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ARTÍCULO DE INVESTIGACIÓN

# Mechatronic Design of a Mobile Platform for Assisted Labors in Coffee Crops

## Diseño mecatrónico de una plataforma móvil para asistir tareas en cultivos de café

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### ABSTRACT

Harvesting tasks in coffee crops in Colombia are conducted manually. Unfortunately, at the moment there is a low supply of labor to carry out these tasks. That is why this article describes the process of designing a mobile platform to help mitigate the aforementioned problem. There are many ways to design the platform, therefore, choosing the most suitable morphology is of vital importance. For this, the design team used the APTE methodology to select, without bias, the morphology that best met the design criteria and the parameters found when analyzing the user's needs and the particular operating conditions of the platform. Similarly, the topology and physical layout of the mobile platform components were selected based on structural design and analysis criteria obtained from a CAD model. The results of the applied methods served as the basis for building the prototype of the mobile platform that aims to solve the problem.

**Keywords:** Coffee crops; Design decision making; Mechatronic design; Mobile platform; Precision agriculture; Engineering.

### RESUMEN

Las tareas en los cultivos de café en Colombia se realizan de manera manual y actualmente hay una baja oferta de mano de obra para realizarlas. Por eso, en este artículo se describe el proceso de diseño de una plataforma móvil para ayudar a mitigar el problema anteriormente enunciado. Existen muchas formas para realizar el diseño de la plataforma, por lo tanto, escoger la morfología que más se adecúe es de vital importancia. Para lo anterior, el equipo de diseño utilizó la metodología APTE para seleccionar sin sesgos la morfología que mejor cumplía con los criterios de diseño y con los parámetros encontrados al analizar las necesidades del usuario y las condiciones particulares de operación de la plataforma. Del mismo modo, la topología y la distribución física de los componentes de la plataforma móvil fueron seleccionados con base en un diseño estructural y criterios de análisis obtenidos de un modelo CAD. Los resultados de los métodos aplicados sirvieron como base para construir el prototipo de la plataforma móvil que tiene como objetivo solucionar el problema.

**Palabras clave:** cultivos de café; toma de decisiones en diseño; diseño mecatrónico; plataforma móvil, agricultura de precisión; ingeniería.

## INTRODUCTION

Producing coffee is one of Colombia's most prominent and representative economic activities. Due to its extension, it has a great socio-economic influence over the Colombian countryside (Arcila P., Farfán V., Moreno B., Salazar G., & Hincapié G., 2007). In recent years, the coffee economic ecosystem has been affected by the reduction of the human labor that executes agricultural tasks such as pest control and harvesting. Additionally, the areas in which coffee is cultivated have increased, as well as the production of coffee and the number of workers required for the process (Castañeda-Beltrán, Montoya-Restrepo, Oliveros-Tascón, & Vélez-Zape, 2011).

During the harvest, agricultural workers are exposed to a difficult environment: They work on high-sloped irregular terrains with unstable weather conditions, they need to adopt different body positions to reach coffee beans in trees whose height ranges from 1.4 to 3 meters and travel long distances carrying the weight of the harvested product (Arcila P., Farfán V., Moreno B., Salazar G., & Hincapié G., 2007). In addition to such arduous physical work, the economic remuneration is very low. Those are the reasons why, nowadays, that labor has stopped being attractive for the inhabitants of the coffee growing zones (Castañeda-Beltrán, Montoya-Restrepo, Oliveros-Tascón, & Vélez-Zape, 2011).

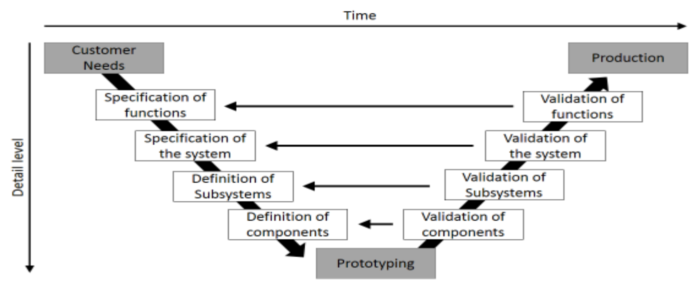
Since human labor in the coffee areas is decreasing, CENICAFE and Federación Nacional de Cafeteros – recognized Colombian research institutions in the field of coffee production – are developing technological solutions, which are intended to optimize and increase the coffee bean harvest, using the lowest possible number of workers to respond to the requirements of the Colombian topography (Castañeda-Beltrán, Montoya-Restrepo, Oliveros-Tascón, & Vélez-Zape, 2011).

Considering the situation mentioned above, our research aims to design a mechanic platform – capable of moving on uneven coffee crop terrains – that will serve as a base for transporting the tools that are used in the coffee harvest. The platform will also be used to move collected fruit and will help other agricultural tasks, such as fertilizing, characterizing soils, estimating crops, etc.

## METHODOLOGY AND METHODS

The design model that was chosen for the development of the current project was created for software planning. The German Engineering Association adapted it to Mechanical Design. The V-model is composed of several successive steps that increasingly specify the details of the design until prototyping, and then, each previous step is validated as it is shown in Figure 1 (Ingenieure, 2004).

**Figure 1.** V-Model Methodology applied to Mechatronic System Design




*Source*: Verein Deutscher Ingenieure.

The V-Model does not constrain the design team to apply a specific methodology on each step.

**Analysis Methodologies**

1. *APTE Methodology*

It is a design and product development methodology created by APTE (Aplication des Techniques d'Entreprise), a French company. The principles of value analysis by Larry Miles inspired this methodology and its aim is to obtain a solution that better fits the needs of the user, to increase quality, to reduce costs and to increase the usability of the product (De La Bretesche, 2000).

The basic principles of the APTE methodology are (Méthode APTE, 2020):

- Problems are defined as goals to achieve.
- The project team members have a common framework.
- Comparisons among solutions are avoided by being objective.
- Creativity is encouraged to find different solutions.

The APTE methodology includes three strategies of analysis which are: The need analysis diagram, the need functional analysis diagram and a functional cost diagnosis diagram.

2. *QFD Methodology*

Quality Function Deployment (QFD) is a Japanese methodology used in quality management to select the alternative or option that best suits the needs or demands of the user.

This methodology is widely accepted and has been adapted into new techniques that have been derived from its concept, such as the quality house, the Pugh's concept selection and the deployment of the modular function (Akao, 1994).

*3. Pugh Methodology*

This type of tool is used to make decisions regarding the development of new products or services. It is useful to differentiate the criteria that provides the most value in a quantitative way, that is, a quick way to prioritize the characteristics of the product that are intended to be launched or improved (Burge, 2020). It is considered as the little brother of a QFD Matrix and is based on the comparative study of different alternatives that can achieve the greatest benefit.

**Methodology Applied**

The use of the methodologies previously defined will be described below.

The first five stages of the V-Model developed for this study were:

- Defining user needs
- Specifying design functions
- Specifying the system architecture
- Defining the subsystems
- Defining the components

User needs and design functions were obtained by conducting an analysis using the APTE methodology. System architecture specification was achieved by applying the QFD methodology to the mobile platform morphologies found in current mobile robots. APTE also served to find the evaluation criteria that was used to compare the different technical and morphological solutions in QFD.

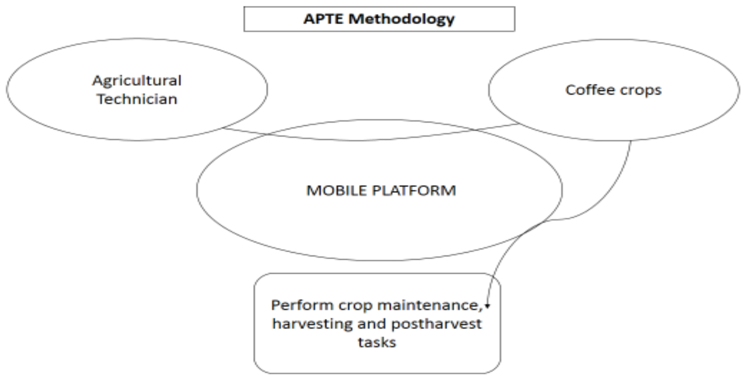
*1. User Need Analysis*

Based on a contest promoted by Federación Nacional de Cafeteros (2017) and in accordance with the results of technical visits conducted to Hacienda el Roble, located in La Mesa de los Santos, Santander, the complexity of the harvest problem was determined.

*2. APTE Methodology*

The APTE methodology was used to determine the design needs and requirements, to analyze the problem and to determine the factors that interact with the mobile platform. Figure 2 relates the factors involved in the identification of the need, such factors were defined by answering the following questions regarding product and services: To whom is the service provided? What is the product? What does it act on? What is the purpose of the product?

**Figure 2.** Platform Need Analysis Diagram



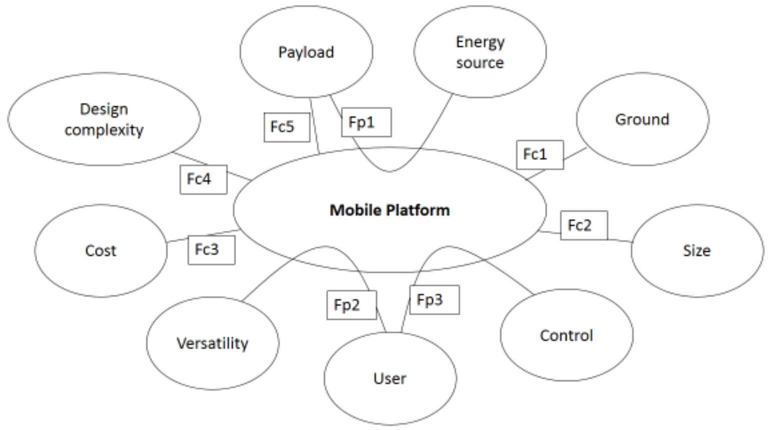

*Source:* Elaborated by the authors.

Considering the parameters and needs mentioned by Federación Nacional de Cafeteros de Colombia (2017) and the findings from the technical visits, the following external parameters were considered in the Need Functional Analysis Diagram:

- Cost: A mobile platform that has the lowest manufacturing cost.
- Size: A platform that is easy to transport and fits vehicles used in Colombia's agricultural tasks.
- Control: A platform whose morphology is easy to control.
- Energy source: A platform with extended working autonomy.
- Ground: A morphology that adapts to or can transit through the off-road target terrain.
- Versatility: The selected morphology has a simple and practical coupling with tools, so that it can be used for various agricultural tasks.
- Payload: The mobile platform must carry a payload of about 25kg, similarly to what a human can carry in those terrains.
- Design complexity: The maintenance of the mobile platform must be simple and fast.

Considering the previous parameters, the following diagram was built:

**Figure 3.** Need Functional Analysis Diagram.




*Source*: Elaborated by the authors

Criteria established to evaluate each morphology:

- FP1: Autonomy
- FP2: Modularity
- FP3: Controllability
- FC1: Adaptability to ground
- FC2: Portability
- FC3: Manufacturing Cost
- FC4: Maintenance Ease
- FC5: Payload Capacity

### 3. *QFD Methodology*

The QFD methodology was used to select the morphology that best adapted to the design problem. To do this, a quality house was applied to correlate the needs or requirements with the specific aspects of each morphology found in the robotics literature.

In the QFD, each criteria was weighted according to their importance in relation to the need fulfillment.

Five different morphologies were considered:

- Phantom X Hexapod (Trossen Robotics, 2020)
- Boston Dynamics Quadruped (Boston Dynamics, 2020)
- Agribotix Drone (Agribotix, 2020)
- Bpg werks DVT Shredder Tracked vehicle (Bpgwerks, 2020)
- Vine Robot Four wheeled robot (Universidad de la Rioja, 2020)

The selected parameters were considered as the most important characteristics of the morphology:

- Power source
- Actuators
- Size
- Design complexity

- Suspension

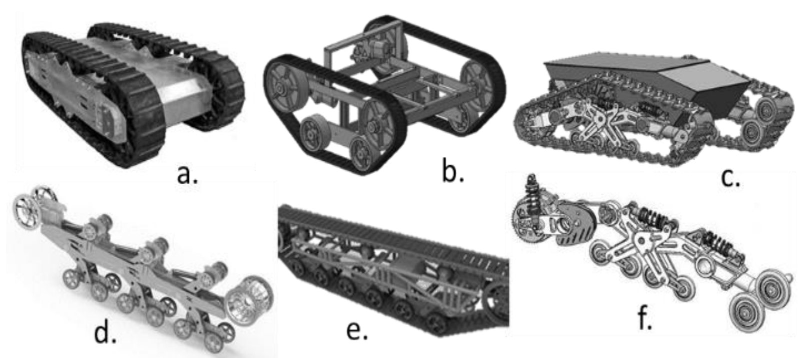
Based on the score obtained from the QFD methodology, the morphologies that best met the design requirements and satisfied the need were the platform with tracks and the 4x4 platform. These morphologies obtained the same score. Therefore, it was necessary to find a new criterion that allowed us to choose only one morphology. The degree of soil compaction caused by the platform was considered as such. Taking that criterion into account, the platform morphology with tracks was chosen, since this type of locomotion exerts less force per unit area, generating less soil compaction.

With the results obtained, the detailed design was made following some mechanical considerations presented by Wong (2010) and the different spatial topological configurations of the tracks, as presented in Figure 4

*4. PUGH Matrix*

To select the most suitable morphology for the platform, the PUGH matrix was used. The designs previously described were compared with a design that had already been implemented. In this case with the HD2 Treaded Tank Robot Platform.

**Figure 4.** Different track configurations: a) HD2 Treaded Tank Robot Platform, b) Design 1, c) Design 2, d) Design 3, e) Design 4, f) Design 5.




*Source:* Terramechanics and Off-road Vehicle Engineering

**Table 1.** PUGH evaluation matrix

| | Design Alternatives | | | | | | |
|---|---|---|---|---|---|---|---|
| | Design (ref) | Design 1 | Design 2 | Design 3 | Design 4 | Design 5 | Relevance |
| Portability | = | 0 | 0 | 1 | 1 | 0 | 85 |
| Adaptability to Ground | = | 1 | 1 | 1 | 1 | 1 | 90 |
| Autonomy | = | 0 | 1 | 1 | 1 | 1 | 50 |
| Payload capacity | = | 0 | 0 | 1 | 0 | 1 | 70 |
| Controllability | = | 0 | 1 | 1 | 1 | 1 | 50 |
| Modularity | = | 0 | 1 | 1 | 0 | 0 | 55 |
| Manufacturing cost | = | 1 | 1 | -1 | -1 | -1 | 45 |
| Maintenance Ease | = | 0 | -1 | 1 | 1 | -1 | 55 |
| Total | 0 | 2 | 4 | 6 | 4 | 2 | |
| Weighted | 0 | 135 | 235 | 410 | 285 | 160 | |

*Source*: Elaborated by the authors

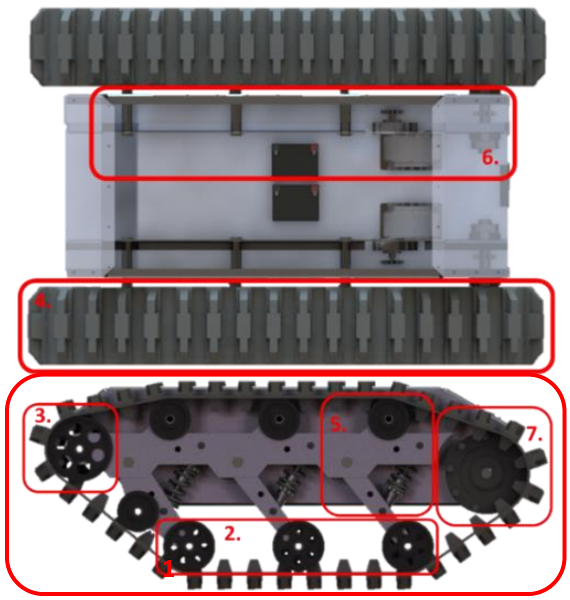
## RESULTS

Once this comparative evaluation was finished, alternative 3 was obtained as the best solution. According to the V-Model shown in Figure 1, the third stage, specification of the system, was already covered. Next stage was the definition of the subsystems. However, before entering that stage, it was important to consider some important mechanical design aspects for tracked vehicles found in the Theory of Ground Vehicles (Wong, 2008).

### Mechanical Design Considerations

According to the literature found regarding the design of off-road vehicles, the following considerations were contemplated at the time of designing our prototype:

**Figure 5.** Considerations of design details




*Source*: Elaborated by the authors

According to the numbers in Figure 5:

1. The configuration has a significant impact if the terrain is highly compressible.
2. It is desirable to install as many wheels as possible. This improves the normal distribution of pressure and makes it more uniform. It also reduces track sinking and resistance to movement, improving the mobility of the vehicle.
3. The initial tension of the track also improves the pushing force of the vehicle. Therefore, it is necessary to implement an adjustable tension system.
4. The width of the tracks generally has beneficial effects on the performance of the vehicle.
5. The suspension improves the distribution of mechanical loads on the wheels.

6. A rear arrangement of the sprocket supported by a double wall with pedestal bearings is recommended.

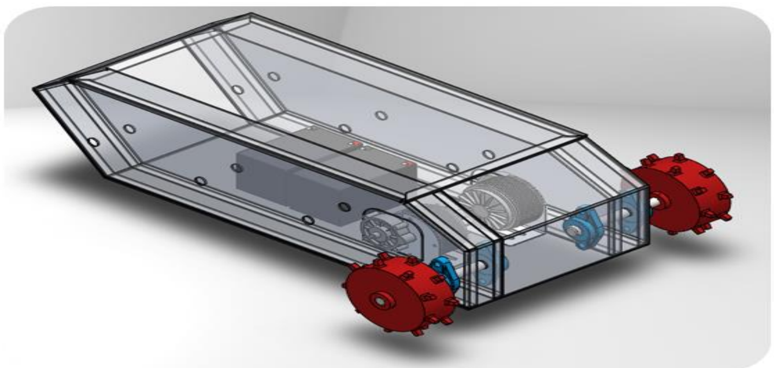
7. The sprocket located in the rear part of the platform improves the performance of the vehicle.

**Mechanical design**

There are four main mechanical subsystems: Chassis, transmission system, suspension system and traction system. The components of each subsystem were listed, thus covering the definition of the components, which is the fifth step of the V-model.

*1. Chassis*

**Figure 6.** Chassis final design



Source: Elaborated by the authors

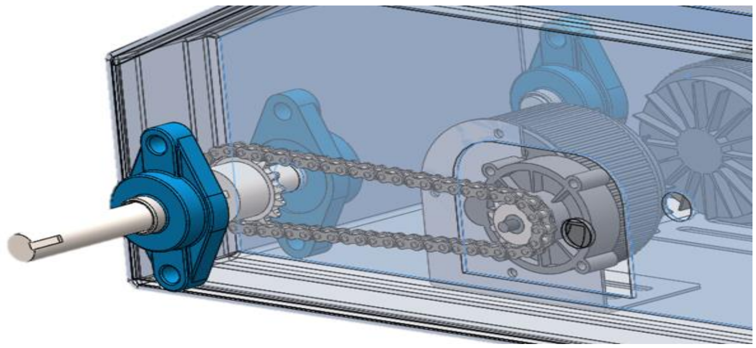
The Chassis was designed to take into account possible collisions. That is why it has a frontal incline plane to overcome low obstacles. It also has an interior double wall to allow a better assembly of rotatory elements and the suspension structure.

The Chassis directly carries the payload, the batteries, the motors, the transmission system, and the suspension system. The chassis was built using aluminum sheets. This material was chosen because it is corrosion resistant and easy to bend and drill.

*2. Transmission System*

The power transmission system is responsible for transmitting the power of the motor to the driving wheel of the crawler system. The components of this subsystem are the sprocket of the motor, the chain of transmission, the sprocket of the output shaft that is supported by two bearings, and their rowlocks as shown in Figure 7.

**Figure 7.** Transmission system



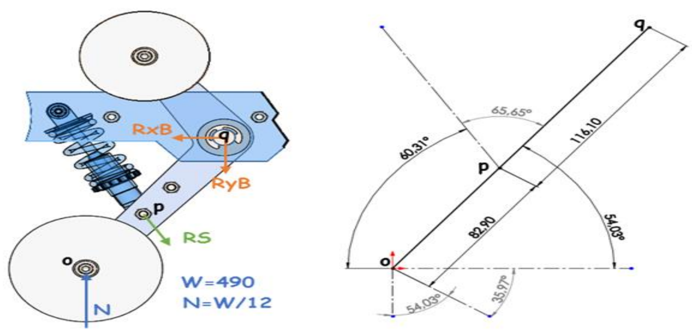
*Source*: Elaborated by the authors

The calculations of each component of this system were based in the methods described by Mott, Vavrek & Wang (2013). The chain transmission ratio was defined at 11:16.

*3. Suspension system*

There are two suspension systems mounted on the chassis. Each system is composed of a support structure, two tensor wheels and three rocker arms with friction dampers, as shown in Figure 8.

**Figure 8.** Suspension system (Swing Arm)




Source: Elaborated by the authors

The swing arms are also made from an aluminum sheet, and they were cut using a CNC laser cutting machine. The design of this suspension system not only attenuates the perturbations generated by bumps on the field with the shock absorber, but also keeps the tension of the track with the upper wheels.

*4. Traction System*

Traction system is composed by the following elements:

- Drive sprocket: It is assembled to the transmission.
- Roadwheels: Distribute the weight.
- Tensor wheel: Applies a tension load to the track.
- Track: Provides movement to the vehicle.

To calculate the length of the track, a CAD program was used to estimate the possible perimeter around the suspension system. According to the CAD software, the track length that fits around the suspension system is 2337.09 mm. To design the traction system components, the following gear formulas were used:

$$p = \frac{\pi * D_{P_{track}}}{Z} \quad (1)$$

In which: Dptrack is the Track pitch diameter and Z the number of perforations. According to the calculation, each perforation had to be done each 64.4986 millimeters.

Since the maximum speed of the vehicle is 10 [km/h], the radius of the sprocket had to be around 80 to 100 [mm], due to the following reasons:

- The motor has a maximum output speed of 400 [rpm].
- The chain transmission has a ratio of 11:16.
- By design, it is desirable that the transmission ratio of the driver sprocket and the track is an integer number. The track has 36 perforations; therefore, the number of teeth has to be a divisor of 36 and those are 4, 9 or 18.
- 9 teeth on the sprocket, with the pitch “p” previously determined, allow a diameter between 160 to 200 [mm], and a maximum speed close to 10 [km / h]. As shown in the following calculations:

$$D_{P_{sprocket}} = \frac{p * Z}{\pi} \quad (2)$$

$$D_{P_{sprocket}} = \frac{64.4986 * 9}{\pi} \quad (3)$$

$$D_{P_{sprocket}} = 184.774\ [mm] \quad (4)$$

Once this calculation was done, the vehicle maximum speed was calculated using the following formula:

$$\mathrm{v}\left[\frac{km}{h}\right] = \omega_{motor}\left[\frac{rad}{h}\right] * 11/16 * \frac{D_{sprocket}}{2}\,[km] \quad (5)$$

Using the formula, the final speed of the vehicle was found as 9.58 km/h.

**Traction Modelling and Electric Motor Selection**

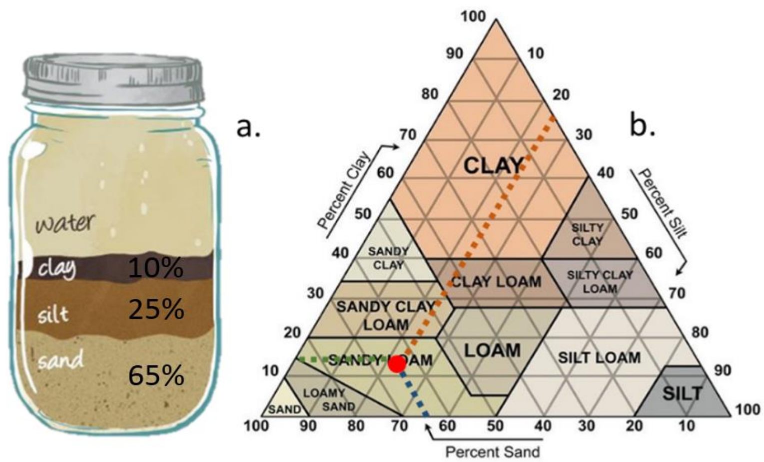
The ground can be modeled as a perfect plastic material from which the maximum thrust can be found in the Theory of Ground Vehicles (Wong, 2008). The following calculation allowed us to obtain the maximum torque value of the motor. Besides, the maximum angular velocity of the motor can be determined by assuming a maximum speed of the mobile platform of 6 km/h. With these values of maximum torque and maximum angular velocity the value of the required power was calculated.

$$F_{max} = \tau A = (c + \sigma \tan\phi)A = cA + W \tan\phi \quad (6)$$

$$F = \frac{M_e \xi \eta_t}{r} \quad (7)$$

Cohesion and internal angle of shear are necessary parameters to compute the soil strength. The first step was to determine the typical type of soil of a coffee crop through a texture evaluation. The proportions of sand, silt and clay had to be determined to find the type of soil using the textural soil type triangle (Es, Schindelbeck, & Ristow., 2017).

**Figure 9.** a) Decanting test. B) Textural classes table.




*Source:* Soil Health Manual

It was determined that the type of soil was Sandy Loam. For this type of soil there are several values of apparent cohesion c and internal angle of resistance to shear φ, used in table 3.

Table 2 contains data for electric motor selection, according to the necessity analysis and the dimensions of the mobile platform.

**Table 2.** Parameters for motor selection algorithm

| | |
|---|---|
| Mass [kg] | 150 |
| Weight [N] | 1,471.5 |
| Track length [m] | 0.43 |
| Track width [m] | 0.15 |
| Reduction ratio of the transmission | 7 |
| Efficiency of the transmission [%] | 78 |
| Pitch radius of the drive sprocket [m] | 0.08 |
| Max. Vehicle velocity [km/h] | 8 |
| Motor angular velocity [rad/s] | 28 |

*Source*: Elaborated by the authors

To select the motor maximum, thrust was found with formula (6) and the torque of the motor was found using formula (7). Previous steps were carried out for different values of apparent cohesion c and internal angle of resistance to shear φ, in which an average value of the required motor wattage was obtained from table 3.

**Table 3.** Necessary motor power from a terramechanical analysis.

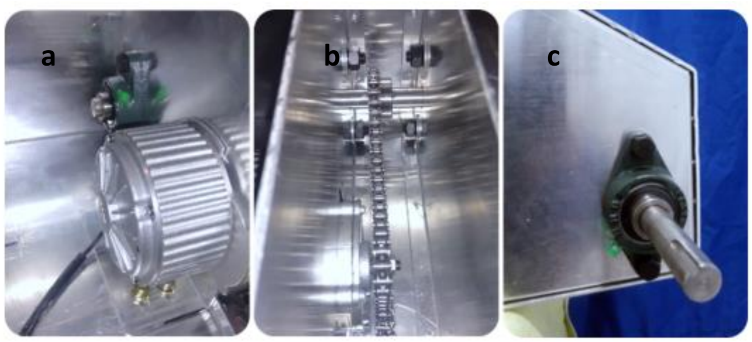
| Cohesion [kPa] | ϕ° [deg] | Fmax [N] | Motor torque [N-m] | Wattage [watt] |
|---|---|---|---|---|
| 1.72 | 29 | 630 | 4.61 | 128 |
| 1.38 | 38 | 753 | 5.52 | 153 |
| 4.83 | 20 | 891 | 6.52 | 181 |
| 9.65 | 25 | 1588 | 11.63 | 323 |
| 9.79 | 22 | 1560 | 11.43 | 317 |
| 5.17 | 11 | 810 | 5.93 | 165 |

Source: Elaborated by the authors

Selecting the motor was the last step of the fifth stage of the V-Model (Selection of components), the next step was prototyping.

For the chassis, aluminum sheets were bent and joined together using pop rivets. The transmission system was mounted into the chassis. The main components can be seen in Figure 10: The motor (a), the sprocket of the motor, the chain, the sprocket of the output shaft (b), the bearings and their rowlocks (c). The double wall of the chassis facilitated the assembly of this system.

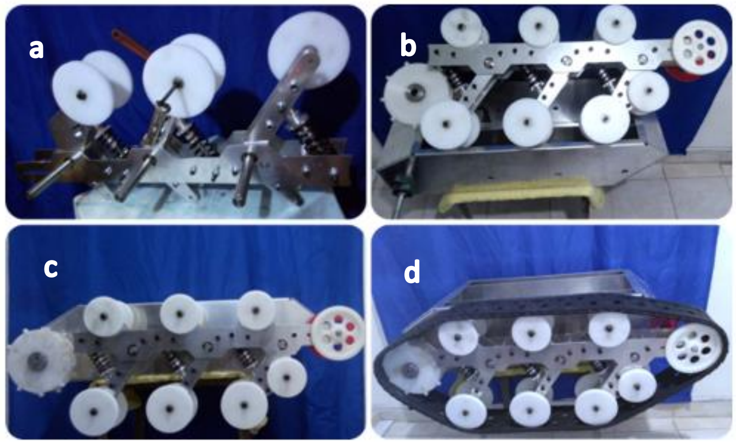
**Figure 10.** Transmission system parts.




*Source*: Elaborated by the authors

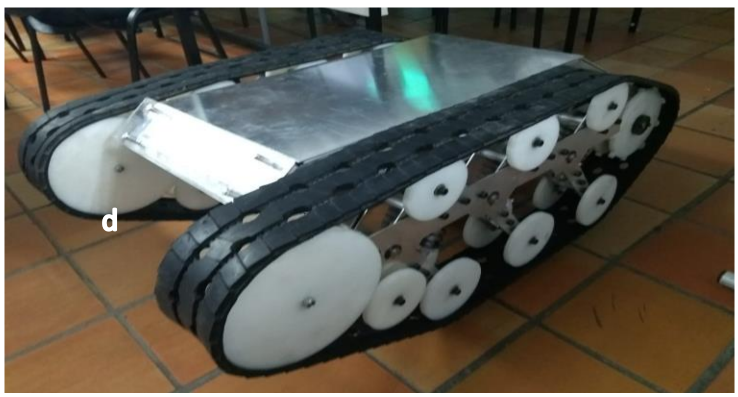
The final system assembled was the traction system. Figure 11 shows the lower roadwheels (a), the upper roadwheels, the lower roadwheels, the tension wheel and the drive sprocket (b), the suspension and traction systems mounted on the chassis (c) and the track assembled to the traction and suspension system (d).

**Figure 11.** Traction system parts.




*Source*: Elaborated by the authors

**Figure 12.** Final result




*Source*: Elaborated by the authors.

The last stages of the V-model were related to the validation of each component, subsystems, system, and their functionality. Validation stages will be covered in a future article.

## CONCLUSIONS

By using a mechatronic design model and methodologies along the design process, the project team was aware of every conceptual detail of the product. Each member contributed from their field of expertise, reducing the risk of finding subjective solutions to the problem.

A tracked vehicle and a chassis with frontal attack angle were chosen for the prototype since their design helped us avoid frontal collisions and belly dragging problems. They also allowed us to overcome obstacles of up to 20 centimeters in height.

To design the chassis, a double internal wall was devised because it provided more rigidity to the chassis and allowed the suspension system and the transmission system to have double support.

A system of rocker arms with monoshock dampers was implemented to provide the prototype with a better platform with better grip and stability.

Completing this research built the foundations for a future project in which the vehicle will be equipped with tools to help coffee workers.

## RECOMMENDATIONS

Validation tests must be conducted outdoors and on rough terrains to assess the performance of all the components of the vehicle and the integrity of the system. Once the vehicle is tested, the next phase is working on its automation to finally perform a specific task in coffee fields.

## ACKNOWLEDMENTS

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## REFERENCES

Agribotix. (2020, September 16). *Agribotix Drone*. Retrieved from Agribotix: https://latam.agribotix.com/agribotixlatam

Akao, Y. (1994). *«Development History of Quality Function Deployment». The Customer Driven Approach to Quality Planning and Deployment.* Tokyo: Asian Productivity Organization.

Arcila P., J., Farfán V., F., Moreno B., A., Salazar G., L. F., & Hincapié G., E. (2007). *Sistemas de producción de café en Colombia.* Chinchiná: Cenicafe.

Boston Dynamics. (2020, September 16t). *Boston Dynamics Quadruped* . Retrieved from Boston Dynamics: https://www.bostondynamics.com/legacy

Bpgwerks. (2020, September 16). *Bpgwerks DVT Shredder*. Retrieved from Bpgwerks: www.bpgwerks.com

Burge, S. (2020, August 22). *"Pugh Matix" from the System Engineering Tool Box.* Retrieved from Burge Hughes Walsh: https://www.burgehugheswalsh.co.uk/

Castañeda-Beltrán, J. A., Montoya-Restrepo, E. C., Oliveros-Tascón, C. E., & Vélez-Zape, J. C. (2011). Evaluación de un Método para la Recolección de Café en Terrenos de Alta Pendiente. *Revista Cenicafé*, 32-47.

De La Bretesche, B. (2000). *La méthode APTE : Analyse de la valeur, analyse fonctionnelle.* Paris: Pétrelle.

Es, H. v., Schindelbeck, R., & Ristow., A. (2017). *Soil Health Manual Series Fact Sheet Number 16-04.* Ithaca: Cornell University-School of Integrative Plant Sciences.

Federación Nacional de Cafeteros de Colombia. (2017, February 17). *CONCURSO – Proyecto de Apoyo a la Cosecha Asistida de Café*. Retrieved from Federación Nacional de Cafeteros de Colombia: www.federaciondecafeteros.org

Ingenieure, V. D. (2004). *Entwicklungsmethodik für Mechatronische Systeme (Design Methodology for Mechatronic Systems).* Düsseldorf: VDI 2206.

Méthode APTE. (2020, August 21). *The method*. Retrieved from Methode APTE: http://www.methode-apte.com/

Mott, R., Vavrek, E., & Wang, J. (2013). *Machine Elements in Mechanical Design.* New York: Pearson.

Trossen Robotics. (2020, September 16). *Phantom X* . Retrieved from Trossen Robotics: www.trossenrobotics.com/phantomx-ax-hexapod-mk1.aspx

Universidad de la Rioja. (2020, September 16). *VineRobot*. Retrieved from Universidad de la Rioja: www.unirioja.es/apnoticias/servlet/Noticias?codnot=3303&accion=detnot

Wong, J. (2008). *Theory of ground vehicles.* New York: John Wiley & Sons.

Wong, J. (2010). *Terramechanics and Off-Road Vehicle Engineering.* Oxford: Butterworth-Heinemann. https://doi.org/10.1016/B978-0-7506-8561-0.00006-3