The Bicycle as a Campus Mobility Solution

Andrés Torres Sánchez

Mechanical and Electrical Engineering

Mechanical Computer-aided Design

Ing. José Eduardo Frias Chimal

Content

Introduction

This project surges of the necessity of having a micro mobility option in the campus of the Universidad Iberoamericana Leon for the usage of students, teachers and all people who work inside the facilities.

As solution to this necessity is proposed the introduction of bicycles available to everyone, the design of this bicycles need to cover some requirements: it needs to be cheap to build, low and easy maintenance requirements, it need to be safe for the cyclist and for the people around, easy to store a few of them in the same space and it must be inclusive for all people with the complete range of mobility of upper and lower extremities.

To comply with the requirements, it needs the following specifications: as minimum parts and mechanisms as possible, the best quality-price materials to keep a low cost, the dimensions are also to keep in mind for safety, storing and usage.

State of the Art

The bicycle is a machine that has revolutionized a lot of things around human life since his development in the early 19th century. It has been not only part of a technological revolution but a social, economic and transportation one. (Wilson, 1973)

Making fast forward to the 21st century, materials and components are getting more efficient each day. There is also a continuous innovation that is pushing the state of the art to new limits with electrical bicycles or even reinventing the whole transmission, something that has work almost without changes since its invention.

For this project, it is going to be analyzed the current different type of bicycles offer in the market. The hybrid and electrical ones are not going to be consider because even though they are improving the technology and mobility around the world, it fit out of these projects, as they are considerably more expensive and harder to maintain. Most importantly, they are not necessary for the needs of the project as the distances are short and low speeds are required to keep safety.

Frame

The frame is what gives structure to the bicycle, it is where the front fork, wheels, staring, seat, and all other components are fitted.

Diamond Frame

The standard frame used is the diamond frame, which has been for over 100 years, and it probably will never be a better frame for rigid bicycles which construction is made with joined.

The diamond frame consists of two triangles: the front triangle and the rear triangle. The front triangle includes the seat tube, the top tube, the down tube, and the head tube. As is visible in figure 1, it is not really a triangle as the head tube prevents the top tube and the down tube form joining. The rear triangle includes the seat tube, seat stays, and chains stays. (Brown, Sheldon Brown's Bicycle Glossary, 2022)

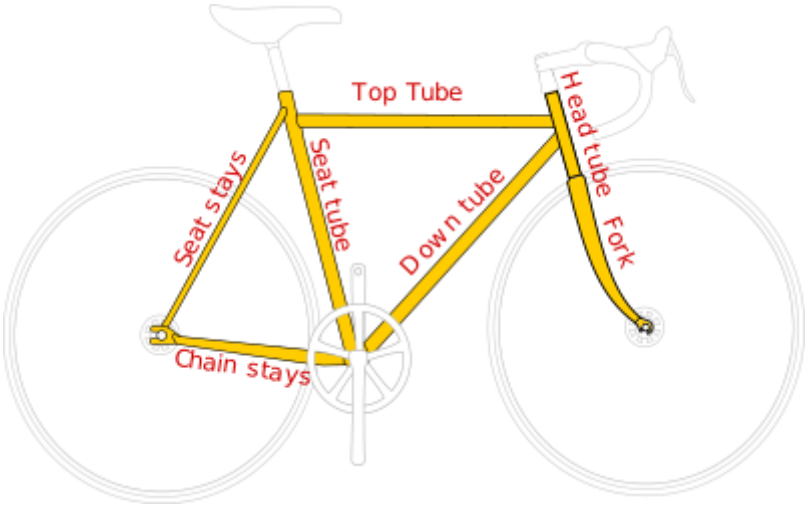


Figure 1. Bicycle frameset (diamond frame).

This frame has managed to keep as the standard for over a century mainly because of his stability and how equitably the forces are distributed around all the tubes of the frame. The triangle is the most stable geometrical figure, even though this is not exactly a triangle we still get the advantage of this geometrical figure.

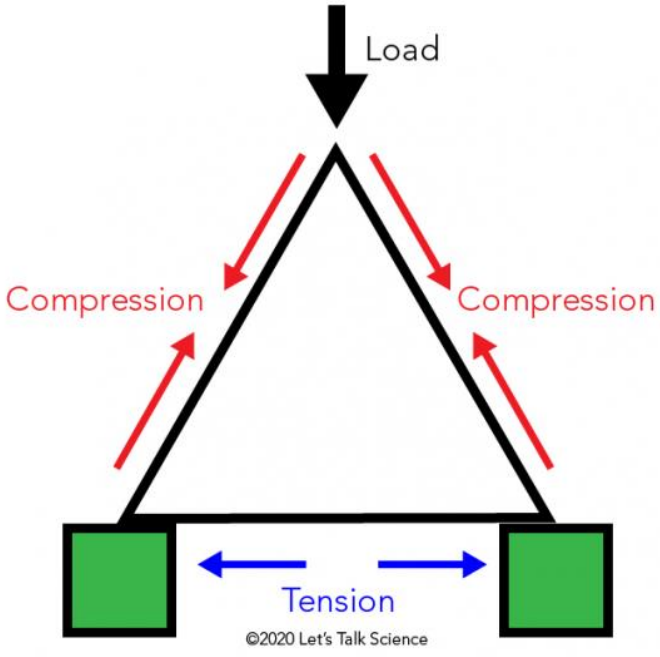


Figure 2. When a downward load is applied to the top corner of a triangle, the sides of triangle experience compression and the base of the triangle experiences tension (Let's Talk Science, 2020).

Even with the diamond frame being the standard that does not mean it is the only viable option at all, there is dozens of frame shapes and thousands of variations dependent on the needs of each project.

Step-through Frame

The step-through frame is a variation of the diamond frame with a low top tube or even sometimes without it. As its name suggests, the frame is designed to step through to it in one step without hosting one leg over the high-top tube. It was developed in the late 19th century as a “Ladies Bike” as it was easy to get on the bike with a skirt or a dress, as it was the most common clothing style for women at the time.

Figure 3. Bicycle with step-though frame (Masoner, 2012).

As it was already mentioned, the main advantage of step-through frames is the facility of getting on and off the bicycle. (Flottorp, 2021) That allows the diversity of usage for different clothing styles and mobility capabilities of riders. On the other hand, the main disadvantage of this type of frame is the lack of sturdy compared to the diamond frame as the absence of a top tube securing together the front tube and seat tube, which from a competitive perspective it is something to have in mind, but for a campus mobility option it won’t represent a problem as you are not looking for the best performance and aerodynamic.

Recumbent bicycle

A recumbent bicycle is not just a type a frame but a whole different concept. The seating position is a more vertical one and the pedals are far in front of the rider, similar to a driving

position. The advantages are the aerodynamic, as the body make less drag with the air because of the more vertical position it is better for long rides in highways where the air flow is going to be considerable. It is also more ergonomic as it allows a better weight distribution along the whole body and not just in a small part of the buttocks, the feet, and the hands.

Figure 4. Cyclist with a recumbent bicycle (Bergen, 2018).

The disadvantages of this kind of bicycle consists of the difficulty of getting on and off it and it is a more complicated mechanic and frame construction compared with the diamond and step-through bikes.

Frame Design							
		Decision Matrix					
Criteria	Weighting	Diamond frame		Step-through frame		Recumbent frame	
		Score	Total	Score	Total	Score	Total
Cost	5	5	25	5	25	3	15
Easy to use	5	4	20	5	25	2	10
Strength	2	5	10	4	8	5	10
	TOTAL:		55		58		35

Drivetrain

The drivetrain of a bicycle consists of all the components, and how they interact with each other, that transform the energy produced by the cyclist into movement of the bike wheels. Although the wheels movement can be powered from different body parts such as arms or from the whole body, this project will focus only on legs powered bicycles as most of the other types of bicycles frequently have more than two wheels, making it less efficient for storing.

Transmission Chain

The most common bike drivetrain is transmission chain. It includes all the components used to drive the bike forward. (McAllister, 2022)

Roller chain – transfers power from the pedals to the rear wheel of the bicycle so it can be propelled.

Pedals – where the rider places his feet and allow him to rotate the crankset.

Crank arms – these are the levers to that your pedals attach to.

Chainrings – the part that engage the change to transfer the power to the wheel, it has spaced teeth (bikecult.com, 2017). It can have different sizes plates, the larger the plate, the harder it is to pedal, and the further each rotation will push you forward (McAllister, 2022).

Crankset – the set of the crack arms and the chainrings.

Cassette – the set of sprockets in the rear wheel, each sprockets represents a gear. It can be only one or multiples.

Derailleur – a mechanism that shift the chain between the different chainrings (front) and sprockets (rear) to change gear usually controlled with the gear levers. They are not necessary when there is just on gear (front and rear).

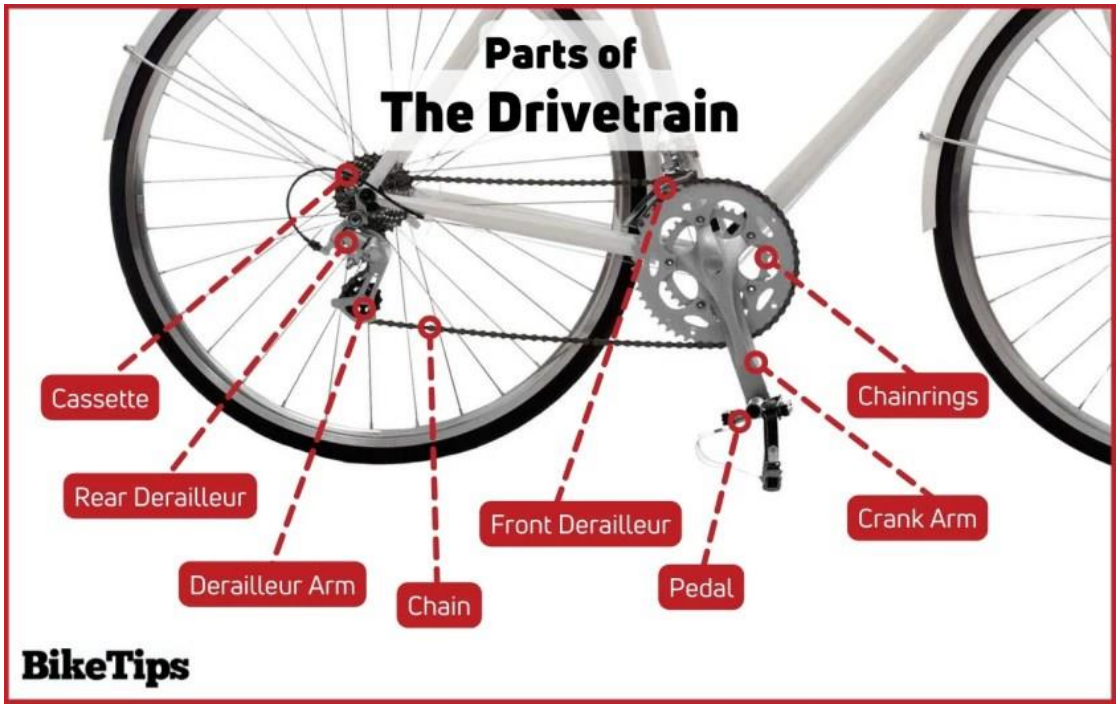


Figure 5. Parts of the drivetrain (McAllister, 2022).

Driveshaft Transmission

As it names suggests, a shaft-driven bicycle uses a drive shaft to transmit power from the cyclist feet to the rear wheel instead of a chain. It was popular in the 18th century but with the time it was replaced by the chain transmission (Brown, Sheldon Brown' Bicycle Glossary, 2022). The

sprockets are replaced by a bevel gear connected through a shaft to another bevel gear that picks the power form the crank arms.

Figure 6. A shaft drive bicycle (Denham, 2021).

The main disadvantages of this type of transmissions are that are way too expensive to repair compared to a derailleur that is cheap, light, and easy to fix or replace if necessary. Other main problem is the lack of efficiency compared to chain transmission. In 1983 Josef Keller found a 7% difference in favor of the chain transmission, this happens due to two changes in rotation direction (Denham, 2021) (Keller, 1983).If that was not enough, we also have a weight problem, as the mechanism is between 1-2 kilograms heavier compared with chain transmissions (Denham, 2021).

Drive train					
		Decision Matrix			
Criteria	Weighting	Transmission chain		Driveshaft	
		Score	Total	Score	Total
Cost	5	4	20	5	25
Easy maintance	5	5	25	3	15
Efficiecny	3	5	15	3	9
	TOTAL:		60		49

Frame Materials

There are diverse types of materials used to build frames. Depending on the need of usage of the bike, you will want to prioritize strength, durability, lightness, or costs. There are four main materials used currently in the industry: steel, aluminum, carbon fiber, and titanium.

	Modulus of Elasticity (GPa)	Yield Strength (MPa)	Tensile Strength (MPa)	Fatigue Strength at 50,000 Cycles (MPa)	Density (kg/m^3)	Weldability and Machinability	Cost (USD pe kg)
Aluminum – 6061-T6	72	193-290	241-320	75	2,700	Excellent	$2.42
Aluminum – 7005-T6	72	290	350	~75	2,780	Excellent	$2.87
Steel - 4130	205	800-1,000	650	250	7,800	Excellent	$0.95
Titanium – Grade 9	91-95	483-620	621-750	250	4,480	Fair	$57.40
Carbon Fiber	275-415	Varies	Varies	Varies	1,800	Fair	Varies

Figure 7. Mechanical properties of the materials (Dwyer, Shaw, & Tombarelli, 2012).

Steel

Steel was the primary material used for frames in the past and it is still used in low-cost bikes that do not need any specific performance requirements. The disadvantages appear in the weight. Steel is heavier than aluminum and carbon fiber, which is a problem when the bike intends to be as power efficient as possible, forcing the rider to produce more power to move the bicycle because of the extra kilograms of the frame. On the other side, the advantages are precisely because of its weight, which allow it to be stronger than aluminum and thus it will make a more resistant frame. It is also the cheapest material out of the four.

Aluminum

Aluminum is the most common material used for bicycle frame because of its good weight-cost ratio. Carbon fiber is lighter but is often considerably more expensive, so it is only used for high performance bikes.

Carbon fiber

Carbon fiber is the way to go for high performance frames because of its low density.The main disadvantage of carbon fiber is cost, according to Rao N., Simha, P. Rao, Ravikumar (2018) “Cost of carbon fiber is directly related to the cost and yield of precursor from which it is obtained and cost of conversion. At present carbon fiber is Polyacrylonitrile (PAN) based, and its averaged cost of non-aerospace grade is around $21.5/kg, with a conversion efficiency of only 50%” (p.3).

Titanium

Titanium is a no often used material because is considerably more expensive that the other three materials analyzed. Is has comparable properties than steel but with more durability. It is recommended when budget is not a problem, and the intention is to make a long-lasting frame.

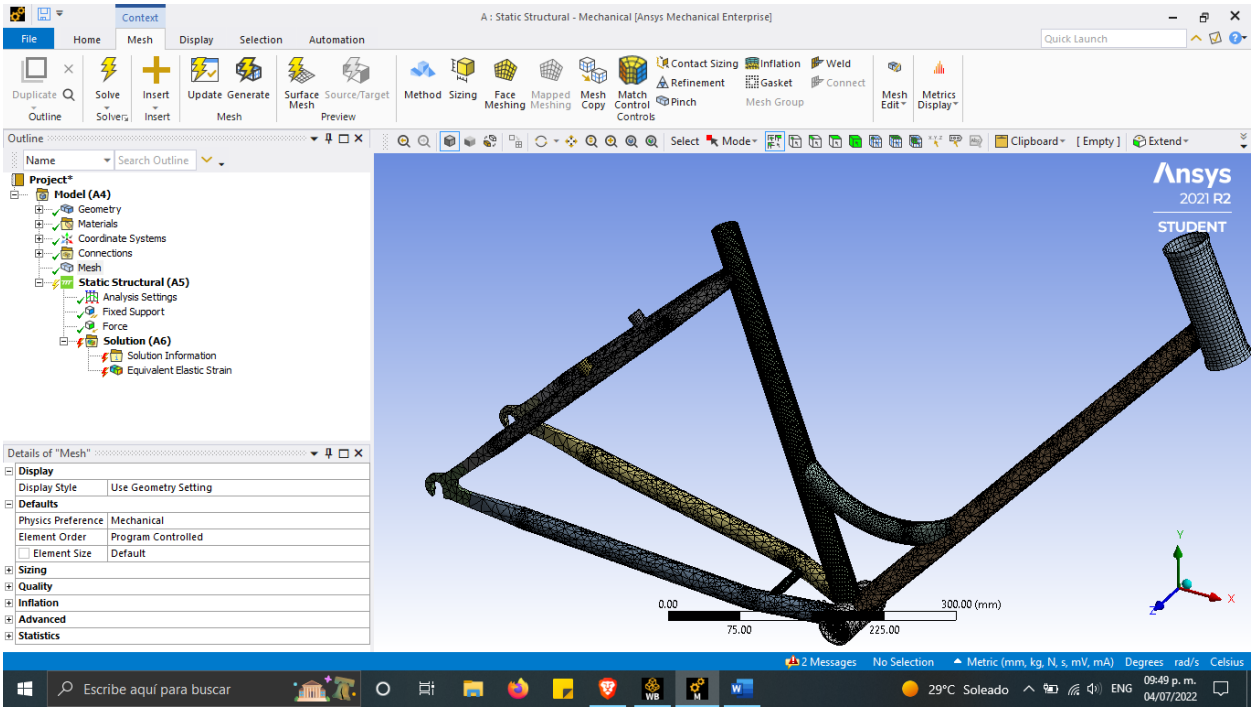
Frame Materials									
		Decision Matrix							
Criteria	Weighting	Steel		Aluminum		Carbon Fiber		Titanium	
		Score	Total	Score	Total	Score	Total	Score	Total
Cost	5	5	25	4	20	2	10	1	5
Durability	4	4	16	4	16	3	12	5	20
Lightness	2	2	4	4	8	5	10	3	6
Strength	2	4	8	3	6	4	8	5	10
	TOTAL:		53		50		40		41

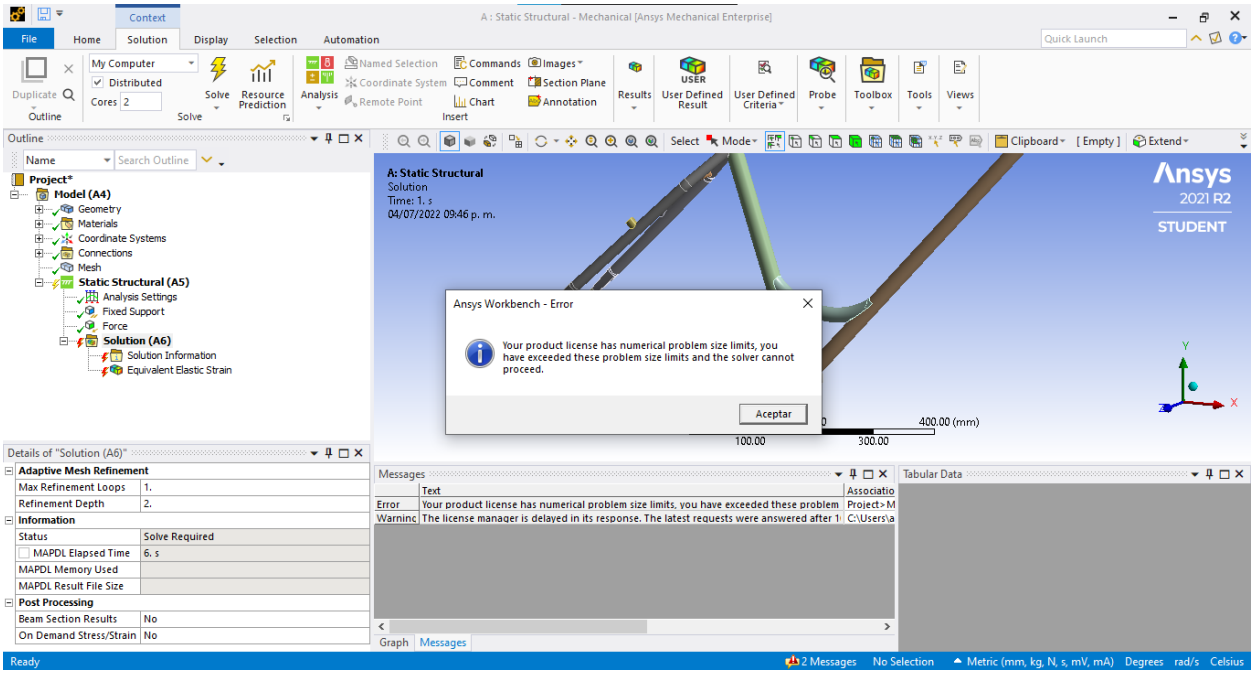
Design of the Model

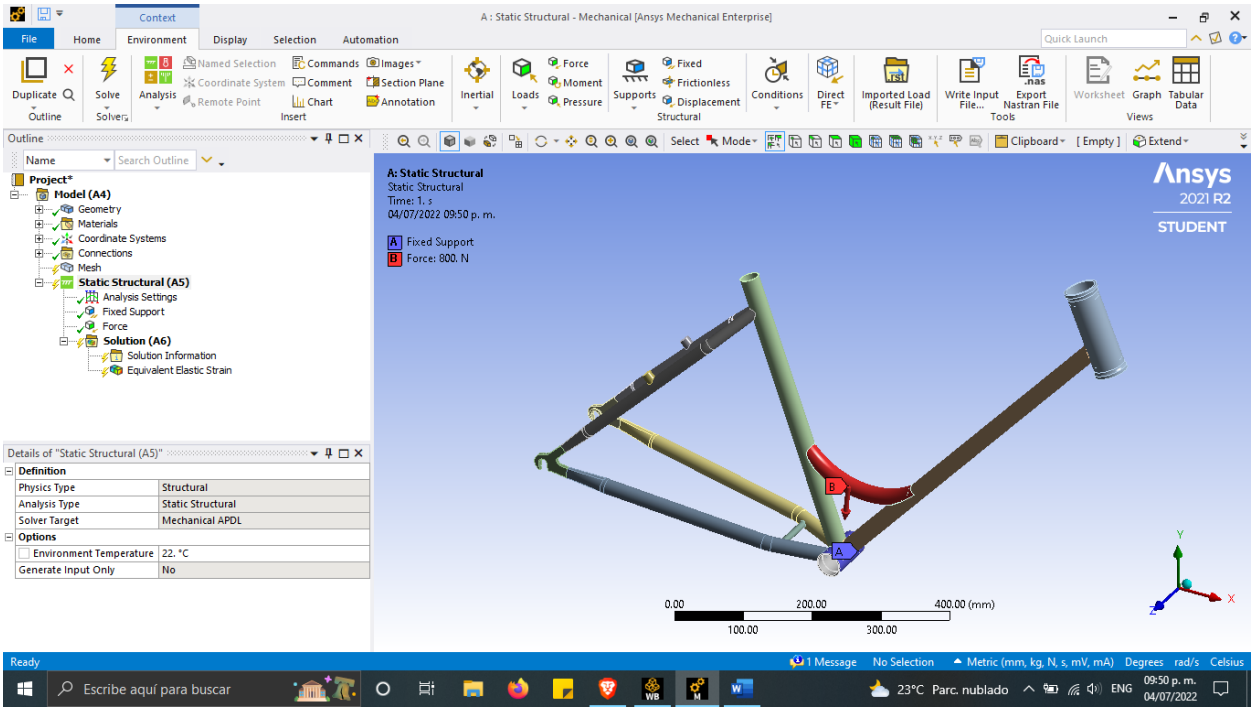
Figure 8. Model of the bicycle.

The model was made in SolidWorks with each part made from scratch.

Forces Evaluation



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