they are the oldest type, they were also the first to be used in electric scooters when they first came about. Even today, they continue to be the most popularly used batteries in many electric scooters because of their sheer power.

The main drawback of the SLA battery is their heavy weight (2,62 kg/L[14]). That said, they are less expensive compared to NiMH batteries and they are also readily available. That is the main reason they continue being used in electric bikes and scooters.

It is worth noting that how long a sealed acid battery lasts really depends on the surrounding temperatures as well as its size and quality.

Nickel Metal Hydride Battery (NiMH)

Just like the SLA batteries, the NiMH batteries have been around for a very long time. Their name explains their chemical composition. They are comparably

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[14] *https://en.wikipedia.org/wiki/Lead-acid_battery*

lighter than sealed lead acid batteries, and thanks to them being lightweight as well as more advanced, the NiMH are pretty expensive.

The NiMH batteries tend to be created specifically for the electric scooter that they come with. It is also important to know that while these kinds of batteries are more expensive than the sealed lead acid batteries, they are also thirty percent lighter than typical sealed lead acid batteries and last longer than a normal sealed lead acid battery.

Lithium Ion Battery (Li-ion, LFP, LiPo)

Lithium ion batteries are a fairly recent development in the industry and, as a result, are the most expensive. They've begun taking the market by storm because of the new features they provide. They have a major advantage over other types of batteries because they are the lightest type on the market today, but not for so long, as graphene batteries are knocking at our door.

Coupled with the fact that they last about three times longer than a regular Sealed Lead Acid (SLA) battery, they are very attractive to electric scooter manufacturers. They weigh a little less than NiMH batteries and are half the weight of sealed lead acid batteries.

There are other factors that make Li-ion battery tech so popular: They require less maintenance when not in use, they do not suffer from the "battery memory" problem that NiMH batteries do and you can basically ignore them for long stretches of time without a problem.

As a result of these significant advantages Li-ion batteries are turning up in all sorts of places. However, on the downside, their price is often much higher than that of the sealed lead acid battery and NiMH battery. In fact, with modern electric scooters a large part of the price is likely to be the cost of the battery, especially if they are NiMH.

Types of Lithium-ion Batteries

There are a couple of sub-types of Li-ion batteries and each one offers its own advantages over standard Li-ion types.

Lithium FerroPhosphate (LFP)

These batteries have a longer life than standard Li-ion's and are generally regarded as significantly safer. The higher quality electric scooters will have an LFP battery but they will cost a lot more.

Lithium Polymer (LiPo)

The LiPo battery is a type of Li-ion that is generally manufactured in a pouch format as opposed to the traditional cell format. They are useful in Electronic gadgets and electric scooters because of their small and flat shape.

Graphene Batteries (*Still in research phase*)

Graphene is seemingly the next generation material, it is 200 times stronger than steel and 6 times lighter. It is even harder than Diamond. Moreover, it can be stretched to a quarter of its length and it can also conduct heat 10 times better than copper. That being said, the better quality of this two-dimensional material is its conductivity and its energy density. In the following figure (*Figure 2.16*) it can be seen an energy density comparison between the different types of batteries that have been presented so far.

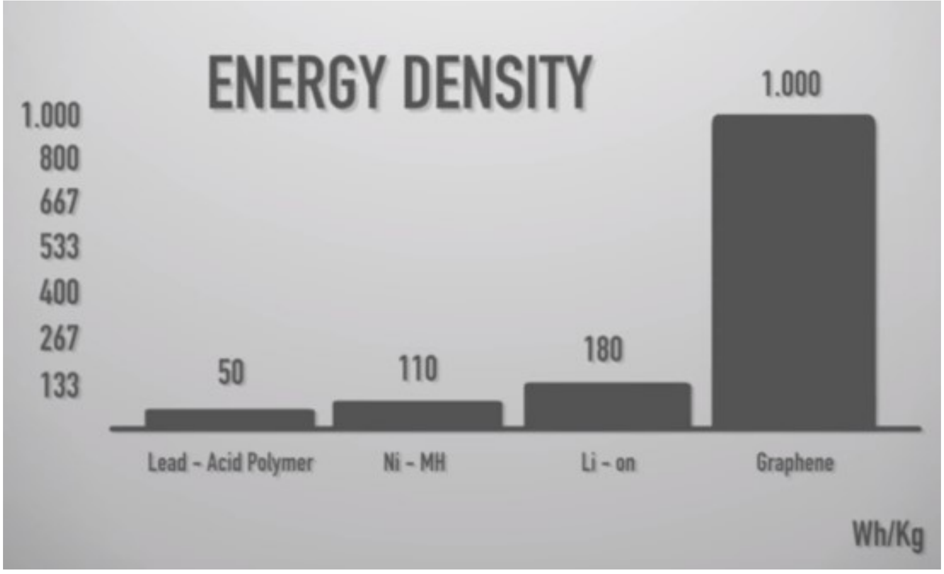

Figure 2.16 *Energy density comparison between types of batteries.*[15]

Despite there are already pure graphene batteries for mobiles or power banks available to buy in the market, they are not still developed enough to be

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[15] *http://www.autoracing1.com/rumors.asp?tid=23411*

produced and installed in an electric vehicle, that is why this type of batteries will not be taken into account for this project.

In order to give a broader, more precise and clarifying perspective of the 3 batteries we can chose for our EcoPatinette, the next table gather their main technical characteristics.

	SLA	**NiMH**	**Li-ion**
Energy density [Wh/kg]	30-50	60-120	150-250
Cost for 1000 mAh [€]	41€	29 €	123 €
Cost per kWh [€/kWh]	50 [16]	70	138 [17]
Cycle life [80% of DoD] [x]	200-300	300-500 [y]	500-1000
Charge time 0 to 100% [h]	8-16	2-4	2-4
Easiness of recycling	High (USA: 99% recycled between 2003 and 2013)	High (100% recyclable)	Low (100% recyclable but very expensive. Not done because € Recycled lithium = 5 x € Mined lithium)
Maintenance	Topping charge every 3 – 6 months (to prevent sulfation)	Discharging every 60 - 90 days	No

[x] Cycle life is based on the depth of discharge (DoD). Shallow DoD prolongs cycle life.

[y] Cycle life is based on battery receiving regular maintenance to prevent memory.

Table 2.1 *Battery technical comparison.*[18]

It is important to state that it is difficult to precise the exact price of these batteries as it is constantly changing. Take a look, for instance, at the price decreasing through the past years for the Li-ion batteries in the next graphic (*Figure 2.17*).

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[16] *https://medium.com/solar-microgrid/battery-showdown-lead-acid-vs-lithium-ion-1d37a1998287*

[17] *https://data.bloomberglp.com/bnef/sites/14/2017/07/BNEF-Lithium-ion-battery-costs-and-market.pdf*

[18] *http://batteryuniversity.com/learn/article/secondary_batteries;*
http://materiaislamica.com/index.php/File:Rechargeable-battery-comparison-table.jpg;
http://batteryuniversity.com/learn/archive/the_cost_of_portable_power;
https://en.wikipedia.org/wiki/Lead-acid_battery#Recycling
https://www.sciencedirect.com/science/article/pii/S0378775305014527
https://en.wikipedia.org/wiki/Battery_recycling#Lithium_ion_batteries

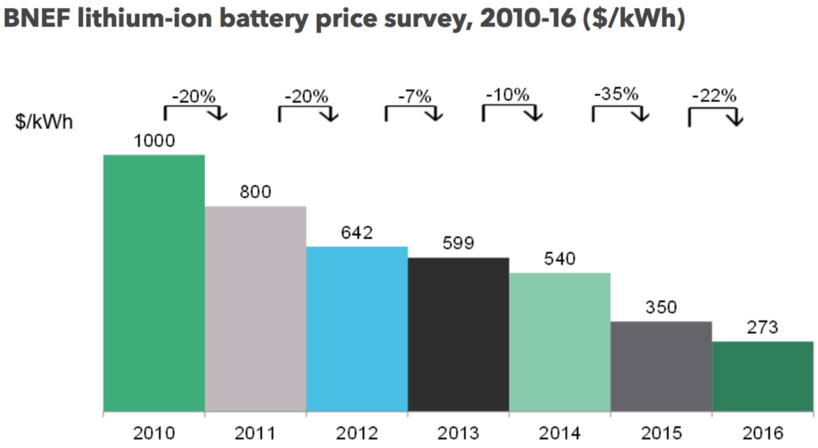

Figure 2.17 *Lithium-ion price survey.*[19]

2.3.2 Wheels

The type of wheels used in a kick-scooter have evolved from small skater wheels to inflated tires. Nowadays there are mainly two types of wheels that can be used for an electric scooter: The solid polyurethane wheels or the inflated tires. The wheel choosing will depend in what kind of performance we expect from them.

Figure 2.18 *Polyurethane kick-scooter wheels.*

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[19] *https://cleantechnica.com/2017/12/11/batteries-keep-getting-cheaper/*

Figure 2.19 *Inflated kick-scooter wheels.*

The main difference between the two types of wheels is that the inflated ones provide an extra cushioning, which can be really useful for uneven and irregular paths. The main drawback of this type of wheels is that they are exposed to possible tire punctures. Regarding the PU wheels, they have been used in skateboard, inline-skate and roller-skate (quad) wheels for decades. It is light, wear-resistant, has a reasonable amount of grip (when dry), and rebound (the ability to return to its original shape after momentary compression due to weight or pressure).

Regarding the size of the wheel, it will depend, again, on the expected performance of the kick-scooter. Here are the main advantages and disadvantages of each wheel size:

Small wheels (100-145 mm)		Large wheels (180-230 mm)	
Advantages	Disadvantages	Advantages	Disadvantages
Lightweight (usually below 4kg)	Shorter glide distance per push	Longer glide distance per push	Heavier to carry around (typically 4 to 6,5 kg)
More agile (easier to speed up and down)	Transmits more vibrations from the ground	Better shock absorption	It takes more space
Better and faster response when avoiding objects	Higher chance of wheels catching on random objects or cracks	Safer to roll over small objects	Less agile (takes more effort to accelerate and avoid objects)

Table 2.2 *Advantages and disadvantages of small and large wheels.*

In conclusion, larger wheels are appropriate to go faster and more comfortable (less vibrations) but make the scooter less convenient to lug around. On the other hand, smaller wheels are more portable (lightweight) but are slower and less comfortable (more vibrations).

2.3.3 Braking system

When talking about kick-scooters braking systems, there are three main types: Physical, Electronic or Mechanical.

Physical: This means that the kick-scooter brakes adding friction to the wheels, normally by pressing the rear wheel with the foot.

Figure 2.20 *Physical brake in the rear wheel. (From Ninebot ES1)*

Electronic: In the electronic brake is the same motor, that is usually positioned in the front wheel, who creates a torque in the opposite direction of the wheel rotation. All electric kick-scooters have this kind of brake. Normally is activated by a small lever allocated on the handlebar.

Figure 2.21 *Electronic brake in the front wheel. (From Xiaomi M365)*

Figure 2.22 *Ninebot ES2 handlebar (Right lever: Accelerator, Left lever: Brakes)*

Mechanical: The mechanical brake simply works as a bicycle brake. A Bowden cable[20] goes from the hand lever to the wheel where an iron brake disc is attached and permits the braking through two dedicated pads.

Figure 2.23 *Xiaomi M365 brake lever.*

In the following picture (*Figure 2.24*), it can be seen an example of a mechanical braking in the rear wheel, where the iron discs and the brake actuator are allocated.

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[20] *A* ***Bowden cable*** *is a type of flexible cable used to transmit mechanical force or energy by the movement of an inner cable relative to a hollow outer cable housing. The housing is generally of composite construction, consisting of an inner lining, a longitudinally incompressible layer such as a helical winding or a sheaf of steel wire, and a protective outer covering. [https://en.wikipedia.org/wiki/Bowden_cable#cite_note-1]*

Figure 2.24 *Xiaomi M365.*

2.3.4 Engines

The engine is, obviously, one of the most important parts of an electric kick-scooter, and it has to be chosen according to its expected performance.

As we have seen in the analysis of the most recent electric kick-scooters on the market, the nominal output power of the engine moves around 300 W (500 W for the Zoom Stryder). Nevertheless, as it has been said, we first have to think about the expected performance of the kick-scooter that is being designed in this project, so first of all some calculations will be needed to approximately know the power demanded by the EcoPat.

Electric kick-scooters usually have the engine directly attached to the wheel axe, so there is no transmission needed. Hence, that makes the kick-scooter more efficient regarding the maintaining issues.

2.3.5 Structure material

Most of the kick scooters are entirely made of CNC machined aluminium, but with the deck, there are two main materials that will both bring solid results.

Firstly, CNC machined aluminum is a durable, yet not too heavy, material for the deck. Kick scooters made of CNC machined aluminum may be more expensive, but they offer unparalleled durability. The second option for deck material is magnesium, which offers an ultra-lightweight advantage. This will make the kick scooter lighter to both manage and carry around.

2.3.6 Electronic system

Finally, is important to explain how works the electronic system between the levers and the engine of an electric kick-scooter. Actually, the system used to control the acceleration is just based in a voltage divider that changes the resistance between the points that we connect to the engine. This resistance variance causes a voltage variance at the engine alimentation, which gives more or less power (the higher resistance, the less the voltage and in consequence, the less the power given by the engine).

That being said, the voltage divider works as it is shown in *Figure 2.25,* and it is governed by the following formula:

$$V_{out} = V_{in} \cdot \frac{R_2}{R_2 + R_1}$$

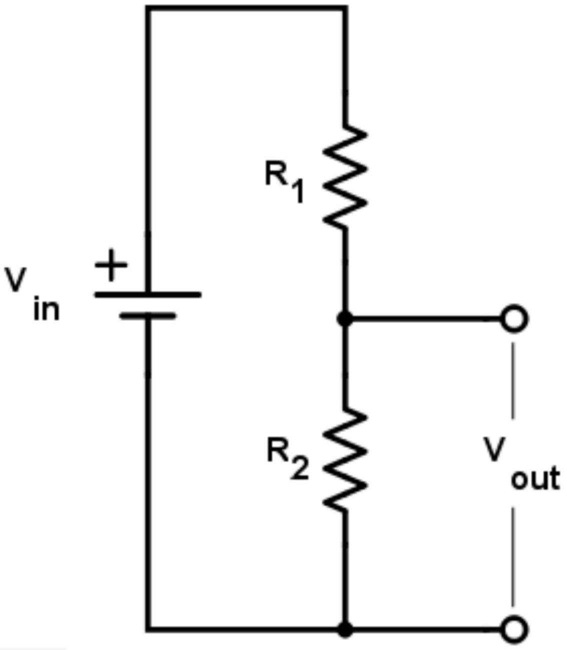

Figure 2.25 *Voltage divider.*[21]

To sum it up, the electric kick-scooter accelerator works as the voltage divider shown in *Figure 2.25*, but with way more resistances, in order to be able to give a smooth rise in the voltage, and therefore, of smooth and secure kick-scooter acceleration.

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[21] *https://www.allaboutcircuits.com/tools/voltage-divider-calculator/*

3. Phases

Within this point of the document, the main phases that will be taken into account in this project will be fully explained and developed. There are going to be 3 different phases concerning the area where the project is going to be implemented, going from a small and controlled area to a medium-sized city.

3.1 Phase 1: INPT Labège

Firstly, this project is going to be tested in a small and controlled area. In this case we are going to take the Toulouse-Labège Campus of INPT facilities all together with the ENSIACET building. In the following figure (*Figure 3.1*), it can be seen an overview of the territory just mentioned.

Figure 3.1 *EcoPatinette Phase 1 domain.*

3.2 Phase 2: Labège

After getting the results from Phase 1, in Phase 2 the project is going to be taken to wider and more complex area: the neighbourhood of Labège, where the service work area will be larger. In order to keep the things as simple as possible, it has been decided to carry out the first 3 phases of the project within the same city, Toulouse (France).

Labège is located on the suburbs of Toulouse and is part of a neighbourhood organization called Sicoval[22], the one who takes care of the well-being of the habitants of the territory shown in *Figure 3.2*.

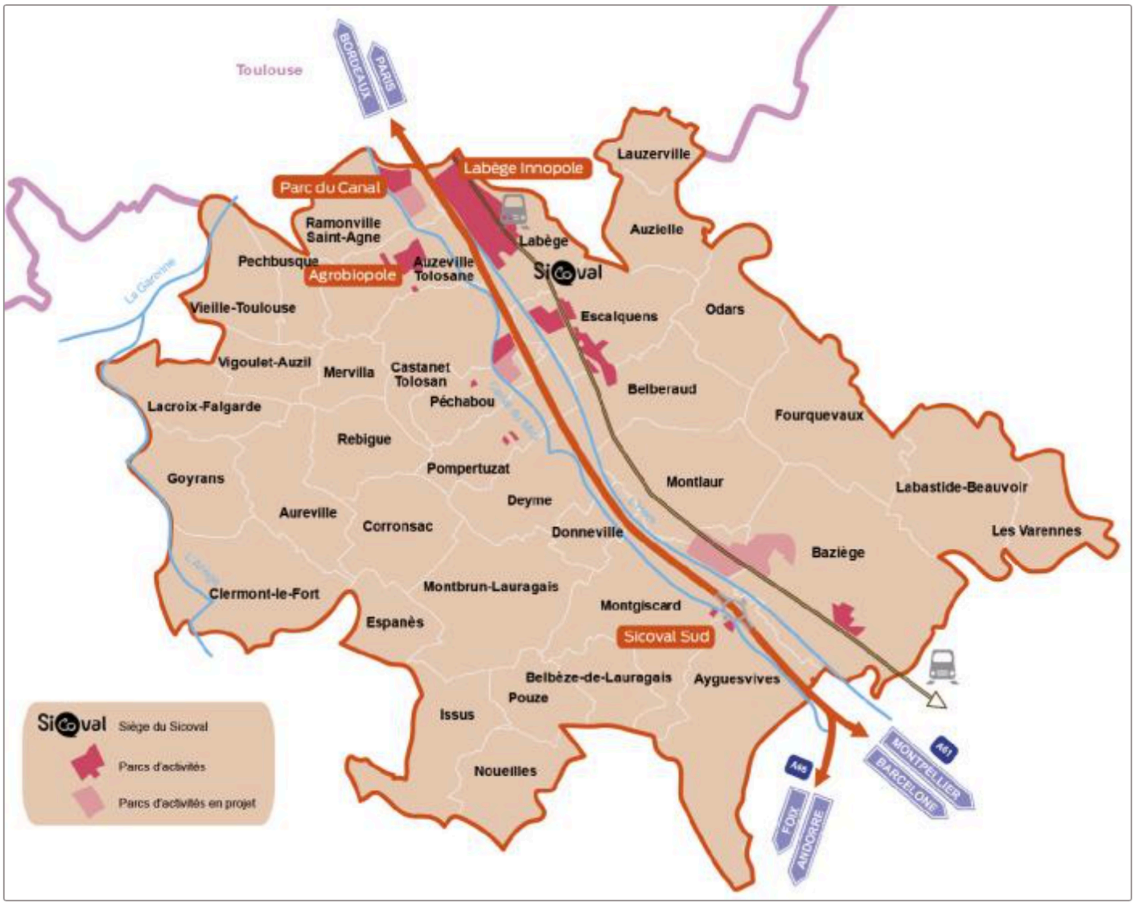

Figure 3.2 Sicoval domain.[23]

This neighbourhood has an overall surface of 7,65 km^2 and 4277 habitants (559 hab/km^2). Obviously, a larger area and more users means that more stations will be needed in this Phase.

In the following figures can be seen the whole extension of Labège (in red) in a scaled map.

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[22] *http://www.sicoval.fr/fr/nous-connaitre.html*

[23] *http://www.sicoval.fr/fr/nous-connaitre.html*

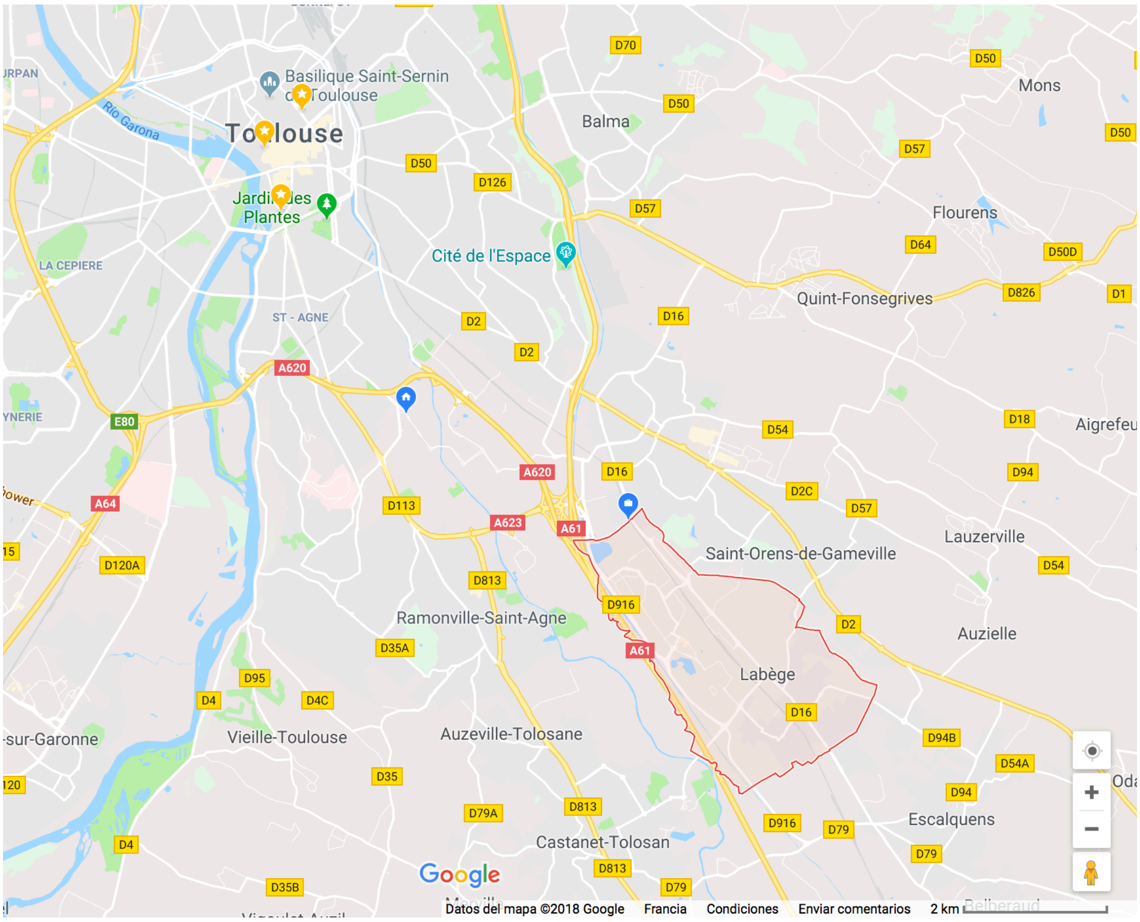

Figure 3.3: *Labège territory.*

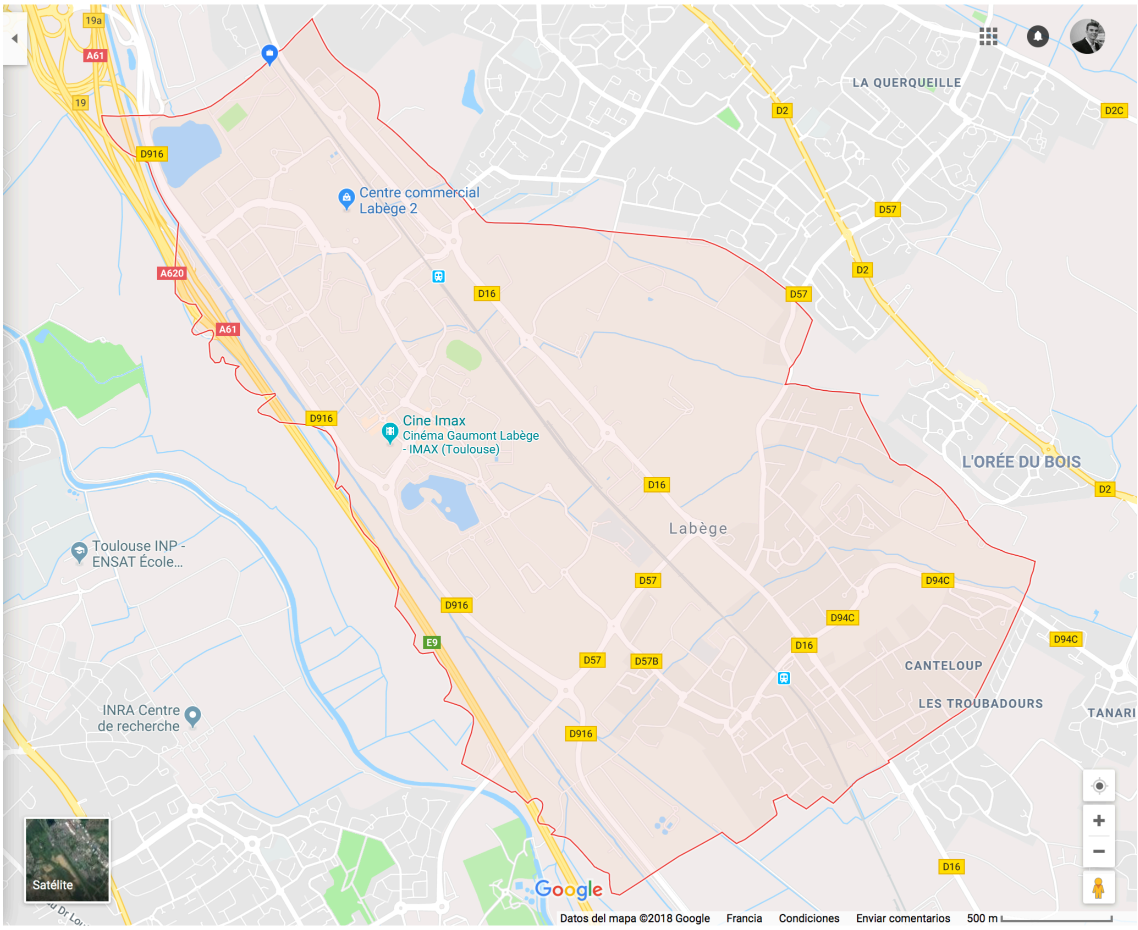

Figure 3.4: *Labège territory.*

Labège is conditioned by government laws in terms of speed limit, more precisely the speed limit applied to scooters and similar urban ways of transport like the EcoPatinette is around 30- 40 km/h[24]. Taking into account that the speed limit we worked with in Phase 1 was 20 km/h, this change gives us the opportunity to not just work in a larger and different area, but to work with a higher speed limit as well.

Labège is known to be a neighbourhood with lots of workplaces, from restaurants and malls to business offices, which means lots of displacements between the workplaces and the restaurants or malls each day from Monday to Friday. This feature gives our service the opportunity to exploit a necessity and extract results and conclusions from the process.

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[24] *http://www.velo.toulouse.fr/Magazine/Actualites/Les-nouvelles-reglementations-sur-la-circulation-a-velo-vers-plus-de-securite*

3.3 Phase 3: Toulouse

Finally, taking all the results and relevant information gathered from Phase 1 and 2, the service is going to be taken to an even bigger domain, the city of Toulouse. Toulouse is the 4th most populated city in France, with an overall population of 479.638 habitants (2015) [25] and an area of 118,3 km^2, which means a population density of 4054 hab/km^2.

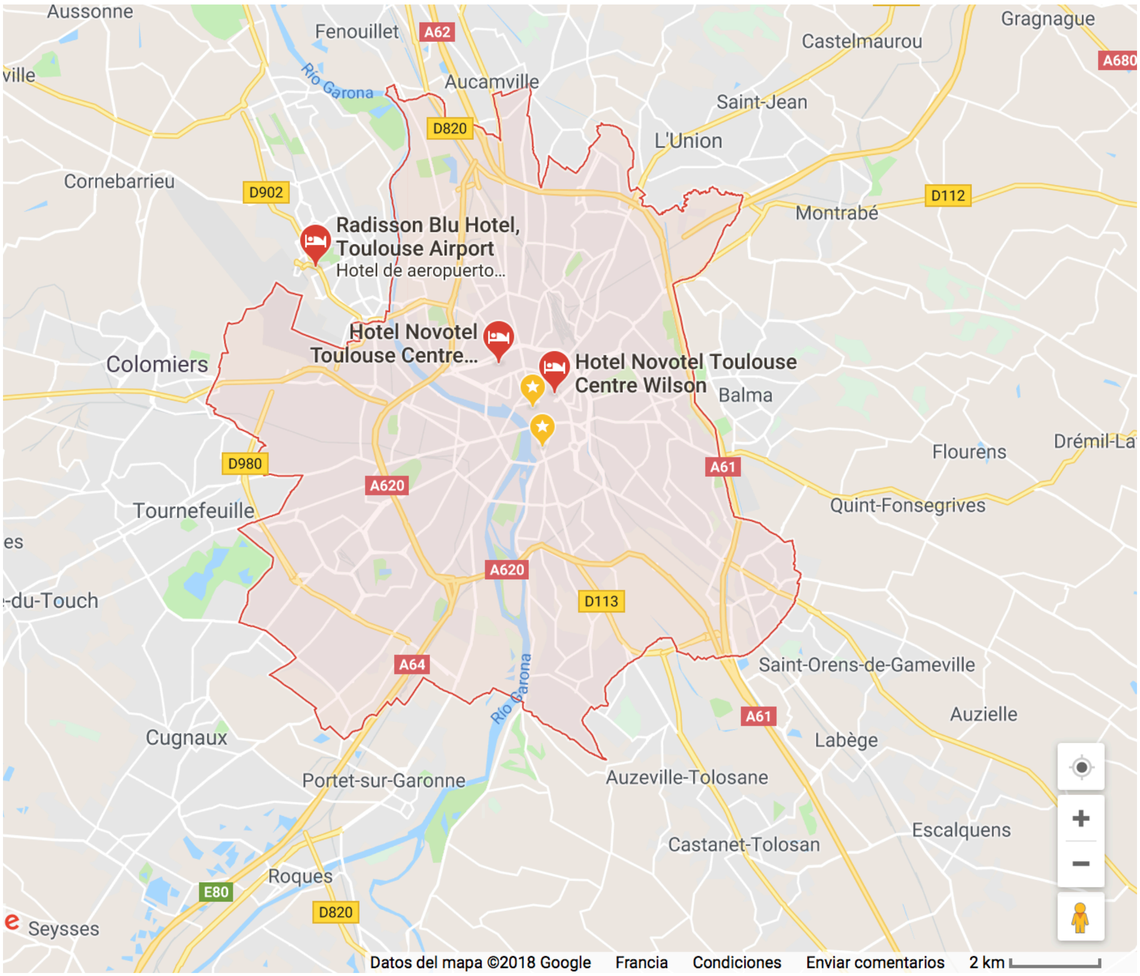

Figure 3.5: *Toulouse domain overview (in red).*

In this last phase, the potential users increased from 4277 to ha479.638 (plus the tourists), which means that the number of patinettes and stations that will be needed to add will be considerably higher than the ones that will be needed to add from Phase 1 to Phase 2.

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[25] *Only the centre population is going to be taken into account for this project. The urban population is around 948.433 hab (Jan. 2013) and the metropole population is around 1.330.954 hab (Jan. 2013). [https://en.wikipedia.org/wiki/Toulouse]*

Toulouse is considered to be a "flat" city, which means that you can hardly encounter steep streets. This feature will take weight from the required specifications of the EcoPatinette, as it will not have necessarily to be able to climb streets with high slopes.

4. System sizing

Within this point of the project, the service system is going to be sized in terms of station size and number of stations per each phase.

4.1 Phase 1: INPT Labège

Firstly, in this first phase we have to take into account that there are hundreds of students attending the facilities of INPT Labège every day, that is why in Phase 1 only the professors and the PhD students will be able to use the EcoPatinette service. If it was allowed to use the service for all the students would not be sustainable taking into account the massive number of users in such a reduced space.

After having gathered all the information necessary, here are the main highlights that will be considered for the charge system sizing:

- 100 professors and 160 PhD students = 260 users in total.
- 15 % of the users go to INP Headquarter at least once a day.
- 90 % of the users go to the Restaurant every day.
- 35 % of the users go to the Sports Centre at least once a day.

Taking into account all the data just presented, the positions where the stations should be are more than clear (see *Figure 4.1*).

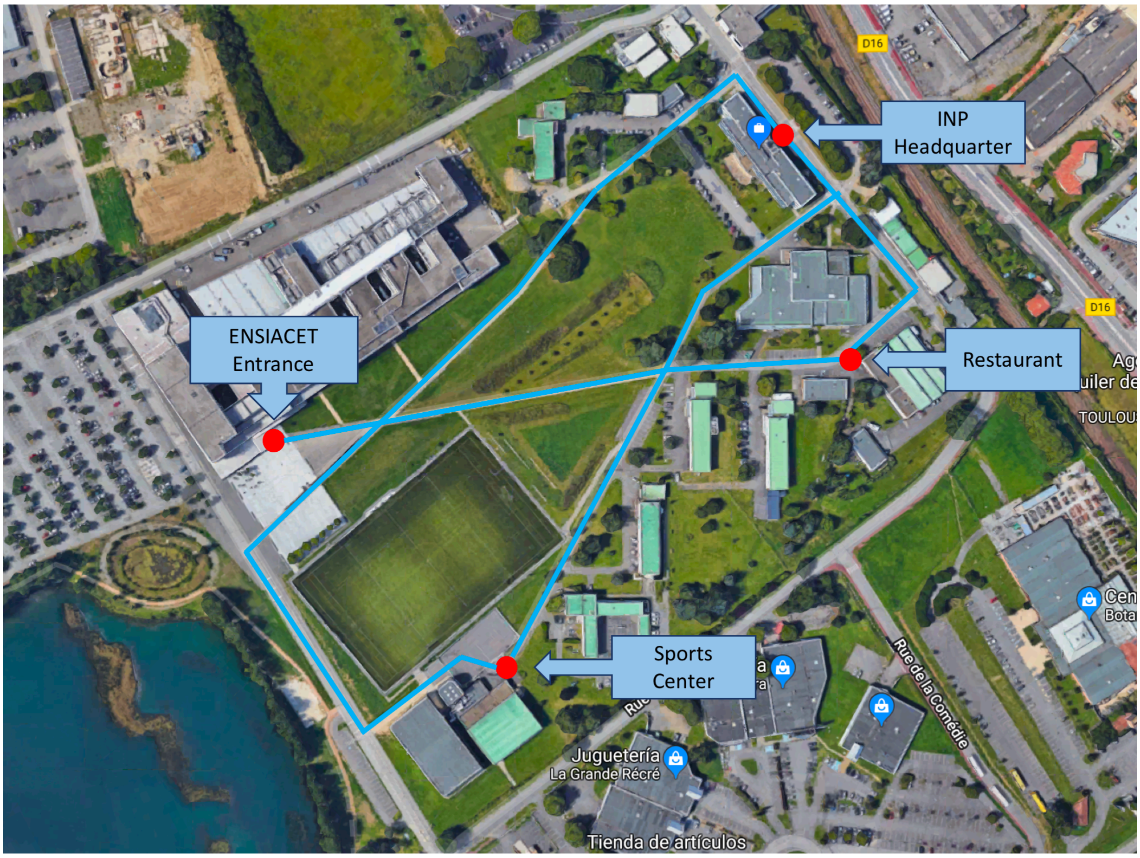

Figure 4.1: *EcoPatinette service distribution: Phase 1.*

Firstly, a specific number of EcoPats will be positioned in each station and several days of trial and observation will determine whether the number of kick-scooters per each station is correct, under-valued or over-valued. For instance, as the restaurant is the most concurred place, two modules of 12 EcoPats each one will be positioned (24 EcoPats in total). Logically, as the majority of the users are starting their routes from ENSIACET entrance, this spot will also possess two modules of 12 EcoPats.

The other 2 stations will only have 1 module, starting with 12 EcoPats per module, letting time decide if this number is correct, under-valued or over-valued.

4.2 Phase 2: Labège

As it has already been said, Labège is a 282-ha neighborhood known to gather lots of workplaces, so most of the people who have their homes in Labège are actually working in Labège. The neighborhood is basically divided in the main zone where the restaurants and workplaces are located (80 % of the territory) and residences (20% of the territory).

Since it is quite difficult to know the percentage of population in Labège actually working in this neighborhood, some hypothesis will be made in order to estimate the number of displacements and how many of these displacements could be done using the EcoPatinette service.

It should be bearded in mind that there will be also lots of displacements between the mall "Centre commercial Labège 2" and the residential area with the intention to shop food, clothes and whatsoever. On behalf of this purpose, a special box will be designed to be attached to the EcoPatinette and by this way be able to carry all the things bought in the mall (see point *5.4* of this document).

Although INPT Ensiacet campus is inside Labège, there is a great and affordable restaurant for everyone inside the campus, so the displacements that the students and professors perform from the university campus to other parts of Labège is not relevant because they mostly move inside it and most of them live outside the neighborhood. Nevertheless, a EcoPat station will be positioned at INP headquarter.

Taking into account the data[26] given by Sicoval about the human activity in Labège (1170 establishments, 16800 jobs and 3000 students) and after making an estimation of the number of users that will be using the EcoPatinette service each day inside the neighborhood (see *Table 4.1*), the main displacements and ways of displacement will be studied to determine how big the stations should be and where they should be located.

Habitants in Labège	People coming from outside / day	**Potential users /day**	Percentage who would use our service	**Users/day**
4 277	15 523	19 800	50 %	**9 900**

***Table 4.1:** Estimation of EcoPatinette users per day in Labège.*

From *Table 4.1* we estimated an overall of 9 900 people in Labège who would use our service every day. The next step is to determine where the main displacements take place in order to know where to locate the EcoPatinette stations and how many kick-scooters these stations should have.

Bearing in mind that the main displacements that will take place every day are between workplaces and restaurants, the main clusters of restaurants and

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[26] *http://economie.sicoval.fr/fr/creer-et-se-developper/s-implanter/labege-innopole.html*

workplaces will be studied and determined. It cannot be forgotten that "Centre commercial Labège 2" is a really important point where lots of people go every day, whether to eat or to buy at the supermarket.

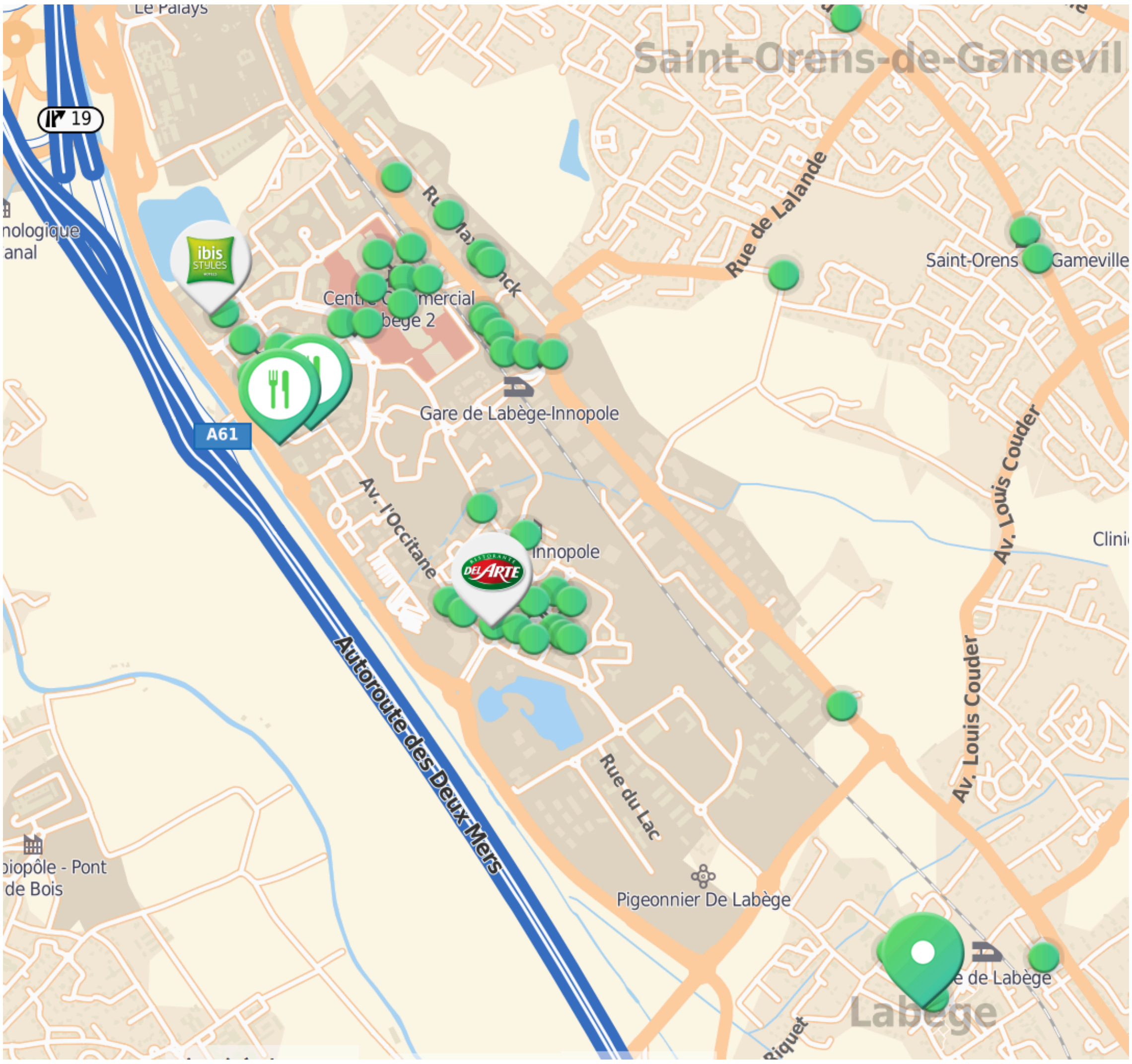

Figure 4.2: *Restaurant distribution in Labège.*[27]

As it can be seen in *Figure 4.2*, there are 2 main clusters of restaurants. The first one in Centre commercial Labège 2 and the other one between "Rue Pierre de Gilles de Gennes" and "Rue l'Occitaine" (see the following figure).

---

[27] *https://fr.mappy.com/#/51/M2/TGeoentity/F5a0e4aeb0351d170bd223ee4/N151.12061,6.11309,1.50548,43.54527/Z15/*

Figure 4.3: *Main cluster of restaurants in Labège.*

Once the main restaurant clusters are determined, the workplaces of most density of people will be determined. It is obvious that restaurant clusters are at the same time workplace clusters, as several jobs are covered there. Regarding the rest of workplaces, they are practically uniformed around the territory, so the position of the new EcoPat stations will be decided taking into account the distance between the restaurant and mall clusters and the future stations. In other words, the new stations will be set in order to reduce the distance that the user has to cover from anywhere to the nearest station.

In the following pictures (*Figure 4.4 and Figure 4.5*) it can be seen the locations of the new EcoPat stations in Labège. The circle size says how big each station is going to be. It is obvious that the mall and the main restaurant cluster stations will possess more kick-scooters than the other stations, regarding the people fluency.

Figure 4.4: *Labège EcoPat stations location (Satellite view).*

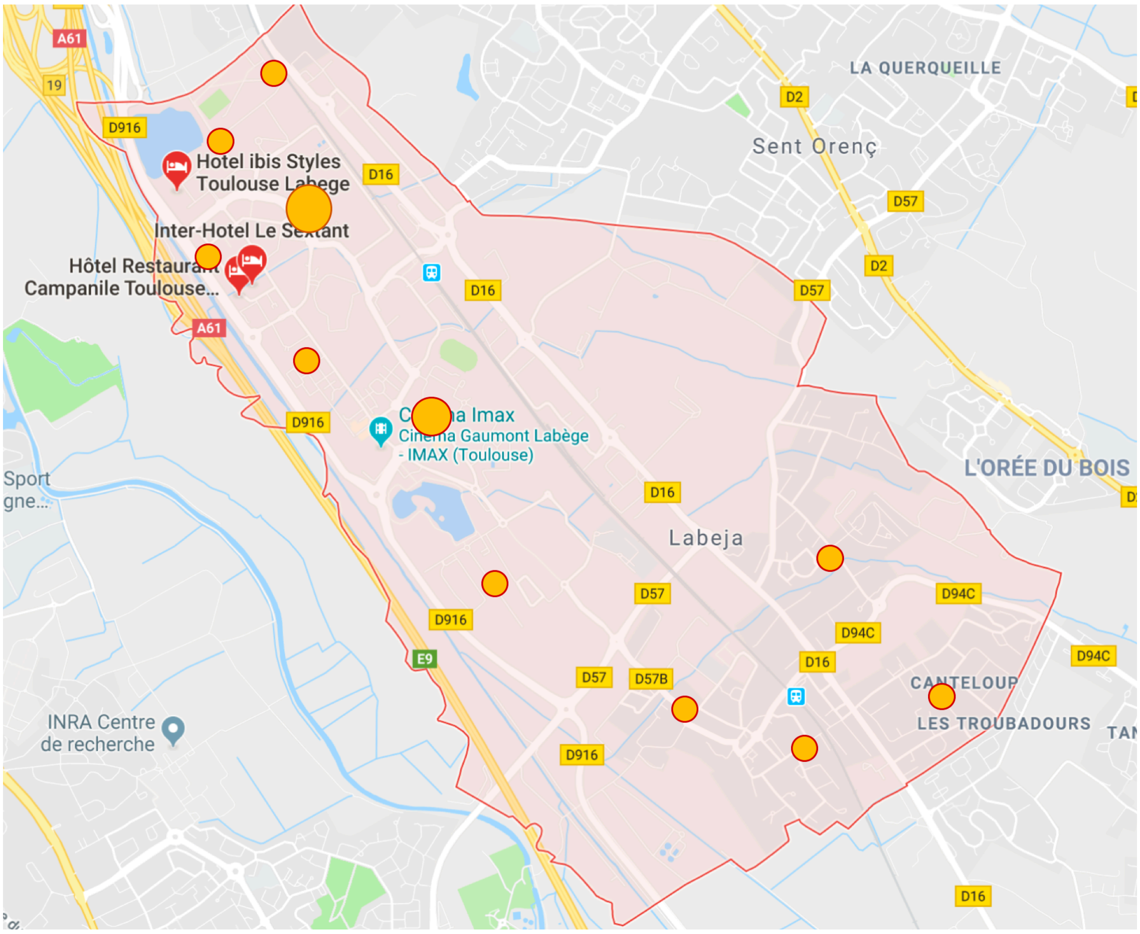

Figure 4.5: *Labège EcoPat stations location (Map view).*

Finally, the methodology that would be followed in order to decide how many charge station modules of kick-scooters will be placed in each station will be a try-error methodology. Since the 9900 users per day it is merely an estimation, the number of people that will use our service and which stations will be the most used are, indeed, unknown. In consequence, firstly a specific number of EcoPats will be positioned in each station and several days of trial and observation will determine whether the number of kick-scooters per each station is correct, under-valued or over-valued.

4.3 Phase 3: Toulouse

Once Phase 2 has reached the equilibrium, Phase 3 is going to kick off following the same procedure but at a higher scale. All things learned in Phase 2 will be applied in this phase to establish the EcoPat service in Toulouse.

5. EcoPat design requirements

At this point of the project, the EcoPatinette design requirements will be thought in order to start designing the kick-scooter and finally reach a first Alpha prototype.

5.1 Functionality

Before starting to draw the first lines, it is best to be clear about what kind of functionality is expected from the EcoPatinette. The following points resume the most important things to take into account before starting the EcoPatinette body design:

5.1.1 Powered electrically

It might sound obvious, but the EcoPatinette will not be powered by direct burn of any kind of fossil fuel, so it is going to be powered purely by electric engines backed up by **Lithium-Ion batteries**. It is important to state that if nowadays graphene batteries were developed far enough, we would use them instead of Lithium batteries, as they do not have the so called "Memory effect"[28] (like Lithium –Ion batteries) and their energy density is much higher (see *Figure 2.1, in point 2: Literature survey*), so they hold way more energy for less space and mass.

5.1.2 Limited maximum speed

Since during Phase 1 the EcoPatinette will be moving inside the campus facilities, it will be strictly forbidden to circulate above 15 km/h.

Nevertheless, it is important to take into account that 15 km/h will not be the real maximum speed of the EcoPatinette. Since after Phase 1 the EcoPatinette will be taken to the public domain (TBD after the Phase 1 results) where this kind of vehicle is allowed to circulate up to 30 km/h, it will have to be able to reach at least 25 km/h.

To solve this issue, during Phase 1, the maximum speed of the EcoPatinette will have to be electronically limited.

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[28] ***Memory effect****, also known as battery effect, lazy battery effect, or battery memory, is an effect observed in nickel-cadmium and nickel–metal hydride rechargeable batteries that causes them to hold less charge. It describes the situation in which nickel-cadmium batteries gradually lose their maximum energy capacity if they are repeatedly recharged after being only partially discharged. [https://en.wikipedia.org/wiki/Memory_effect#cite_note-BergveldKruijt2002-1]*

5.1.3 GPS geolocation and guidance

Each EcoPatinette will be able to be located at any moment by a GPS system. Moreover, a small screen connected to Internet will be available on the handlebar to ease the user displacements through the city using the GPS navigation technology.

5.1.4 Box reserved to carry documents and bags

Since during Phase 1 the users will be Professors and PhD students, it is important that the EcoPatinette has a reserved space to carry documents or small bags without compromising the vehicle stability.

A small metallic box allocated just in front of the EcoPatinette could serve well as a recipient for documents, boxes or bags.

Although not all the users will be Professors or PhD students after Phase 1, a little space reserved to carry their belongings will be highly appreciated by the users.

Moreover, a small hook could be added as well in order to hang up a small/medium bag, such as the plastic supermarket bags.

5.2 Engine

In order to choose the right engine for our kick-scooter, the maximum power needed will have to be calculated.

To calculate the maximum power needed, the worst-case scenario for the kick-scooter performance has to be defined. Hence, the worst-case scenario consists of **ascending a slope of 15 ° with a user that weights 100 kg** at half max speed, which means **at 15 km/h.** The EcoPat weight is still unknown but we are going to suppose that it weights 15 kg at maximum.

Firstly, the drag forces will be calculated.

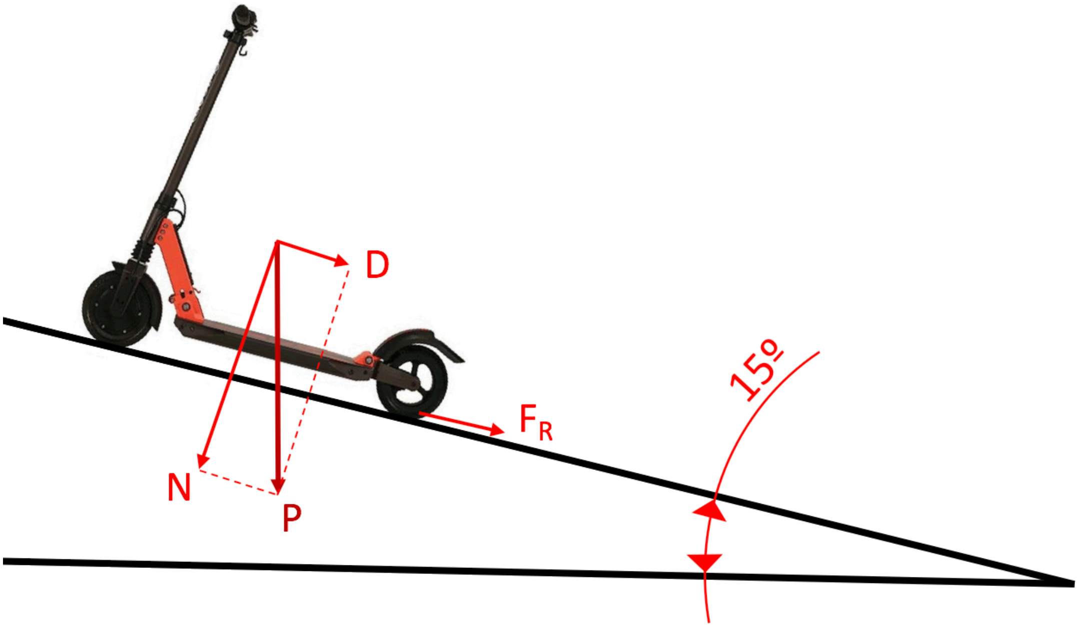

Figure 5.1: *Force decomposition of a kick-scooter climbing a 15° steep.*

In *Figure 5.1* it can be seen a representation of a kick-scooter ascending a slope of 15 ° with the main forces represented, where:

$$P = (100\ kg + \ 15\ kg) \cdot 9{,}81 \frac{m}{s^2} = 1128{,}15\ N$$

$$D = P \cdot \cos\ (75º) = 291{,}99\ N$$

$$N = P \cdot \sin(75º) = 1089{,}71\ N$$

Thereafter, the total force that drags the kick-scooter in the opposite direction of its course is calculated as follows:

$$F_{TOTAL} = F_R + D$$

Where F_R is the friction force with the ground, and it is calculated as follows:

$$F_R = \ \mu \cdot N$$

Where μ is the friction coefficient, that in this case takes the value of a rolling resistance of approximately 0,005[29].

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[29] *https://en.wikipedia.org/wiki/Rolling_resistance*

$$F_R = \mu \cdot N = 0{,}005 \cdot 1089{,}71\, N = 5{,}45\, N$$

Therefore, the total drag force is equal to:

$$F_{TOTAL} = F_R + D = 5{,}45\, N + 291{,}99\, N = 297{,}44\, N$$

If the kick-scooter needs to overcome this drag force and still manage to achieve a speed of 15 km/h, the power needed from the engine is calculated as follows:

$$P_{max} = F_{TOTAL} \cdot v = 297{,}44\, N \cdot \left(15 \frac{km}{h} \cdot \frac{1000\, m}{1\, km} \cdot \frac{1\, h}{3600\, s}\right) = \mathbf{1239,33\, W}$$

After an exhaustive searching through internet, the next 1200 W motor sold in *Alibaba*[30] fulfil the power and dimensions requirements.

Figure 5.2: *Electric engine chosen for the EcoPat.*

The following table sums up the main technical specifications of the chosen engine.

---

[30] *https://www.alibaba.com/product-detail/Patent-outrunner-motor-1200W-DC-brushless_60741267026.html?spm=a2700.7724857.main07.50.27fd464eRtwr9m*

Output power	1200 W
Type	Gear motor, Brushless DC
Continuous current	1,2 – 3,2 A
Voltage	24 V
Load current	41,7 A
Max speed	3299 - 3720 rpm
Construction	Permanent magnet
Length of the motor	63,3 mm
Output shaft	22,5 mm
External diameter	49,5 mm

Table 5.1: *Engine specifications*

As it can be seen in *Table 5.1*, the maximum speed that the engine can reach is between 3299 rpm and 3720 rpm. In order to understand this in most common terms, 3299 rpm is going to be converted into m/s:

$$v = w \cdot r = 3299\, rpm \cdot 0{,}1\, m = 3299\, rpm \cdot \frac{2\pi\, \mathrm{rad}}{1\, revolution} \cdot \frac{1\, minute}{60\, s} \cdot 0{,}1\, m = \mathbf{34,6\; m/s}$$

Hence, it is assured that the engine will be able to reach the maximum speed set for the EcoPat, which is 8,33 m/s (30 km/h).

5.3 Battery

Once the engine has been chosen, some calculations will be done in order to choose the right battery for our EcoPat.

Firstly, the maximum distance that the EcoPat can cover with the battery full charged will have to be decided. Since this electric kick-scooter is thought to be used inside the city and the distance between charge stations never overpass the 20 km, it has been decided that **25 km along an even floor is the maximum distance that the EcoPat will be able to cover with the battery full charged.**

As the 25 km are thought to be covered in an even floor (0°), the force N is equal to the total force P. So, N=1128,15 N *(see 5.2)*.

Since the force N has changed, we will have to recalculate the force Fr:

$$F_R = \mu \cdot N = 0{,}005 \cdot 1128{,}15\, N = 5{,}64\, N$$

The demanded workforce is calculated as follows:

$$W_n = F_R \cdot distance_{max} = 5{,}64\ N \cdot 25\ km = 141\ kJ$$

Hence, the battery workforce is expressed as:

$$W_d = C \cdot V$$

Knowing that the battery workforce has to equal the demanded workforce:

$$W_d = W_n$$

$$C \cdot V = 141\ kJ$$

So, the battery capacity will be calculated as follows:

$$C = \frac{141 \cdot 10^3\ J}{V\ [V]}$$

Since the chosen engine demands a voltage of 24 V (V=24 V):

$$C = \frac{141 \cdot 10^3\ J}{V} = \frac{141 \cdot 10^3\ J}{24\ V} = 5875\ A \cdot s \cdot \frac{1\ h}{3600\ s} = 1{,}632\ A \cdot h = \mathbf{1632\ mAh}\ \ (\mathbf{at\ 24\ V})$$

Once the battery capacity demanded is calculated, it is time to choose a battery among those that are available in the market.

The following is the battery chosen to use for our EcoPat:

Figure 5.3 Battery chosen (NiMH)[31]

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[31] http://www.batteryspace.com/custom-nimh-battery-pack-24v-2200mah-20xaa-battery-with-5-5x2-5mm-male-plug.aspx

Its most relevant specifications are summarized in the following table:

Type	Nickel Metal Hydride (NiMH)
Voltage	Working: 24 V, At peak: 29 V
Capacity	2200 mAh
Charging current	1,5 A
Discharging rate	2,2 A
Dimensions	142 x 28,8 x 51 mm
Weight	550 g

Table 5.2: *Battery specifications*[32]

As it can be observed in *Table 5.2,* the voltage and the capacity of the battery chosen are according to the voltage needed by the motor (24 V) and the minimum demanded capacity for the battery (1632 mAh, *Point 5.3).*

If we take a look at its dimensions, it can be seen that there will be no problem to allocate the battery just below the desk.

5.4 Body design

At this point, the functionalities presented in the last point (*See point 5.1*) have been taken into account to draw a first simple sketch to get a first idea of how the system is going to work and how approximately it will look like (*See Figure 5.1*).

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[32] *http://www.batteryspace.com/custom-nimh-battery-pack-24v-2200mah-20xaa-battery-with-5-5x2-5mm-male-plug.aspx*

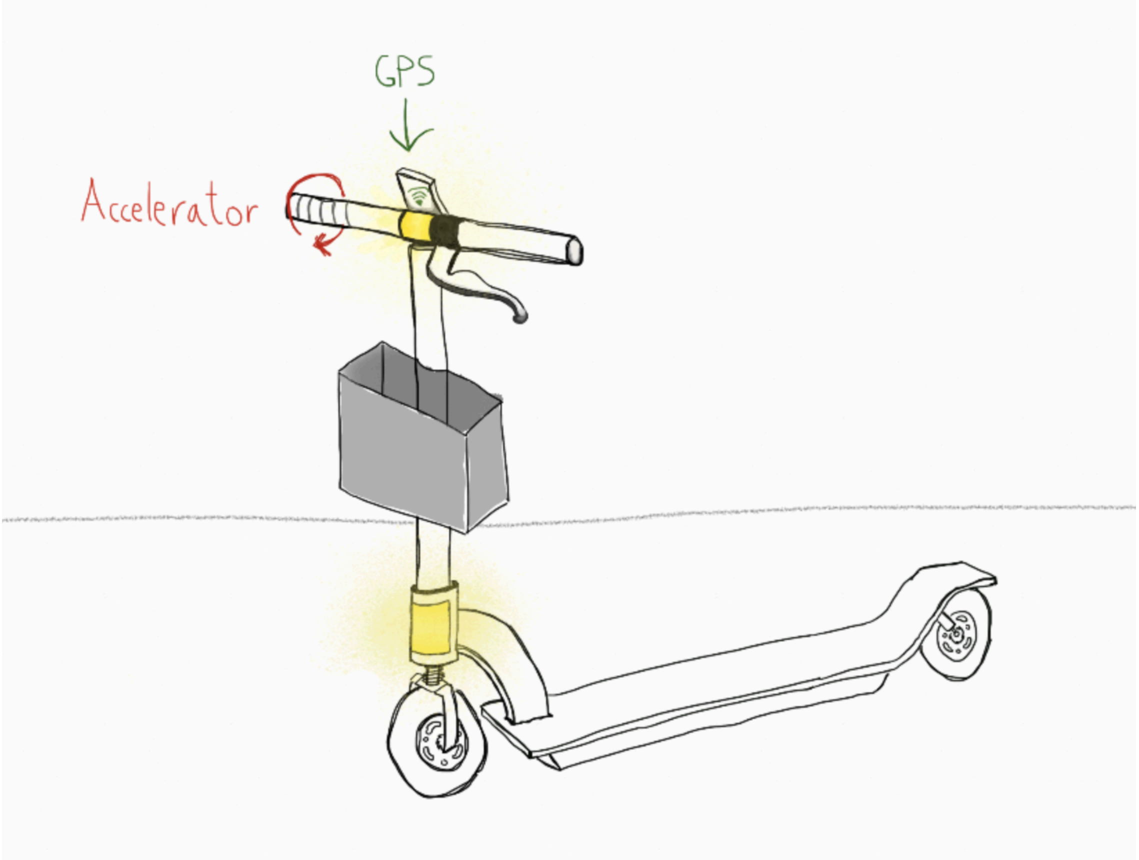

Figure 5.1 *EcoPatinette first sketch.*

5.5 Materials

As it has already been said, the battery is the heavier kick-scooter element, so the materials chosen to build the rest of the scooter have to be lightweight. By this way, it will not be required a great effort by the user to carry it around.

The main material used to fabricate the EcoPat will be the CNC machined aluminium, as is the best material regarding the price-quality aspect. CNC machined aluminium is a both resistant and light material used in all kick-scooters existing until today. Aluminium naturally generates a protective oxide coating and is highly corrosion resistant. Besides, aluminium is 100% recyclable without any loss of its natural qualities.[33]

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[33] *https://www.waykenrm.com/technologies/cnc-aluminum-machining?gclid=Cj0KCQjwu_jYBRD8ARIsAC3EGCKnkZDrF0j5h4WYWFX-ZMh7NI7zDutziM1AkX3SsC4LZVnwUP6HQikaAtOYEALw_wcB*

6. Final EcoPat design

Once the most important requirements are established, is time to start the 3D design. This design is going to be done with a CAD software called PTC Creo Elements. In order to make this brief, the final version will be directly presented. Nevertheless, while designing the EcoPat some changes were made regarding the first expectations described in point *5* of this document:

- The throttle will be activated by a lever and not by the motorbike-like manner. It has been proved that this manner is a safer and more precise one.

- Regarding the brakes, the front brake (electronic) will be activated by a lever allocated on the handlebar and the rear break will be activated manually with the feet. By this manner we reach a still safe system while saving a lot of money in brake discs, brake pads and Bowden cables, among others.

- Since the requirement pointed in point *5.1.4* (allocating a Box) is taking a lot of space and consequently making the kick-scooter less practical, it has been decided to replace it with a hook in the main bar. With this hook, the user will be able to hang up small and middle bags.

In the following pictures, it can be seen the final design of the Alpha version of the EcoPat.

Figure 6.1 *EcoPat Alpha version.*

The EcoPat battery will be positioned just under the deck and well protected from any scratch or hit.

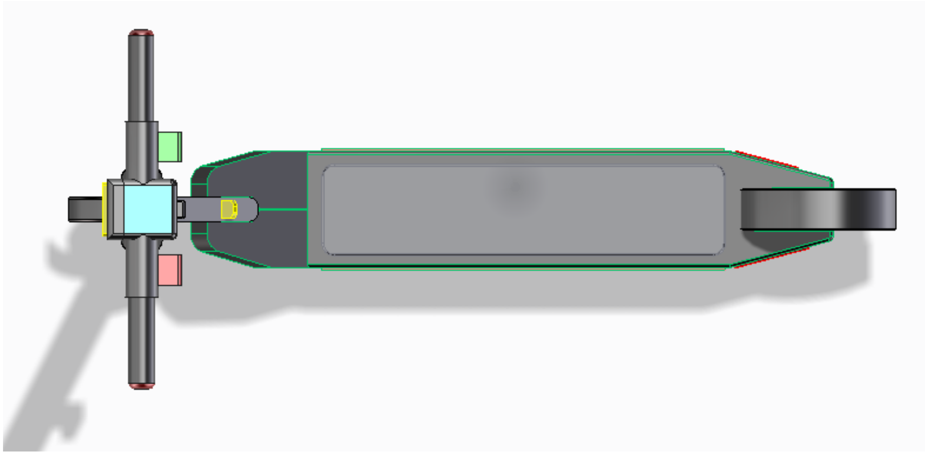

Figure 6.2 *EcoPat Alpha version.*

In the next figure (*Figure 6.3*) we observe the red security reflectors positioned on the deck sides and on the tip of the handlebar. These reflectors make the EcoPat more visible during night, and consequently, more secure.

Figure 6.3 *EcoPat Alpha version.*

The next picture (*Figure 6.4*) shows us in more detail the LED lights allocated on the front of the EcoPat. These lights will both lighten the path ahead and make the EcoPat more visible during night.

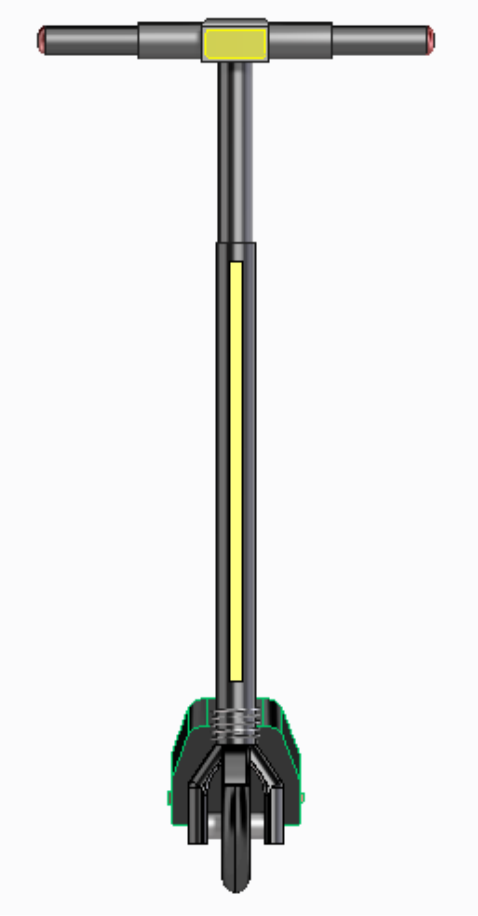

Figure 6.4 *EcoPat Alpha version.*

In *Figure 6.5* it can be seen in more detail the EcoPat handlebar. On the handlebar, one can find the throttle lever (in green), the front wheel break lever (in red) and the GPS screen (in blue). It can also be seen the red reflector situated on the tip of the handlebar.

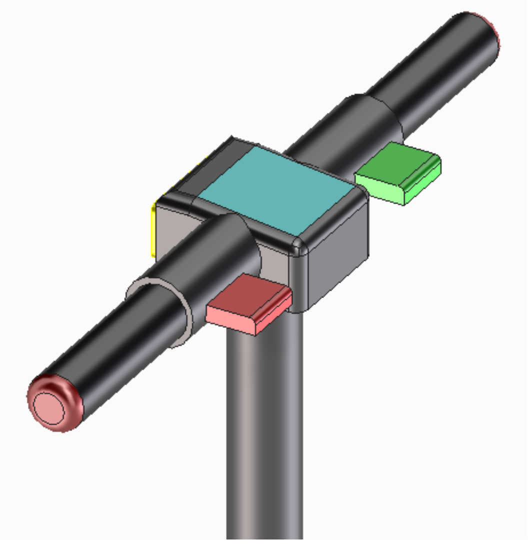

Figure 6.5 *EcoPat Alpha version, handlebar detail.*

As it has already been said at the beginning of this point, one of the changes that has been introduced during the EcoPat design is the box replacement. Instead, a hook (*Figure 6.6*) will be positioned to let the user hang up a small or middle-sized bag.

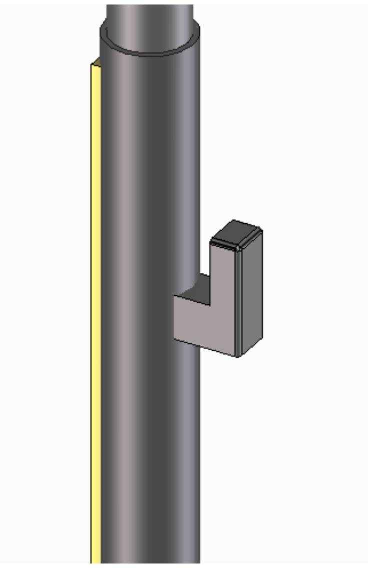

Figure 6.6 *EcoPat Alpha version, hook detail.*

Finally, *Figure 6.7* shows us the trigger (in yellow) that is going to be used to fold the EcoPat. In order to fold the kick-scooter we just have to press the yellow trigger and accompany the main bar until it reaches the end.

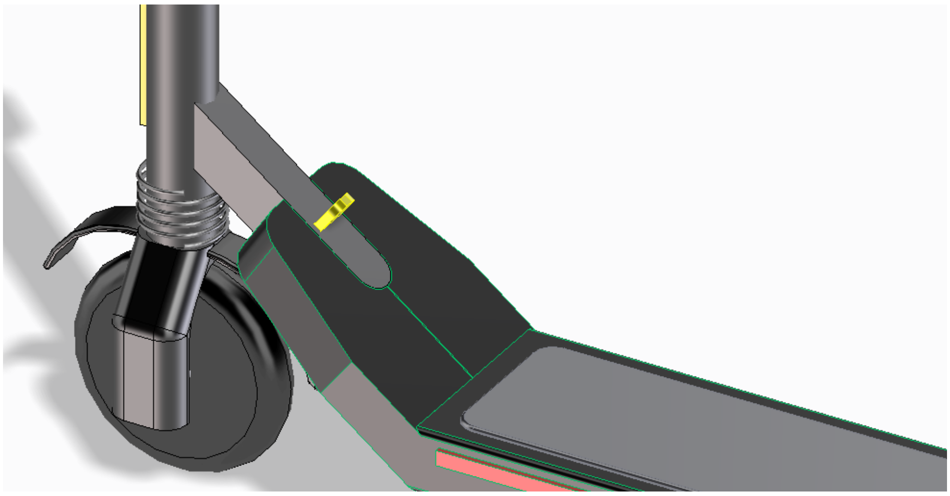

Figure 6.7 *EcoPat Alpha version, folding trigger detail.*

Regarding the wheels, it has been decided that **both EcoPat wheels are going to be PU solid rubber**. Since the EcoPat already has a shock absorbing system, there is no need to add more shock absorption. As it has already been explained and detailed in point 2.3.2, PU wheels are light, wear-resistant, have a reasonable amount of grip (when dry), and rebound (the ability to return to its original shape after momentary compression due to weight or pressure). Besides, the most important advantage of PU wheels is that we avoid the punctures.

In this final picture, it can be seen the dimensions of the designed electric kick scooter:

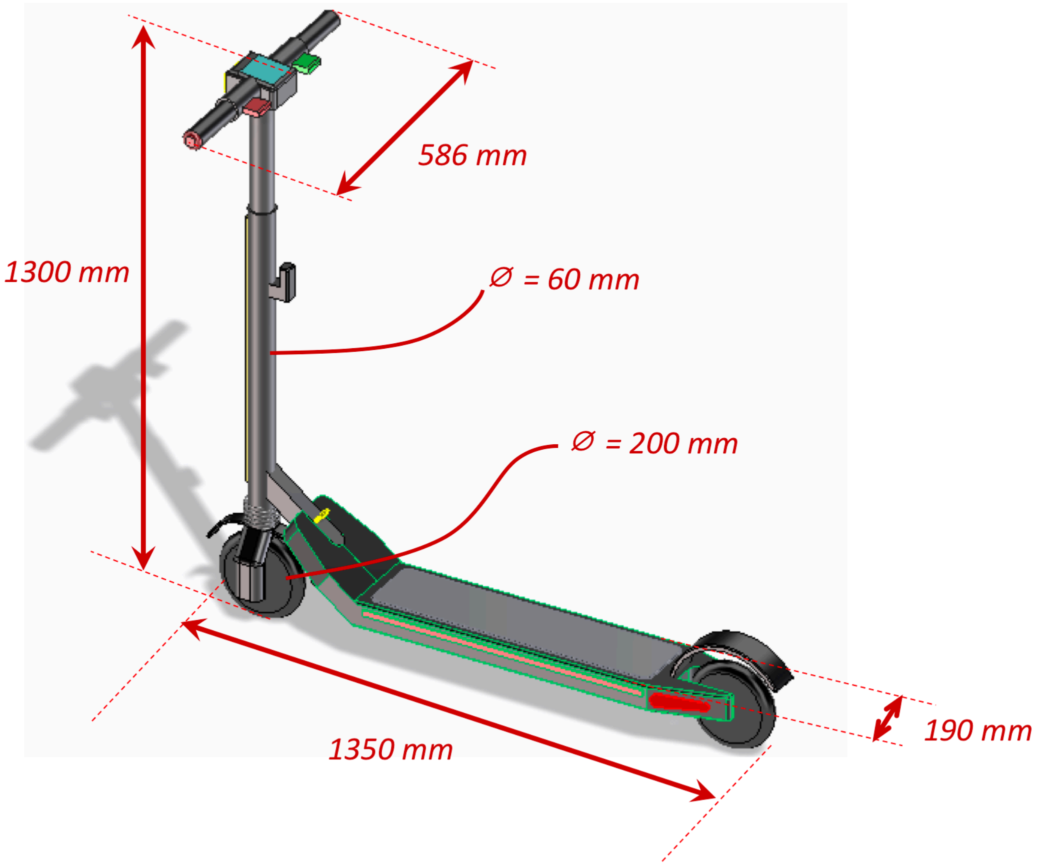

Figure 6.8 EcoPat Alpha version dimensions.

7. Charge stations design requirements

At this point of the project, the EcoPatinette charge stations design requirements will be thought taking into account all of its expected functionalities.

7.1 Expected functionalities

The EcoPatinette charge station expected functionalities, in decrease order of importance, are the following:

- Locking and securing the EcoPattinetes.
- Charging the EcoPattinetes while parked in the station.

- EcoPatinettes protection from weather conditions.
- Position sensors and connection to the Internet.
- Smart and quick Log-in / Identification system.

7.2 System design

At this point the expected functionalities will be taken care of separately by order of importance to start building the body system.

7.2.1 Locking and securing the EcoPattinetes

This one is a very important point to be taken care of. Without an efficient system of locking and securing, the system is exposed and vulnerable to vandalism acts. So first of all, the charge station will have to lock the EcoPatinettes in a way that they can be charged without additional gadgets.

7.2.2 Charging the EcoPatinettes while parked in the station

The first thing to consider to start designing the charge station electric system is the voltage, power and time needed to charge the EcoPatinette.

Regarding the battery charging, in order to do it properly, the EcoPatinette will need a source of electricity at 24 V and 50Hz. The electricity in France is provided at 220V and 50 Hz, so the charge station will need a transformer.

7.2.3 Protection from weather conditions

It is truly important to protect the EcoPatinettes from weather conditions such as the rain, the wind and the sun. Even though the EcoPatinette is going to be fully resistant to use it under the rain, it is better not to leave it under the rain for a long period of time, as in the long run it can damage some of its materials.

Moreover, it is not advisable to let the kick-scooter under the sun for long periods of time because it can also damage some of the materials the EcoPatinette is made of.

To fulfil these requirements, the stations will have a ceiling to protect the patinettes from the rain and the sun and a system strategically thought to protect them from the wind.

7.2.4 Position sensors and connection to the Internet

In order to inform at every moment of the number of EcoPatinettes available in every station, it has to have one sensor in each parking position and all the information has to be uploaded to an online database.

With a simple and user-friendly application, the user will be able to check through any kind of device how many EcoPats are available in the nearest station.

7.2.5 Smart and quick Log-in / Identification system

The costumer journey at the time of taking an EcoPatinette out of the station must be as quick and easy as possible.

There will be two ways of logging in: Registered or Not Registered.

- **Registered**

  This way is intended to be used by frequent users such as inhabitants of the city. The registration will be done either from the same charge station or from a separated device such as a computer or a smartphone. For this matter, the **charge station will be provided with a touch screen** working as a registration device connected to the Internet.

  Once a user is registered, a card with NFC technology will be sent to him to allow a quick and easy use of the service. Before the user receives the card, he will log in with the account password.

- **Not Registered**

  This method is intended to be used by punctual users such as tourists. In order to charge the amount of time the user is using the service, this one will have to provide a credit card number or bank account and will be provided with a temporarily account.

8. Final charge stations design

Regarding the Alpha version of the charge station, all the requirements presented in the previous point that affect the physic design have been fulfilled.

In *Figure 8.1 and 8.2* it can be seen the isometric view of the charge station. First thing we can see is the touch screen (painted in cyan), which fulfils the requirement 7.2.5, which says, among other things, that the station must have an interactive touch screen to manage the registration issues and the daily EcoPats withdrawal.

This figure also gives us a good perspective of the ceiling that will be installed. This ceiling will protect the EcoPats from the rain and the sun (requirement 7.2.3).

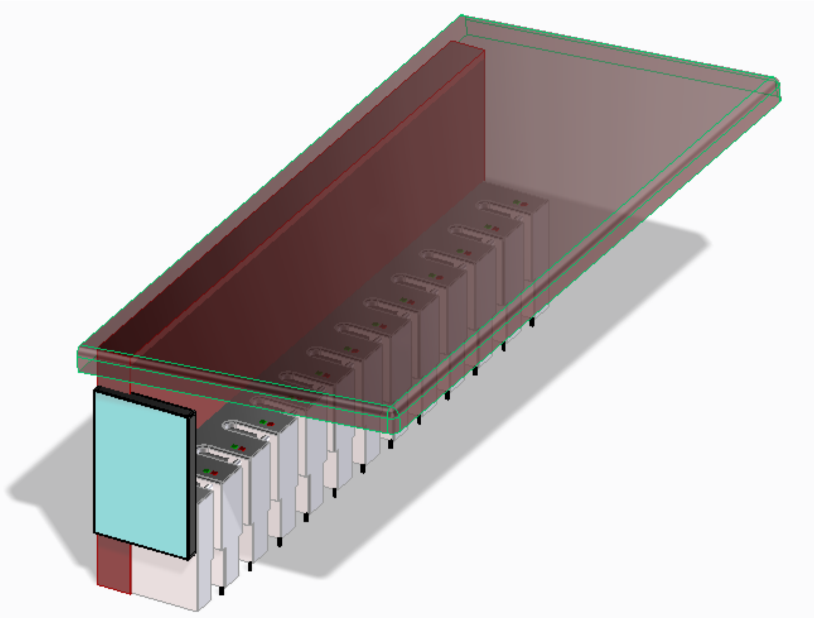

Figure 8.1 *Charge station Alpha version.*

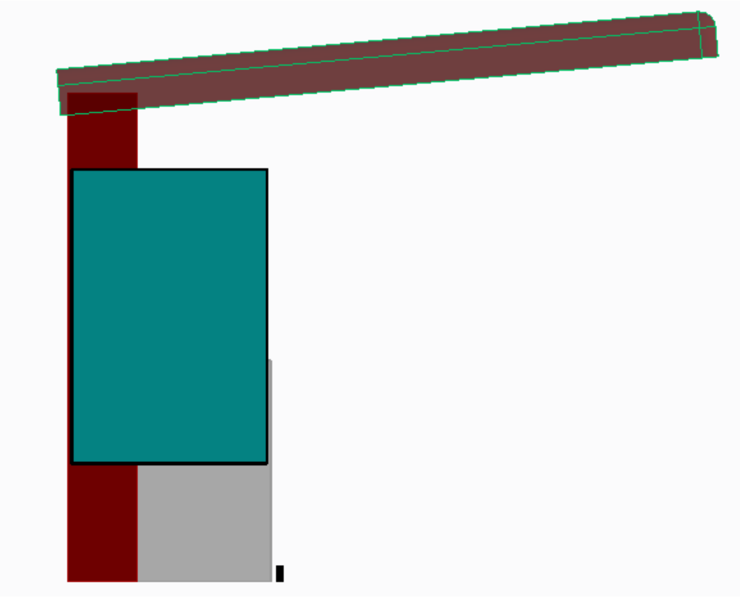

Figure 8.2 *Charge station Alpha version.*

The next representation (*Figure 8.3*) shows us the 12 EcoPat slots allocated in each module (each charge station). Simply several modules will be allocated together in order to reach a higher number of slots per station.

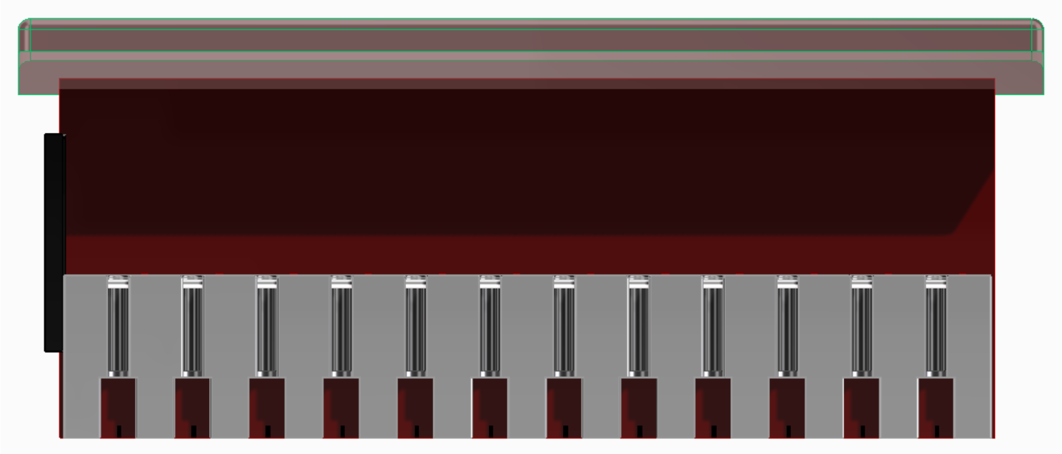

Figure 8.3 *Charge station Alpha version.*

In *Figure 8.4* it can be seen a closer detail of the kick-scooter slots. In it we observe the securing system, composed by 2 parts: the locking bar and the locking pin on the ground. Once the user correctly allocates the EcoPat in a slot, the locking bar closes itself and the pin positioned in the ground rises until it gets to the slot made in the EcoPat deck. With this securing system, we fulfil two requirements at once: robbery and wind protection. Since the kick-scooter is attached by two points, it makes it immovable towards wind gusts.

In this picture, we can also see a red and green button. These buttons are created to ease the allocation and withdrawal of the EcoPats. They work as follows:

- Red button enlightened: There is an EcoPat in that slot and it CAN'T be withdrawn.
- Green button enlightened: There is an EcoPat in that slot and CAN be withdrawn. Right after registering or logging in, the user will choose a kick-scooter among those who are available. Afterwards, the green button corresponding to the chosen slot will enlighten, showing that the EcoPat can be withdrawn when pressing it.
- No button enlightened: There is no EcoPat in that slot.

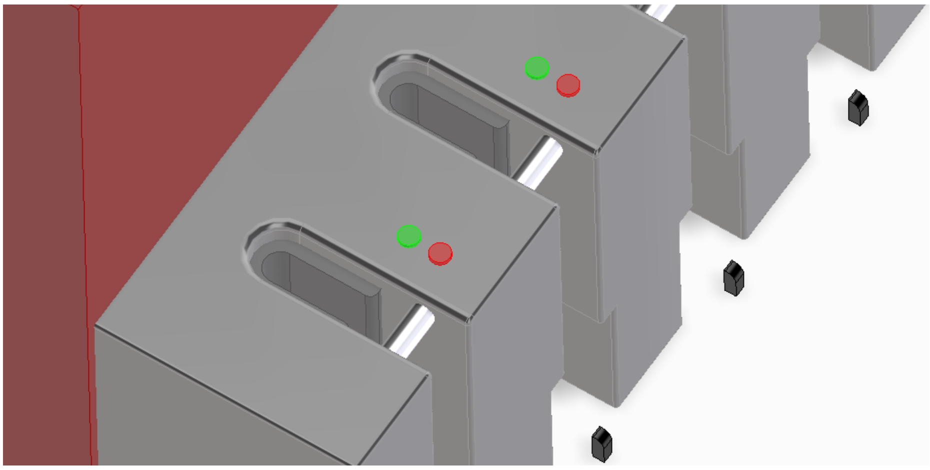

Figure 8.4 *Charge station Alpha version.*

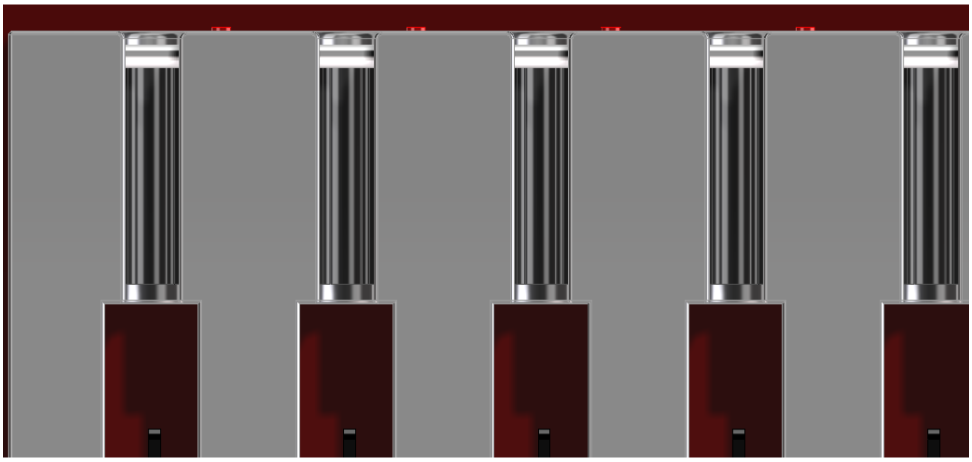

Figure 8.5 *Charge station Alpha version.*

9. Fleet management

A plan will have to be thought in order to manage the fleet of EcoPats in terms of kick-scooter distribution. It is obvious that it would be ideal to achieve a system that was managed on his own, but in the kick-off phase are little chances of that happening, so a plan has to be designed to always have enough EcoPats available in each station and also have enough place to leave the EcoPats. Hence, an equilibrium must be reached.

Since each charge station will provide information on how many EcoPats are in them, each time a station is empty, a car will transport EcoPats from the fullest station to the empty one. The opposite procedure will be done when a station is completely full. By this manner, no station will be empty nor full for a long period of time, ensuring the service quality.

The long-term aim is to add or remove kick-scooters until we reach a point where the manual EcoPats transports are no longer necessary and the natural balance is established.

10. Business plan

At this point, a summarized business plan will be developed in order to realize if the project is economically feasible or not. Since Phase 3 is still too difficult to predict without having the results of Phase 2, the business plan will be carried out taking into account just Phase 2.

10.1 Income

Firstly, the way the enterprise is going to create income has to be defined. It has been decided to set the business plan horizon at 7 years.

YEAR	1	2	3	4	5	6	7
Regular Users [€/month]	6	6	7	7	7	8	8
Occasional users [€/20 min]	1	1,5	2	2	2	2	2

Table 10.1 *Yearly user prices.*

Once the charges of our service have been defined, the average number of regular users and occasional users will be estimated to know the approximate income per year. In point 4.2 of this document it has already been defined the estimated number of **regular users** that will rely on our system among the total population in Labège (see *Table 4.1*). The estimated number is of 9900 regular users, but obviously, this number is not going to be reached during the first years of the service. So, *Table 10.1* shows the estimation of the number of regular users per year.

Year	1st	2nd	3rd	4th	5th	6th	7th
Regular users	3000	4500	5000	6500	7500	7900	8100

Table 10.2 *Regular users estimation.*

As it can be seen in the previous table, the registration of new users during the last years is converging, as it happens to all this kind of systems.

Regarding the average number of **occasional users**, taking into account that Phase 2 is allocated in a neighborhood outside Toulouse, there will be no significant number of tourists using this service. Hence, bearing in mind that for people living in the neighborhood is undoubtedly better to pay the monthly fee, the income coming from the occasional users has been ignored for this phase.

Hence, the total income perceived each year is summed up in the following table:

Year	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**
Regular users	3000	4500	5000	6500	7500	7900	8100
Regular users [€/month]	6	6	7	7	7	8	8
Occasional **users** [€/20min]	1	1,5	2	2	2	2	2
Months	12	12	12	12	12	12	12
Total Income [€/year]	**216000**	**324000**	**420000**	**546000**	**630000**	**758400**	**777600**

Table 10.3 *Total income calculation.*

10.2 Investments

Investment is all money spent with material or non-material values just before the start of the project (Year 0). These values are going to be amortized each year until the end of the business plan horizon.

In this case, the investments are the total cost of the EcoPats and charge stations modules fabrication. It has been decided that to start this phase, even though we had already spent money in some stations and EcoPats in Phase 1, all stations and kick-scooters will be tabulated again as they were fabricated all from scratch.

As it has been already presented in point 4.2 of this document, there are 11 stations in Phase 2, of which two of them are bigger than the others. Hence, it has been decided that these two big stations (Mall and Restaurant cluster) will be provided with 3 modules of 12 EcoPat slots, and the other 9 stations will be provided with 1 module of 12 EcoPat slots. So, 15 charge station modules will be installed in total.

Regarding the number of electric kick-scooters fabricated, it has been decided to assign 8 EcoPats for each small station (leaving 4 free slots per station) and 30 EcoPats for the big ones (leaving 6 free slots per station).

The cost of fabrication for the charge station modules and the electric kick-scooters has been estimated taking into account several cost prices such as the batteries, LED lights, wheels, GPS, CNC aluminum, etc. Its final price also contains the workforce and other general costs.

Here below is the table that sums up the investment calculation in terms of fabrication and installation.

EcoPat		Charge station module	
1. Cost/unit	346€	1. Cost/unit	6000€
2. Amount	132	2. Amount	15
Total (1 x 2)	45.672€	Total (1 x 2)	90.000€
Office material		1000 €	
Total Investment		136.672€	

Table 10.4 *Investment calculation.*

10.3 Costs

The costs are mainly seen as all the money spent each year to keep the business going. In this project, the main costs are the staff wages.

There are 2 types of employees in the EcoPat service: the customer service employees and the technical maintaining employees. A wage of 24.000€ per year has been set for both of them, which means a 2000€ company spent per each month.

The evolution of the number of employees per year is summarized in the next table:

Year	Nº Costumer employees	Nº Maintaining employees	€/month	€/year
1	5	3	16.000,00 €	228.000,00 €
2	7	4	25.000,00 €	300.000,00 €
3	9	5	31.000,00 €	372.000,00 €
4	9	5	31.000,00 €	372.000,00 €
5	9	5	31.000,00 €	372.000,00 €
6	10	5	31.000,00 €	372.000,00 €
7	10	5	31.000,00 €	372.000,00 €

Table 10.5 *Cost calculation.*

Apart from the staff wages, in order to have offices and a workshop to work, it has been estimated 25000 € will be paid every year in terms of rent.

10.4 Taxes and Interests

The **taxes** applied to each year profits is the one according to the French policy, which is **33%** of the taxable profit.

The **interests** applied in the credit demanded to the bank are set to **5%**, more than reasonable taking into account the current interest rates in France.

10.5 Business plan results

Once the main parts of the business plan have been explained, it is time to do it. This one can be found in Annex 1, at the end of this document.

10.5.1 Result

The following table sums up the results of the business plan that can be found in the Annex.

10.5.2 Net Present Value (NPV) and Intern Rate of Return (IRR)

One of the best indicatives that the business plan gives us is the **Net Present Value or NPV**. The NPV is the difference between the present value of cash inflows and the present value of cash outflows. NPV compares the value of a euro today to the value of that same euro in the future, taking inflation and returns into account. NPV analysis is sensitive to the reliability of future cash inflows that an investment or project will yield and is used in capital budgeting to assess the profitability of an investment or a project. For this project, it has been assumed an annum discount rate of 10%. For this project, the **NPV is equal to 312.546 €** in a seven-year horizon business plan, which means that the project is profitable.

Secondly, **Internal rate of return (IRR)** is the discount rate often used in capital budgeting that makes the net present value of all cash flows from a particular project equal to zero. Generally speaking, the higher a project's internal rate of return, the more desirable it is to undertake the project. As such, IRR can be used to rank several prospective projects a firm is considering.

IRR is sometimes referred to as "economic rate of return" or "discounted cash flow rate of return." The use of "internal" refers to the omission of external factors, such as the cost of capital or inflation, from the calculation. For this project, the **IRR is equal to 0,25**, which is a positive and good value to work with, as it is going to be difficult to find return interests higher than 25% in the stock market.

10.5.3 Pay-out time

As it can be seen in the business plan, the pay-out time is of **4,29 years**. In this time, the income perceived will surpass the total costs (variable + fix) and the company will start to see benefits from all work done. It could be said that is a high pay-out time, but looking at the amount of investments (above all regarding the costs of installing the charge stations) it is a fair and understandable pay-out time.

10.5.4 Business plan conclusions

On one hand, the results obtained from the business plan say that the project is economically viable (NPV > 0) and our money will come back with an approximate interest of 25%, which are very good news.

On the other hand, the pay-out time is the villain of our business plan, as the company will have to wait 4,29 years in order to see the first benefits. As it has already been said, this high pay-out time is due of the serious and high costs of installing the charging stations. In order to install the charge stations, it has to be taken into account the civil works, the installation of power outlets and other construction costs the follow these ones and are truly expensive.

11. Conclusion

First of all, it is worth stating that this project was not only meant to be a project to help decrease the air pollution levels and ease the day to day people mobility, but also to let the author of the project the opportunity to learn new and valuable knowledge. This knowledge can be divided into two main categories: the engineering part and the management part.

Within the engineering part, the author has learnt how to size both the engine and the battery needed for the electric kick-scooter. In order to do so, some rough calculation and hypothesis had to be done and analysed to see if the numbers that came out of that calculations made sense or not. Moreover, the CAD design skills had been renforced as well as the creativity and innovation skills.

Within the management part, the author has mostly learnt how to elaborate a business plan taking into account the economic key figures of the whole system CapEx & OpEx. Some key indicators such as the NPV or the IRR have been studied and calculated to realize if, after all, the project was profitable or not.

But most of all, the best ability learnt through the elaboration of this project is the decision-making skill. In several moments of this work, the author had to choose whether it was better to use one system or another, one material or another, one structure or another…and so on and so forth. Hence, this project has been like an entrepreneurial trip in which the author has had the opportunity to realize some of the beauties and problems of creating a product and a company from scratch.

To summarize, this project ends with the same vision with which it started, the creation of an ecological and user-friendly way of city transport that could (and maybe will) ease the stressed lives of the urbanites.

12. ANNEX

	Year	0	1	2	3	4	5	6	7
CAPEX	*Investments*	-136672,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
OPEX	*Amortization*	0,00	-20668,00	-20668,00	-20668,00	-20668,00	-20668,00	-20668,00	-20668,00
CAPEX	*Credit*	68336,00	0,00	0,00	0,00	0,00	0,00	0,00	1,00
OPEX	*Credit refund*		9762,29	9762,29	9762,29	9762,29	9762,29	9762,29	9762,29
CAPEX	*Still to be refunded*	68336,00	58573,71	48811,43	39049,14	29286,86	19524,57	9762,29	0,00
OPEX	*Interests*		3416,80	2928,69	2440,57	1952,46	1464,34	976,23	488,11
OPEX	*Sellings*		216000,00	324000,00	420000,00	546000,00	630000,00	758400,00	777600,00
OPEX	*Costs*		253000,00	325000,00	397000,00	397000,00	397000,00	421000,00	421000,00
	Taxable profit		-61084,80	-24596,69	-108,57	126379,54	210867,66	315755,77	335443,89
	Income tax		-20361,60	-8198,90	-36,19	42126,51	70289,22	105251,92	111814,63
	Result	-136.672	-40.723	-16.398	-72	84.253	140.578	210.504	223.629
	Gross cash flow	-68336,00	-29817,49	-5492,08	10833,33	95158,74	151484,15	221409,56	234535,97
	Cumulation	-68336,00	-98153,49	-103645,56	-92812,23	2346,51	153830,67	375240,23	609776,20
	Updated cash flow	-68336,00	-27106,81	-4538,91	8139,24	64994,70	94059,74	124979,93	120354,04
	NPV	-68.336	-95.443	-99.982	-91.842	-26.848	67.212	192.192	312.546
	TOTAL NPV	312.546							
	Break-even point								
	Pay-out time	**4,29**							
	IIR	**0,25**							