Futuristic Transportation System developed with QFD

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Abstract

This paper presents a project proposal about the design of an innovative and futuristic transport system that aims to replace highways and major roads with a fast, safe and ecological new arrangement. The aim was to conceive an innovative new infrastructure of transport that fits into a future city scenery. In the current historical period we are invested by fast, frenetic and unstoppable evolution that leads to the continuous replacement of products and technologies that in a few years went from being innovative to become obsolete and outdated. Moreover, this process has inevitably affected the whole world of transport: it has assisted and is still witnessing the replacement of diesel and petrol engines with hybrid and electric ones. These evolution and change have led us into the research and understanding of increasingly innovative technologies such as the ones with zero impact motors or magnetic levitation, which in the near future will probably become a valid alternative, or even the new pioneers of transport around the world.
At the beginning, the methodology used for the present case study was adopted to analyze how people used to move in the current period (i.e. 2019-20); then, it was taken into consideration the problems linked to the main means of transport diffused, with clean and green technologies; later, it was carried out a market analysis for each category, with related Benchmarking, in order to find the most significant technical characteristics of each one. According to the emerged results, a concept of an innovative transport system was developed, in order to guarantee the safety and privacy of passengers in addition to other performance items, as high speed or integration with other means. The intention was to create a transport network that could connect many cities with direct and easily practicable routes that could replace highways.

Keywords
Future transport, Future city, Safe, Ecological, High Speed, Magnetic Levitation.

1. Environment Analysis
In order to realize a coherent and winning project we started from the understanding of what will be the context in which our means of transport will be placed, The future City. Always in line with this period of great changes, we realized that cities are also quickly evolving and that presumably within a few years the perception of reality and our sensory experiences will be radically changed, compared to what we are currently experiencing. The cities themselves will be increasingly linked and will therefore need direct and fast connections that allow safe and fast moving.

1.1 How the five senses experience will be in the Future City?

Hearing
Cities will be increasingly connected; With the invasion of the IoT all objects will be in connection and using one finger pressed on a screen you will be able to control anything. With our hands we will be able to modify and manage our future.

Smell
Cities will be increasingly perfumed; in line with the struggle against global pollution, the vehicles themselves will reduce emissions to a minimum level by eliminating bad smells from the streets. Petrol, diesel and methane will only be bad memories replaced by totally sustainable mobility.

Sight
Cities will be less and less invasive; the cars will be placed in underground parking that will free the streets and the views, allowing us to admire ever wider landscapes where nature will mix perfectly with technology.

Touch
Cities will be increasingly silent; engines will be replaced by new, more efficient and quieter ones, noise and pollution will be reduced to a minimum.

Taste
Cities will be more and more beautiful. The development of a new aesthetic sense will lead cities to be greener and vertically developed with tall modern and safe skyscrapers.

1.2 Traffic Issue

One of the biggest challenges for future transportation is to abolish traffic from the streets.
We spend hours of our lives stuck behind miles of cars. This causes us a huge waste of time that we cannot afford in a world that goes so fast.
Furthermore, it is scientifically demonstrated that this situation involves an enormous investment of psychophysical energies that turn into a physical damage with a considerable increase in stress and tiredness. This therefore leads to a lower efficiency and productivity that can be noticed both in personal life and in work. The commitment to find new solutions to solve this problem therefore becomes fundamental from the point of view of personal well-being and also towards the planet and the serious damage it entails.
Considering environment and global pollution, these very long lines of machines blocked on the streets have a devastating impact with a Co_2 production cellar and many other polluting substances that are released in the air. All thermal engines produce water, if powered by fossil fuels they produce carbon dioxide (CO_2). Diesel powered vehicles mainly emit particulates such as PM_{10} and lower, hydrocarbons (HC), nitrogen oxides (NO_x) and sulfur dioxide (SO_2) . A petrol vehicle emits particulate matter, NO_x and CO, while natural gas and LPG vehicles emit NO_x, ultrafine particulate matter and scarce hydrocarbons. In recent years, more and more researches have identified and measured the health consequences of traffic pollution. According to a recent report by the World Health Organization, there are as many as three million deaths attributable to pollution every year.

2. Market Analysis

2.1 Transports Analysis

We thought that the best thing to do was to start our analysis by going to take the main means of transport individually, trying to understand the positive and negative peculiarities. We have therefore analyzed considering the themes of Ecology, Cost Efficiency and Traffic related to the following means of transport: CAR, TRAM, UNDERGROUND, TRAIN, BIKE and PRT vehicles.

Car
The main cause of the traffic that congests cities and highways has on its side the great advantage of ensuring Privacy and Comfort that are practically unmatched by any other means of transport. On the other hand, we are still far from the goal of making the car environmentally friendly and zero-emission; also the issue of safety highlights that cars are one of the less safe means of transport.
CAR SHARING services are being developed more and more, but they add further inconveniences and waste of time to the problems of a personal car.

Underground
The great weak points of the subways are the enormous costs and the long production times that imply to limit their use and that are unattainable for long distances. Allow me to solve the problem of road traffic.

Bike
The ideal means of transport for reducing environmental pollution to zero is however a means limited to small distances and which does not allow to reach advantageous speeds. Furthermore, another extremely critical point is that in case of adverse weather conditions it becomes unusable.

Train
They are not suitable for short distances and are difficult to integrate inside cities. From the point of view of the environmental impact and in terms of speed and safety, however, they are certainly more advantageous than the means of transport analyzed so far. The new generation trains (magnetic levitation trains) that reach extraordinary speeds need expensive infrastructures that require high investments.

Tram
They have a number of disadvantages that lead them to be inevitably be at the bottom of the ranking.
They are extremely invasive both from the point of view of viability and from that of infrastructures, becoming a real burden for urban traffic. They are also considerably slow.

PRT
Personal Rapid Transit are means of transport with automatic pilot that allows you to transport people from one place to another. They are extremely interesting vehicles even if they have never had a particular development because they have very limited speeds and require private infrastructures that limit their use in cities. Nowadays the only noteworthy example is the Prt system that connects Heathrow airport with London city.

3. Method Used

When the problems of the main means of transport were clear, we thought that the most correct and professional way to understand the characteristics of proceeding was to carry out a market analysis for each category with consequent QFD *(figure 1)* in order to find the most significant characteristics for any of them. We therefore carried out for each of the following categories:

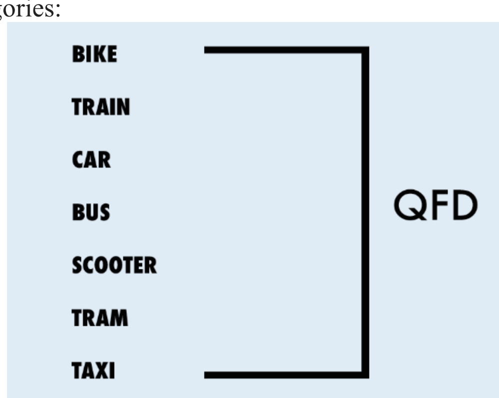


Figure 1. QFD means of transport

3.1 The six questions
We wanted to answer the six questions while keeping a vision as futuristic as possible trying to imagine a transport that could be used by anyone at any time that was technological, safe and extremely fast (*figure 2*).

Figure 2 The six questions

3.2 Benchmarking Cars

The four main cars used for sharing in Italy have been compared to understand which is the best one. The relevant features have been highlighted in green while the worst ones in red. Adding up the advantageous and disadvantageous characteristics, it turned out that the best car is Cart2Go. (*figure 3*)

	Car2Go Smart Fortwo	Drive Now MINI	Drive Now BMW I3	Enjoy 500
Price	24 cent al min	31 cent al min	31 cent al min	25 cent al min
Weight	935 Kg	1270 Kg	1345 Kg	906 Kg
Power	71/90 CV	136 CV	170 CV	85CV
Lenght	2695 mm	3821 mm	4006 mm	3571 mm
Height	1555 mm	1414 mm	1590 mm	1488 mm
Width	1663 mm	1727 mm	1775 mm	1627 mm
Extra	App	App	App	App
GPS	Yes	Yes	Yes	Si
Bluetooth	Si	Si	Si	Si
Engine	Electric	Fuel	Electric	Fuel
Gear	Automatic	Automatic	Automatic	Manual
Security devices	Unlock QR Code	Unlock PIN	Unlock PIN	Unlock whit code
Number of doors	3	3	5	3
Trunk	260 L	290 L	360 L	185 L
	4	1	3	1
	2	3	5	4
	2	-2	-2	-3

Figure 3 Benchmarking Cars

3.2.1 Matrix of Importance and Matrix of Dependence-Independence

	Driving	Dimension	Accelerazion	Comfort	Technology	Engine power	Safety	Aesthetic	Sustainability
Driving	1	1	0	1	0	1	2	1	2
Dimension	1	1	0	1	0	0	2	1	1
Acceleration	2	2	1	2	2	1	2	2	2
Comfort	1	1	0	1	1	0	1	0	1
Technology	2	2	0	1	1	1	2	1	2
Engine power	1	2	1	2	1	1	2	2	2
Safety	0	0	0	1	0	0	1	1	1
Aestethic	1	1	0	2	1	0	2	1	1
Sustainability	0	1	0	1	0	0	1	1	1
	9	11	2	12	6	4	15	10	13

Figure 4 Matrix of importance

	Driving	Dimension	Accelerazion	Comfort	Technology	Engine power	Safety	Aesthetic	Sustainability	
Driving	0	0	0	9	0	0	3	0	0	12
Dimension	3	0	3	9	0	0	3	0	3	21
Accelerazion	1	0	0	1	0	0	1	0	1	4
Comfort	3	0	0	0	0	0	0	1	0	4
Technology	3	3	1	9	0	1	1	1	3	22
Engine power	1	0	9	0	0	0	3	0	1	14
Safety	0	1	0	3	0	0	0	0	0	4
Aestethic	0	0	0	3	0	0	0	0	0	3
Sustainability	1	1	1	0	3	1	0	0	0	7
	12	5	14	34	3	2	11	2	8	

Figure 5 Matrix of Dependence-Independence

Thanks to the matrix of importance (*Figure 4)* we have defined what characteristics are essential for cars by attributing a grade from 0 to 2 for each of them by comparing them. Thanks to the matrix of dependence/-independence (*Figure 5)* we investigated the dependence between the various characteristics of cars to understand which ones were manageable individually and which should be considered in relation to others. In this case, the votes ranged from 0 to 9. The results showed that the essential features for cars are comfort and safety. While engine technology, size and efficiency are the characteristics that most influence the quality of the final product.

3.3 Benchmarking Trains

Four new and innovative trains have been compared to understand which is the best one. The relevant features have been highlighted in green while the worst ones in red. Adding up the advantageous and disadvantageous characteristics, it turned out that the best train is Rock Pop. (*figure 6*)

	ART	Rock/Pop	R1	Coradia iLint
Max Speed	70 Km/h	160 Km/h	50 Km/h	140 km/h
Accessibility	wheelchairs	Bike and wheelchairs		
Capacity	307	1400		
Lenght	32000 mm	136000 mm		2726 mm
Height	3400 mm			4340 mm
Width	265000 mm	2800 mm		2750 mm
Extra	montion sensor		IoT Hygenic system	
GPS	Si	SI	SI	Si
WiFI	No	No	SI	No
Engine	Electric	Cables	Cables	Hydrogen cells
Plans	1	2	1 ribassato	1
Seats		700		300
	1	4	1	3
	2	2	3	2
	-2	1	-2	1

Figure 6 Benchmarking Trains

3.3.1 Matrix of Importance and Matrix of Dependence-Independence

	Dimensions	speed	Aesthetics	Comfort	Sostenibility	Safety	Punctuality	Technology
Dimensions	1	1	1	2	2	2	2	2
Speed	1	1	0	1	2	2	2	1
Aesthetics	1	2	1	1	2	2	2	1
Comfort	0	1	1	1	2	2	2	1
Sostenibility	0	0	0	0	1	2	1	0
Safety	0	0	0	0	0	1	0	0
Punctuality	0	0	0	0	1	2	1	0
Technology	0	1	1	1	2	2	2	1
	3	5	4	6	12	15	12	6

Figure 7 Matrix of importance

	Dimensions	speed	Aesthetics	Comfort	Sostenibility	Safety	Punctuality	Technology	
Dimensions	0	9	1	9	1	3	0	1	23
Speed	0	0	3	3	3	3	9	0	21
Aesthetics	1	1	0	3	3	1	0	0	9
Comfort	0	0	1	0	0	0	0	0	1
Sostenibility	1	3	1	0	0	0	0	3	8
Safety	3	0	0	1	0	0	0	3	7
Punctuality	0	3	0	3	0	0	0	0	6
Technology	1	3	3	3	3	3	3	0	19
	6	19	9	22	10	10	12	7	

Figure 8 Matrix of Dependence-Independence

Thanks to the matrix of importance (*Figure 7)* we have defined what characteristics are essential for trains by attributing a grade from 0 to 2 for each of them by comparing them. Thanks to the matrix of dependence/independence (*Figure 8)* we investigated the dependence between the various characteristics of train to understand which ones were manageable individually and which should be considered in relation to others. In this case, the votes ranged from 0 to 9. The results showed that the essential features for trains are efficiency and safety. While technology, dimensions and speed are the characteristics that most influence the quality of the final product.

3.4 Benchmarking Taxi

Five modern taxi have been compared to understand which is the best one. The relevant features have been highlighted in green while the worst ones in red. Adding up the advantageous and disadvantageous characteristics, it turned out that the best taxi is Toyota Auris Hybrid. (*figure 9*)

	Aptis	Sora	Next	Toyota Prius	Toyota Auris hybrid
Weight	15000 Kg			1440 Kg	1335 kg
Speed	70 Km/h			160 Km/h	194 Km/h
Lenght	12000 mm	10525 mm	2500 mm	4575 mm	4595 mm
Height	32000 mm	3340 mm	2500 mm	1470 mm	1485 mm
Width	3400 mm	2490 mm	2000 mm	1760 mm	1760 mm
Extra	4 steering wheels		Individual dockable modules		
GPS	Si	Si	Si	Si	Si
Engine	Electric	Hydrogen	Electric	Hybrid	Hybrid
Gear	Automatic	Automatic	Automatic	Automatic	Automatic
N° doors	3 doppie	3	2	5	5
Passenger capacity	95	79	10	5	5
	1	0	1	2	3
	3	1	1	1	1
	-2	-1	0	1	2

Figure 9 Benchmarking Taxi

3.4.1 Matrix of Importance and Matrix of Dependence-Independence

	Dimension	Comfort	Speed	Costs	Punctuality	Efficiency	Safety	Technology	Aesthic
Dimension	1	2	2	2	2	2	2	1	0
Comfort	0	1	1	1	1	1	2	0	0
Speed	0	1	1	1	1	1	2	0	0
Costs	0	1	1	1	1	1	2	0	1
Punctuality	0	1	1	1	1	1	2	0	0
Efficiency	0	1	1	1	1	1	1	0	0
Safety	0	0	0	0	0	1	1	0	0
Technology	0	2	2	2	2	2	0	1	0
Aesthetic	2	2	2	1	2	2	2	2	1
	4	11	11	10	11	12	14	4	2

Figure 10 Matrix of importance

	Dimensions	speed	Aesthetics	Comfort	Sostenibility	Safety	Punctuality	Technology	
Dimensions	0	9	1	9	1	3	0	1	23
Speed	0	0	3	3	3	3	9	0	21
Aesthetics	1	1	0	3	3	1	0	0	9
Comfort	0	0	1	0	0	0	0	0	1
Sostenibility	1	3	1	0	0	0	0	3	8
Safety	3	0	0	1	0	0	0	3	7
Punctuality	0	3	0	3	0	0	0	0	6
Technology	1	3	3	3	3	3	3	0	19
	6	19	9	22	10	10	12	7	

Figure 11 Matrix of Dependence-Independence

Thanks to the matrix of importance (*Figure 10)* we have defined what characteristics are essential for taxi by attributing a grade from 0 to 2 for each of them by comparing them. Thanks to the matrix of dependence/independence (*Figure 11)* we investigated the dependence between the various characteristics of taxi to understand which ones were manageable individually and which should be considered in relation to others. In this case, the votes ranged from 0 to 9. The results showed that the essential features for train are efficiency and safety. While technology, dimensions and speed are the characteristics that most influence the quality of the final product.

3.5 Benchmarking Scooter

Three scooter have been compared to understand which is the best one. The relevant features have been highlighted in green while the worst ones in red. Adding up the advantageous and disadvantageous characteristics, it turned out that the best scooter are Ujet and Appscooter. (*figure 12*)

	UJet	Me	Appscooter
Price	8600	3670	3399
Weight	43 Kg	75 Kg	74 Kg
Speed	45 Km/h	70 Km/h	49 Km/h
Materials		SMC, sturdy and light	Reinforced glass fiber
Additional Functions	From saddle to trolley	Rechargeable anywhere	Multifunction display
GPS	Yes	No	Yes
Bluetooth	Yes	No	Yes
Engine	Electric	Electric	Electric
Security Device	Theft Protection App	No	No
	4	1	3
	2	4	1
	2	-3	2

Figure 12 Benchmarking scooter

3.5.1 Matrix of Importance and Matrix of Dependence-Independence

	Speed	Comfort	Practicality	Sustainability	Technology	Safety	Price	Aesthetics
Speed	1	2	2	2	1	2	1	1
Comfort	0	1	1	2	1	2	1	1
Practicality	0	1	1	2	1	2	1	0
Sustainability	0	0	0	1	0	2	0	0
Technology	1	1	1	2	1	2	1	1
Safety	0	0	0	0	0	1	0	0
Price	0	1	1	2	1	2	1	1
Aesthetics	1	1	2	2	1	2	1	1
	4	7	8	13	6	15	6	5

Figure 13 Matrix of importance

	Speed	Comfort	Practicality	Sustainability	Technology	Safety	Price	Aesthetic	
Speed	0	3	3	3	0	3	9	3	24
Comfort	0	0	3	0	0	1	9	1	14
Practicality	3	9	0	0	0	0	3	1	16
Sustainability	9	1	1	0	0	0	9	0	20
Technology	3	9	3	3	0	9	9	1	37
Safety	1	0	0	0	0	0	9	0	10
Price	0	1	0	3	3	3	0	1	11
Aesthetic	1	3	1	0	0	0	3	0	8
	17	26	11	9	3	16	51	7	

Figure 14 Matrix of Dependence-Independence

Thanks to the matrix of importance (*Figure 13)* we have defined what characteristics are essential for scooters by attributing a grade from 0 to 2 for each of them by comparing them. Thanks to the matrix of dependence/independence (*Figure 14)* we investigated the dependence between the various characteristics of scooter to understand which ones were manageable individually and which should be considered in relation to others. In this case, the votes ranged from 0 to 9. The results showed that the essential features for scooters are sustainability and safety. While technology, sustainability and speed are the characteristics that most influence the quality of the final product.

3.6 Benchmarking bike

Three bike have been compared to understand which is the best one. The relevant features have been highlighted in green while the worst ones in red. Adding up the advantageous and disadvantageous characteristics, it turned out that the best bike is Gi Fly Bike. (*figure 15*)

	Gi Fly Bike	Loas Solar Bike	Lopifit
Price	2424	4800	2750
Weight	25 Kg	22 Kg	55 Kg
Brakes	Disk	Disk	Disk
Wheels	26 inches antipuncture	26 inches	26 inches
Security Device	Smart Locking Sistem	No	No
Additional functions	Smartphone Charger	Serratura Loas	Tapis roulant
GPS	Yes	No	No
Bluetooth	Yes App	No	No
Folding	Yes	No	No
Engine	Electric	Solar power	Electric
Full speed	60 Km/h	45 Km/h	25 Km/h
	2	2	0
	0	5	7
	0	-3	-7

Figure 15 Benchmarking bike

3.6.1 Matrix of Importance and Matrix of Dependence-Independence

	Speed	Maneuverability	Ergonomics	Safety	Technology	Sustainability	Price
Speed	1	2	2	1	1	2	2
Maneuverability	0	1	1	1	0	1	1
Ergonomics	0	1	1	1	0	1	1
Safety	0	1	1	1	1	2	2
Technology	1	2	2	1	1	1	1
Sustainability	0	1	1	0	0	1	1
Price	0	1	1	0	1	1	1
	2	9	9	5	4	9	9

Figure 16 Matrix of importance

	Speed	Maneuverability	Ergonomics	Safety	Technology	Sustainability	Price	
Speed	0	1	0	0	0	0	9	10
Maneuverability	3	0	0	0	0	0	1	4
Ergonomics	9	9	0	0	1	0	3	21
Safety	0	0	0	0	0	0	9	9
Technology	0	1	1	3	0	1	9	15
Sustainability	9	0	1	1	3	0	9	23
Price	1	0	0	1	0	0	0	2
	22	11	2	5	4	1	40	

Figure 17 Matrix of Dependence-Independence

Thanks to the matrix of importance (*Figure 16)* we have defined what characteristics are essential for bikes by attributing a grade from 0 to 2 for each of them by comparing them. Thanks to the matrix of dependence/independence (*Figure 17)* we investigated the dependence between the various characteristics of bike to understand which ones were manageable individually and which should be considered in relation to others. In this case, the votes ranged from 0 to 9. The results showed that the essential features for bike are sustainability, punctuality and safety. While technology, ergonomics and sustainability are the characteristics that most influence the quality of the final product.

3.7 Benchmarking electric scooter

Three electric scooter have been compared to understand which is the best one. The relevant features have been highlighted in green while the worst ones in red. Adding up the advantageous and disadvantageous characteristics, it turned out that the best electric scooter is Audi e-tron. (*figure 18*)

	Unagi	Audi e-tron	Aktivo Scoot
Price	650	2000	450
Weight	10 Kg	12 Kg	13 Kg
Wheels	Full		Empty
Additional functions	Led light	One-handed handlebar	Brushless engine
GPS	Yes	Yes	Yes
Bluetooth	No	Yes	Yes
Folding	Yes	Yes	Yes
Electric	Yes	Yes	Yes
Full speed	25 km/h	20 Km/h	25 Km/h
	1	2	2
	3	1	2
	-2	1	0

Figure 18 Benchmarking electric scooter

3.7.1 Matrix of Importance and Matrix of Dependence-Independence

	Speed	Comfort	Practicality	Sustainability	Technology	Safety	Price	Aesthetic	Maneuverability
Speed	1	1	2	2	1	2	2	1	2
Comfort	1	1	1	2	1	2	0	1	1
Practicality	0	1	1	2	1	2	0	1	1
Sustainability	0	0	0	1	0	1	0	0	1
Technology	1	1	1	2	1	2	1	1	2
Safety	0	0	0	1	0	1	0	0	1
Price	0	2	2	2	1	2	1	1	2
Aesthetic	1	1	1	2	1	2	1	1	2
Maneuverability	0	1	1	1	0	1	0	0	1
	4	7	8	14	6	14	5	6	13

Figure 19 Matrix of importance

	Speed	Comfort	Practicality	Sustainability	Technology	Safety	Price	Aesthetics	Maneuverability	
Speed	0	3	1	1	0	3	3	0	3	14
Comfort	0	0	9	0	0	1	3	3	1	17
Practicality	1	9	0	0	0	3	3	3	3	22
Sustainability	3	0	1	0	1	0	9	0	0	14
Technology	9	3	9	3	0	3	9	3	9	48
Safety	1	1	0	0	0	0	3	1	0	6
Price	0	3	1	1	1	3	0	1	0	10
Aesthetic	0	3	1	0	1	0	3	0	1	9
Maneuverability	3	3	3	0	3	9	0	1	0	22
	17	25	25	5	6	22	33	12	17	

Figure 20 Matrix of Dependence-Independence

Thanks to the matrix of importance (*Figure 19)* we have defined what characteristics are essential for electric scooters by attributing a grade from 0 to 2 for each of them by comparing them. Thanks to the matrix of dependence/independence (*Figure 20)* we investigated the dependence between the various characteristics of electric scooter to understand which ones were manageable individually and which should be considered in relation to others. In this case, the votes ranged from 0 to 9. The results showed that the essential features are sustainability and safety. While technology, practicality and maneuverability are the characteristics that most influence the quality of the final product.

3.8 Final Matrices

After having extrapolated the most important characteristics for each means of transport, we combined them doing other matrices that included them. In sequence:
-Final Matrix of importance (Figure 21)
-Final Matrix of dependence / independence (Figure 22)
We concluded with a *WHAT / HOW matrix (Figure 23)* in which we crossed the characteristics emerged from the total matrices with the most important design characteristics that we had identified in the Benchmarkings In this way we came to obtain the best characteristics of each means of transport which, together, embodied an ideal future means of transport *(Figure 24)*

3.8.1 Final Matrix of importance

	Ergonomics	Technology	Sostenibility	Dimensions	Motor power	Rapidity	Speed	Convenience	Privacy
Ergonomics	1	1	2	1	0	2	1	1	1
Technology	1	1	2	1	0	2	2	2	2
Sostenibility	0	0	1	0	0	1	0	0	0
Dimensions	1	1	2	1	2	2	2	2	2
Motor Power	2	2	2	0	1	2	2	2	2
Rapidity	0	0	1	0	0	1	1	1	1
Speed	1	0	2	0	0	1	1	2	2
Convenience	1	0	2	0	0	1	0	1	1
Handling	1	0	2	0	0	1	0	1	1
	8	5	16	3	3	13	9	12	12

Figure 21 Final Matrix of importance

3.8.2 Final Matrix of dependence/ independence

	Ergonomics	Technology	Sostenibility	Dimensions	Motor Power	Rapidity	Speed	Convenience	Maneggevolezza	
Ergonomics	0	0	0	0	0	3	1	3	9	16
Technology	0	0	3	3	0	3	3	3	3	18
Sostenibility	1	1	0	1	0	1	1	0	0	5
Dimensions	3	1	3	0	1	1	1	3	3	16
Motor power	1	0	9	3	0	3	9	1	3	29
Rapidity	0	1	1	0	0	0	3	1	1	7
Handling	0	1	1	0	0	9	0	1	3	15
Convenience	3	0	0	0	0	0	1	0	9	13
Speed	9	0	0	0	1	1	3	9	0	23
	17	4	17	7	2	21	22	21	31	

Figure 22 Final Matrix of dependence/ independence

3.8.3 Final Matrix of What/ How

	Motor	Weight	Prize	Privacy	Dimensions	Max Speed	Materials	Capaity	Safety	Self-driving
Ergonomics	3	3	3	0	0	0	1	9	1	9
Technology	9	0	3	9	9	9	0	0	3	9
Motor Power	9	0	0	0	9	9	1	0	1	0
Dimensions	1	0	1	0	0	3	0	1	0	9
Sostenibility	3	1	9	0	9	0	0	0	0	0
Speed	3	1	1	9	1	0	3	3	0	3
Convenience	0	0	1	1	0	0	0	3	0	1
	28	5	17	19	28	21	5	16	5	131

Figure 23 Final Matrix of What/ How

3.8.4 Final Features

Figure 24 Final Features

4. Feasibility Analysis

We have taken MAGLEV magnetic levitation trains as study models, that are already produced and operating in different territories and they gave us guarantees of efficiency and allowed us to access information, patents and data without any problem.
We moved trying to understand the possibility of creating a transport system similar to that of the maglev on a small scale. We therefore analyzed several magnetic levitation vehicles to first understand how they work, to understand the energy quantities necessary for their operation, the environmental impact from the point of view of magnetic fields and the production costs of the equipment.

4.1 The magnetic levitation

The super-speed Maglev system has no wheels, no axles, no gear transmissions, no steel rails, and no overhead electrical pantographs. The maglev vehicles do not roll on wheels; rather, they hover above the track guide way,using the attractive magnetic force between two linear arrays of electromagnetic coils—one side of the coil on the vehicle, the other side in the track guideway, which function together as a magnetic dipole. During levitation and travelling operation, the Maglev vehicle floats on a frictionless magnetic cushion with no mechanical contact whatsoever with the track guideway. On-board vehicle electronic systems measure the dipole gap distance 100,000 times per second to guarantee the clearance between the coils attached to the underside of the guideway and the magnetic portion of the vehicle wrapped around the guideway edges. With this precise, constantly updated electronic control, the dipole gap remains nominally constant at 10 millimeters (0.39 in). When levitated, the maglev vehicle has about 15 centimeters (5.9 in) of clearance above the guideway surface.
The Maglev vehicle requires less power to hover than it needs to run its on-board air conditioning equipment. A linear motor is an electric motor that has had its stator and rotor “unrolled" thus instead of producing a torque (rotation) it it produces a linear force along its length. However, linear motors are not necessarily straight. Characteristically, a linear motor’s active section has ends, whereas more conventional motors are arranged as a continuous loop. The most common mode of operation is as a Lorentz-type actuator, in which the applied force is linearly proportional to the current and the magnetic field.

4.2 Propulsion

The Maglev system uses a synchronous long stator linear motor for both propulsion and braking. It works like a rotating electric motor whose stator is "unrolled" along the underside of the guideway; instead of producing torque (rotation) it produces a linear force along its length *(Figure 25)*. The electromagnets in the maglev vehicle which lift it also work as the equivalent of the excitation portion (rotor) of this linear electric motor. Since the magnetic travelling field works in only one direction, if there were to be several maglev trains on a given track section, they would all travel in the same direction thereby reducing the possibility of collision between moving trains *(Figure 26*).

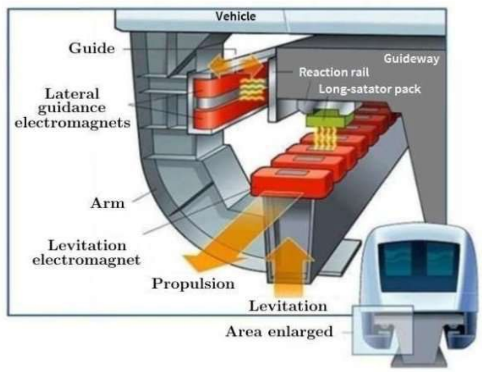


Figure 26 Propulsion System

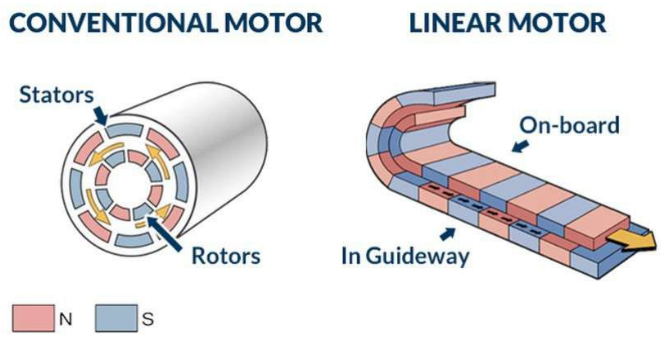


Figure 25 Linear Motor

4.3 Rail section feeding system

The train track is divided into many 5 km long sections. These sections of track are activated only when the maglev train crosses them, otherwise they remain deactivated. This involves a great saving of energy. Each section is equipped with its own motors LSM and requires 110 kW of current from the public grid to operate *(Figure 27).*

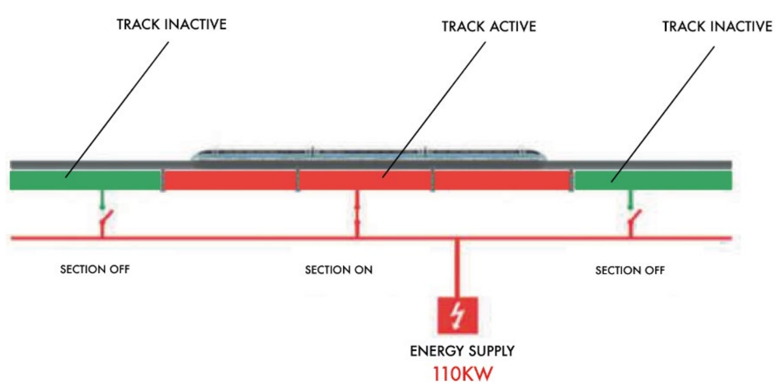


Figure 27 Rail section system

4.4 Magnetic fields

The air opening for the levitation of a Maglev train is very narrow (about 10mm). This small opening effectively contains the electromagnetic field and greatly reduces its extension *(Figure 28)*.

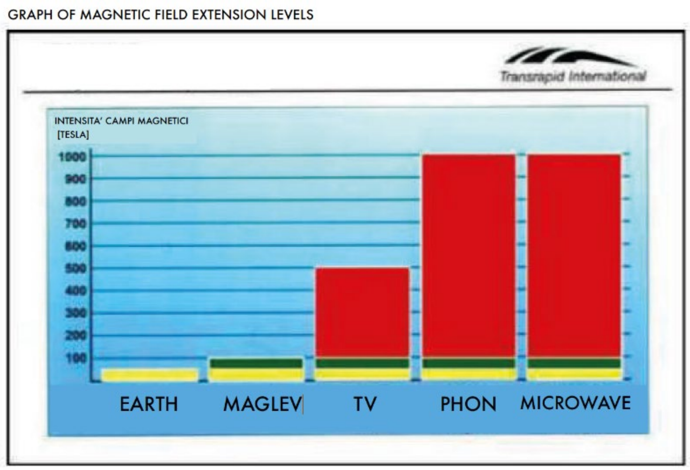


Figure 28 Magnetic fields

4.5 Ecological impact

The Maglev Train is an electrically driven, clean, high-speed, high-capacity means of transport able to build up point-to-point passenger connections in geographically challenged surroundings. This has to be set in comparison with the impact on heritage and or landscape protection areas. Any impact of emissions has to take into account the source of electrical energy. The reduced expense, noise and vibration of a people-only Maglev system versus a cargo train track is not directly comparable. The reuse of existing tracks and the interfacing with existing networks is limited. The Train indirectly competes for resources, space and tracks in urban and city surroundings with classical urban transport systems and high-speed trains.

4.6 Energy requirements

The normal energy consumption of the Transrapid is approximately 50 to 100 kilowatts (67 to 134 hp) per section for levitation and travel, and vehicle control. The drag coefficient of the Transrapid is about 0.26. The aerodynamic drag of the vehicle, which has a frontal cross section of 16 m2 (172 sq ft), requires a power consumption, at 400 km/h (249 mph) or 111 m/s (364 ft/s) cruising speed, given by the following formula *(Figure 29)*

$$P = c_w \cdot A_{\text{Front}} \cdot v^3 \cdot (\text{density of surrounding air})/2$$

$$P = 0.26 \cdot 16\,\text{m}^2 \cdot (111\,\text{m/s})^3 \cdot 1.24\,\text{kg/m}^3/2$$

$$P = 3.53 \cdot 10^6\,\text{kg} \cdot \text{m}^2/\text{s}^3 = 3.53 \cdot 10^6\,\text{N} \cdot \text{m/s} = 3.53\,\text{MW}$$

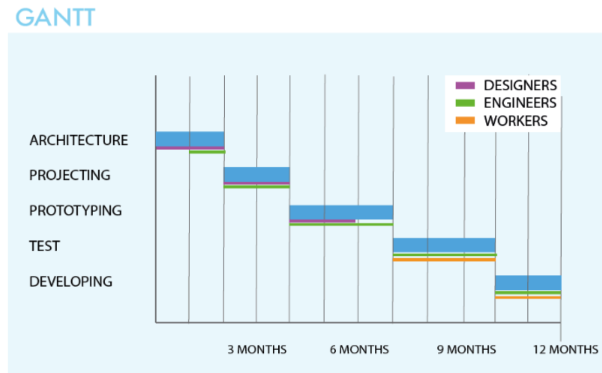
Figure 29 Formula

Power consumption compares favorably with other high-speed rail systems. With an efficiency of 0.85, the power required is about 4.2 MW. Energy consumption for levitation and guidance purposes equates to approximately 1.7 kW/t. As the propulsion system is also capable of functioning in reverse, energy is transferred back into the electrical grid during braking. An exception to this is when an emergency stop is performed using the emergency landing skids beneath the vehicle, although this method of bringing the vehicle to a stop is intended only as a last resort should it be impossible or undesirable to keep the vehicle levitating on back-up power to a natural halt.

5. Budget

The estimated total cost of carrying out the project is 617.40 £ *(Figure 30)*

COST OF EQUIPMENT	MATERIALS	EQUIPMEN
PROTOTYPING	93.600	55.000
TEST	50.000	55.000
DEVELOPING	33.600	30.000
COST	176.200	140.000
TOTAL COST	316.200	



ORGANIC COST	3 DESIGNERS	3 ENGINEERS	3 WORKERS
	50.000	15.000	
	50.000	40.000	
	50.600	55.000	20.000
	20.000	20.000	15.000
	10.600	15.000	20.000
COST	181.200	145.000	55.000
TOTAL COST		381.200	

	DESIGNER	ENGINEER	WORKER
HOURLY COST	65	75	25
DAILY COST	8	8	8
MONTHLY COST	160	160	160

316.200+301200=

617.400 £

Figure 30 Budget

6. Concept development

According to the results that emerged from our matrices, we had the will to develop a transport system that could guarantee the safety and privacy of passengers in addition to a high speed. The intention was to create a transport network that could unite many cities with direct and easily practicable routes that could replace today's highways. The idea was to create an elevated track system on which individual machines could travel quickly and safely. The idea of creating the elevated tracks was born coherently with our research and environmental analysis as the final mission was to decrease more and more the asphalt and the roads on the ground allowing a huge space saving with a consequent requalification of the territories with green areas and extension of urban areas.

6.1 First Sketches

Here we can see the first sketches *(Figure 31)*

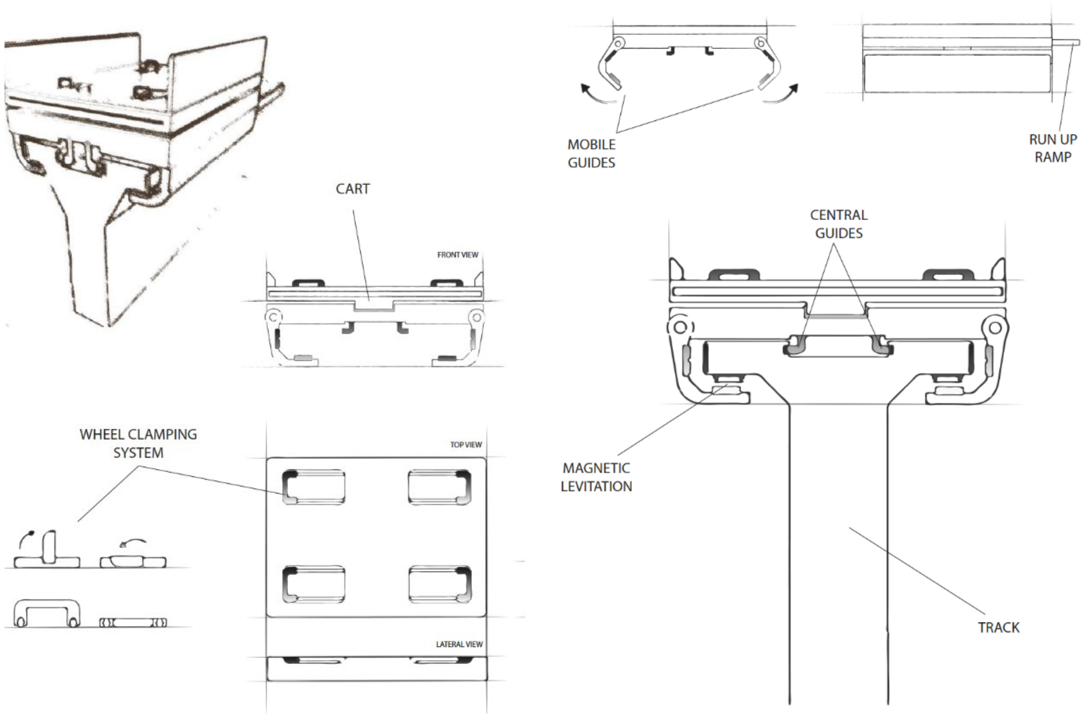


Figure 31 Cart details

6.2 Design and development

From the sketches we moved on to the digitalization of our concept with a more in-depth and detailed study of its functioning. Specifically, we went to define separately, first all the components inherent to the Cart, through the definition of the various components and through a product's architecture *(Figure 32)*. Then we did the same regarding to the supporting structure (the track) by going to insert the various technical components, choosing the motors and the type of magnetic levitation system that we considered more suitable.

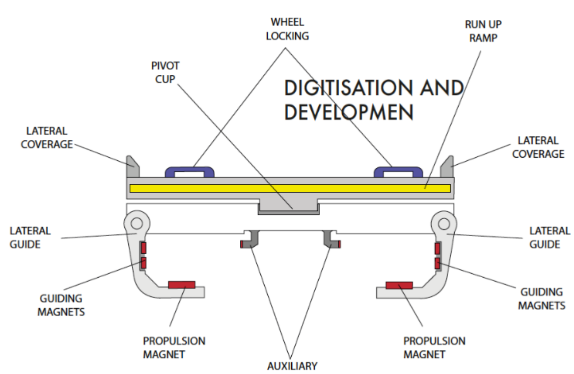


Figure 32 Details

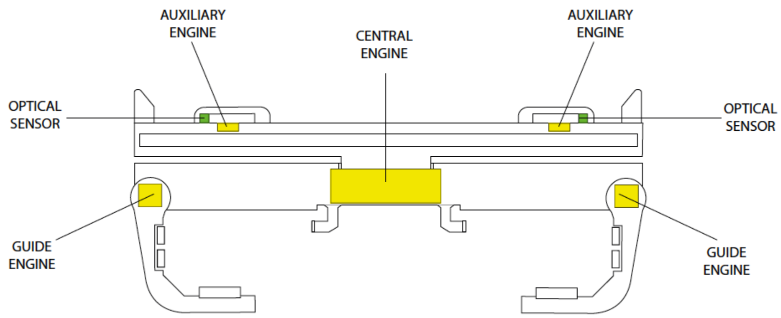


Figure 33 Operation details

Let's analyze some details *(Figure 33)*

CENTRAL MOTOR: electric motor that allows the rotation of the upper part of the Cart during the loading and unloading of the vehicle.

GUIDE MOTOR: secondary electric motor that allows the movement of the side guides in case of a fork in the track. It therefore allows the release of the guide.

AUXILIARY MOTOR: motor that allows the movement of the locks for the wheels avoiding the movement of the loaded vehicle.

OPTICAL SENSOR: Sensor that detects the exact position of the vehicle wheels on the Cart allowing the locks to be positioned correctly.

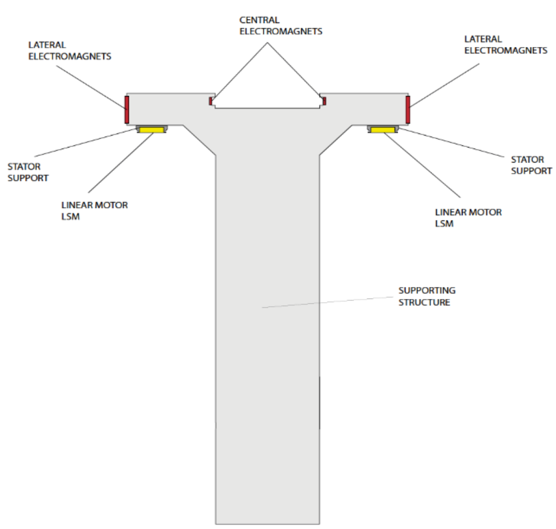


Figure 34 structure operation details

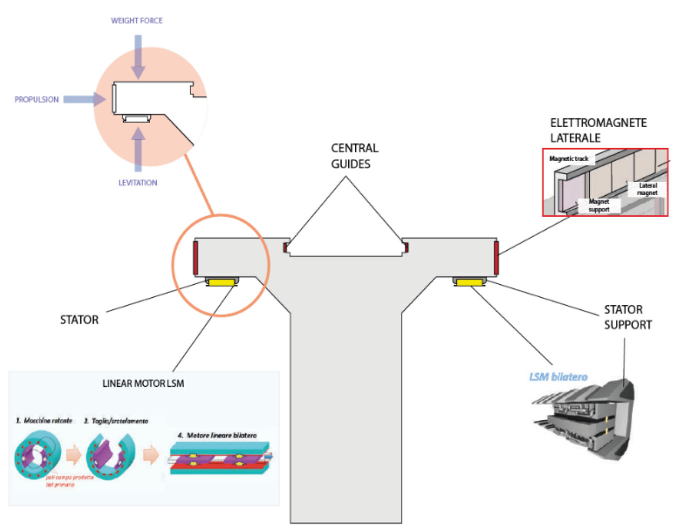


Figure 35 operation details of the hooks

LSM MOTOR: bilateral linear motor which is positioned on the track *(Figure 34)*. This means that the energy needed to produce levitation is totally charged to the track and does not have to be provided by the trolley. On the track, in fact, we have a pair of stators which will be coupled with the lateral guides of the Cart; we also have two lateral electromagnets placed outside and two central electromagnets placed in the internal cavity which have the function of stabilizing the Cart during the movement, preventing it from going out of the roadway. As shown in the figure, on the track, there are three different forces act: Propulsion, Levitation and Weight Force (of the cart) *(Figure 35)*.

6.3 Wheel clamping System

There is a slight recess in which the vehicle wheel is expected to enter. When it enters, the wheel lock is lowered. Once the wheel is in the correct position the wheel block rises and advances until it reaches the wheel and lock it. This happens for each of the four wheels. The movement of the wheel block is guided by four optical sensors that detect the exact position of the tires. *(Figure 36)*

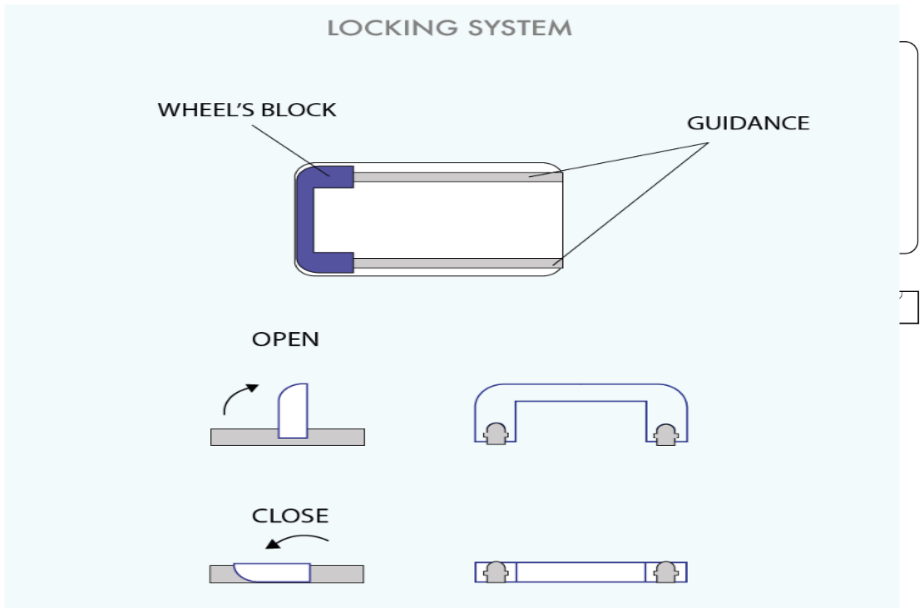


Figure 36 Wheel's block details

6.4 Lateral guides release system

In the event of a junction of the rails, the system of mobile lateral guides allows the Cart, to release the external guide to the deviation that must be made by continuing in the desired direction *(Figure 37)*. The stability of the trolley is guaranteed by the two central support guides. For example, in the case of an exit to the right, the left side guide of the trolley will be released in order to allow the latter to follow the correct path *(Figure 38)*.

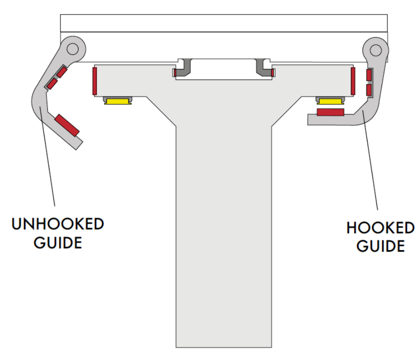


Figure 37 Cart guides

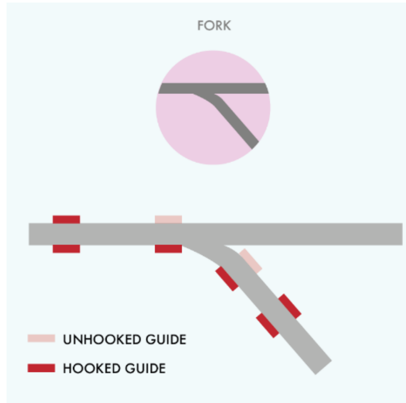


Figure 38 Lateral guides

6.5 Loan and unload stations

The upper part of the Cart rotates on the lower one. In this way, the upper part manages to enter in continuity with the road and it can load unload the latter in a simple and fast way through a mobile ramp that exits the Cart itself when it is needed. *(Figure 39)*

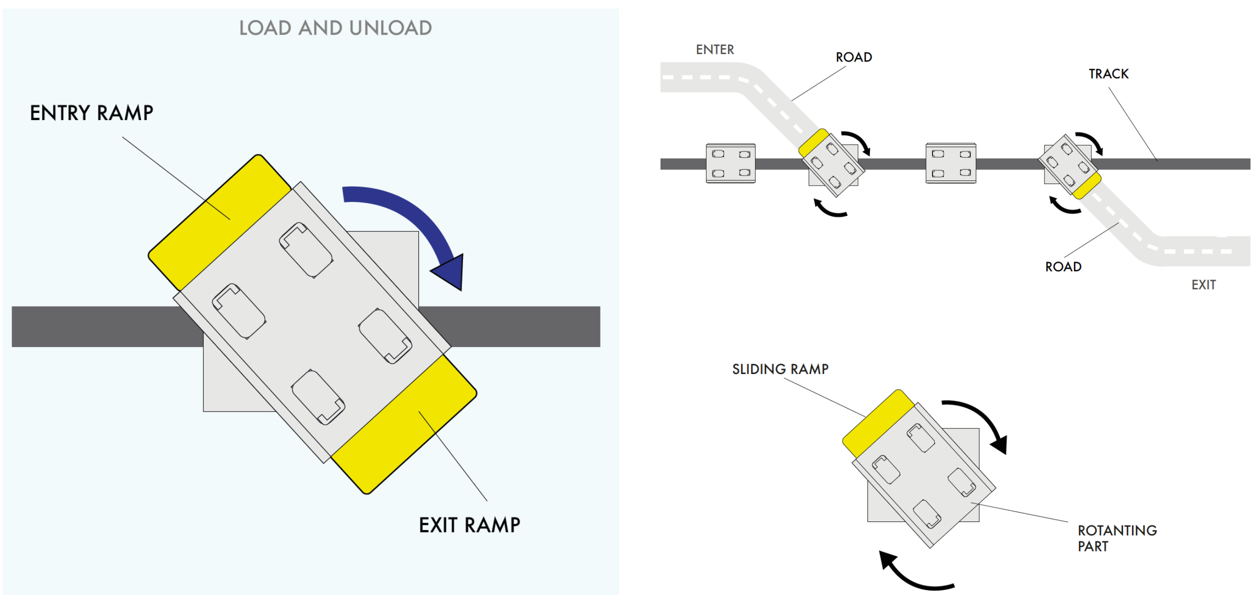


Figure 39 Rotation of the cart

7. Product development

We have worked on a 3D model of the Cart reproducing all the components using Alias Studio and Creo. We have also created a 3D model of the rail. *(Figure 40)*At the end we have made many renderings, hypothesizing how the cart could be placed in the environment. *(Figure 41)*

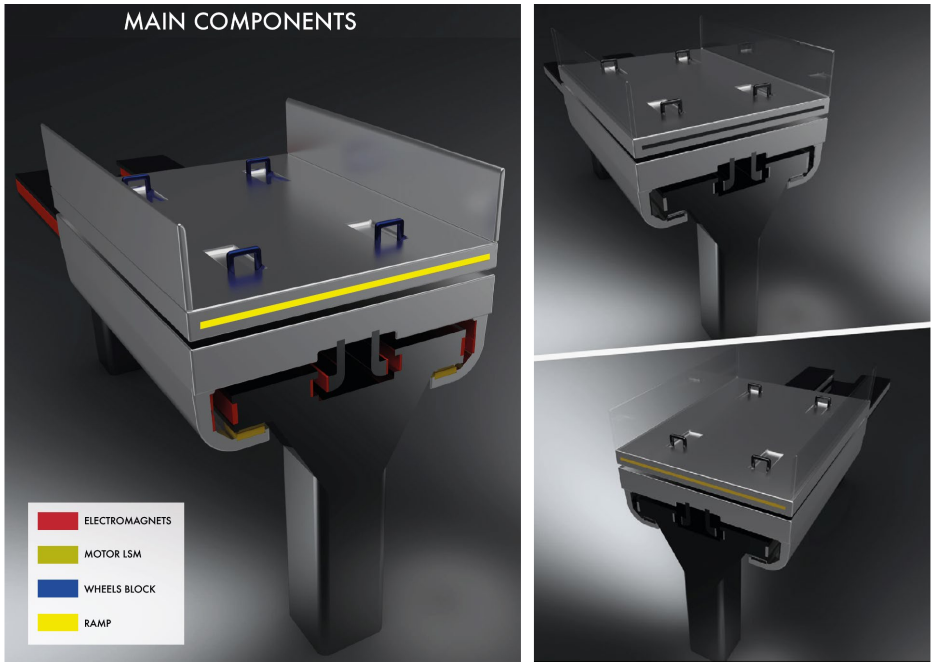


Figure 40 rendering

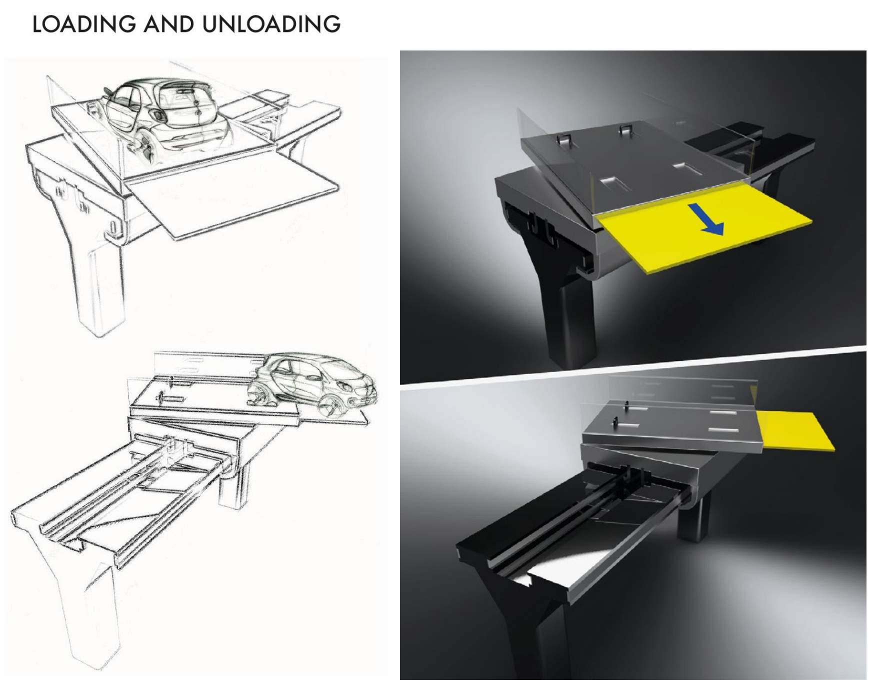


Figure 41 Drawings and renderings

8. Highways

The idea is to replace traditional asphalt highways with new faster and safer ONES. *(Figure 42), (Figure 43)*
Traffic problems would thus be avoided and accidents would be eliminated with consequent and undeniable well-being for each person.

Figure 42 Flow of machines

Figure 43 Visual impact

8.1 Milano-Bologna

Milan- Bologna: total distance 215 Km

A car with an average speed of x100 Hm/h takes 2h 30 m to travel the entire route. With Fly Trans, on the other hand, you travel at an average speed of 300 Km/h and therefore it takes only 45 minutes to travel the same distance *(Figure 44)*.

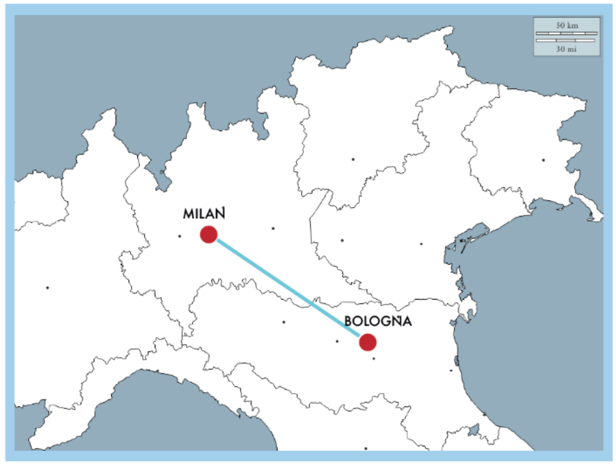


Figure 44 Road between Milan and Bologna

8.2 The mission

Through this new typology of elevated highways it would be possible to definitively eliminate asphalted roads. This would result in an incredible increase in space that could be used for cultivation, remediation or to extend housing areas. There would be a perfect cohesion between the roads and the territory.

9. Future Developments and Conclusions

As already presented in IEOM Plzen Conference 2019 by Frizziero et al. and Donnici et al., future developments must be oriented to the implementation of the emerging technologies (derived from Industry 4.0) instead of the techniques nowadays used for SDE.
In particular, we can put the attention mostly on two aspects:

1) Pencil Sketches can be evolved into Digital Sketches
2) Physical Model can be substituted by Digital Model (for example using A.R. or V.R.)

In conclusion, it can be affirmed that in the present work, a new innovative car project was developed using the method and the technologies illustrated.
In particular, through Stylistic Design Engineering applications, sketches, 2D drawings, 3D models and Physical Prototype were realized, in order to help the design process to be performed.

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Biography / Biographies

Leonardo Frizziero is a Senior Assistant Professor of the Department of Industrial Engineering, at Alma Mater Studiorum University of Bologna. He promotes the scientific issues related to the Mechanical Design and Industrial Design Methods (CAD 2D, 3D, Advanced Design, QFD, TRIZ, DFSS, DFD, DFA, ecc.). In 2005, he was recruited by Ferrari Spa, as project manager of new Ferrari cars projects. In 2009 he came back to University, obtained the Ph.D. degree and started collaborating with the Design and Methods Research Group of Industrial Engineering becoming Junior Assistant Professor in February 2013 at DIN of AMS University of Bologna. He teaches and follows researches in the design fields, participating at various competitive regional, national and international research projects. Since 2018 he has been a Senior Assistant Professor. Since 2017 he is qualified Associate Professor of Design and Methods of Industrial Engineering (ING-IND/15). Prior to the role of university professor, he held relevant positions for some industrial companies.

Giampiero Donnici is a Ph.D. Student of the Department of Industrial Engineering, at Alma Mater Studiorum University of Bologna. Giampiero Donnici worked as a mechanical designer in agricultural machinery companies and machine companies. As a consultant he has worked in numerous companies producing automatic machines and PLM and PDM systems. He is now a tutor and adjunct professor at the aforementioned university.

Alfredo Liverani is a Full Professor and Chief of Mechanical Engineering Degree Course at the Department of Industrial Engineering of Alma Mater Studiorum University of Bologna. Prof. Alfredo Liverani is a member of CbEM (Computer-based Engineering Methodologies) research group and he is involved in several activities related to Computer Aided Design (CAD), Computer Graphics, Virtual and Augmented Reality. In detail he focuses on real-time visualization and interaction with particular attention to mechanical, aeronautical applications and also Industrial Design. Surface modelling, reverse engineering, mesh generation (FEM) and manipulation, virtual prototyping and live simulations are fields investigated in the several publications available at http://diem1.ing.unibo.it/personale/liverani.

Alessandro Cerullo, Elisa Ghirlandi, Eleonora Sonnati are students of the course “Advaced Design-Design and Methods of Industrial Engineering”, held by Prof. Leonardo Frizziero at Alma Mater Studiorum University of Bologna**.**