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# A Long-Distance WiFi Network as a Tool to Promote Social Inclusion in Southern Veracruz, Mexico

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**Abstract:** The United Nations Organization established 17 sustainable development goals in 2015, including No Poverty, Good Health and Well-Being, Quality Education, Reduced Inequalities, and Responsible Consumption and Production. Latin America stands out as a region marked by significant levels of inequality, encompassing disparities in income and inadequate social protection. The rural municipality of Mecayapan in the Selvas region of Veracruz state, Mexico, is a community where these issues are prominently present. Another specific challenge that exacerbates the situation is the absence of connectivity, which hinders the utilization of technological advancements in three fundamental areas: health, education, and the economy. The project began with a thorough evaluation of the geographical, social, economic, cultural, educational, and health factors within the region. Following this, the network design and implementation phase was executed, considering the available resources, prioritizing recycled materials, and utilizing simulations when required. The subsequent step involved deploying the network in a prioritized manner, utilizing strategic management approaches. To assess the impact of this implementation, a qualitative descriptive study was conducted. This likely entailed the collection of data through interviews, observations, or surveys to gain comprehensive insights into how the WiFi network influenced the community. Results indicate that the implementation of a long-distance WiFi network with wide, open-access coverage in Mecayapan will yield favorable outcomes in terms of social inclusion, poverty reduction, and the overall enhancement of residents' quality of life. By leveraging technological advancements and promoting connectivity, the WiFi network can contribute to long-term sustainability by fostering economic development, enabling access to educational resources, facilitating communication and networking opportunities, and promoting sustainable practices in various sectors.

**Keywords:** sustainability; social inclusion; cost strategy; WiFi; homemade antennas

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## 1. Introduction

Latin America is one of the regions with the most inequality, including income level and lack of social protection. With the COVID-19 pandemic declared by the World Health Organization (WHO) in March 2020, this situation worsened [1].

Their usefulness is particularly significant in developing countries, where most of the population lives in rural areas or areas with difficult access [2–4]. In these zones, the education and health care system are often deficient, with an undersupply of material means, insufficient qualification of educational and medical personnel, deficiency of roads and transportation, and a paucity of connectivity services [5–8].

Strategic analysis generates perspective on the present and future of an organization, clarifying the opportunities of the environment, as well as the competencies that are available, to formulate a logical process of strategic development aimed at achieving the established objectives. Therefore, there is an evident need to adopt new methods and techniques according to the present time that allow survival, growth, and consolidation in turbulent and complex environments [9].

Currently, the world revolves around the internet; therefore, it has changed from being a privilege, as it was two decades ago, to a social necessity [10]. Although this is the fourth industrial revolution, since it is part of Information and Communication Technologies (ICTs), there are places in the world that have lagged and have not received the benefits of this revolution or where it is still incipient [11,12]. This is due to the lack of both public and private investment in these areas [13,14]. In Latin America, there are many towns in this situation [15–17], and Mexico is among the countries that have difficulty including technologies in their health, educational, and industry systems [18]. The municipality of Mecayapan in Veracruz is populated mostly by indigenous citizens, which represents a community that has been characterized by outdated handling of technological tools such as cell phones, tablets, and computers. Therefore, it is necessary to solve this and similar problems in this population, which will contribute to the inclusion of this community in a society, and, making good use of the internet, promote the entrepreneurial activities among them. Doing so will also allow them to show the products that they have harvested, making these products known to the world and attracting more customers.

Worldwide, it has been shown that applying technology in rural sectors improves their inclusion in society. Several studies have focused on applying technology to improve the quality of life of people living in these areas. In Australia, a large country, different telehealth initiatives have been carried out that have contributed to reducing the health gap between the rural and urban populations, based on opportunities for professional development and the support of specialists who contribute to improving the recruitment and retention of the rural medical workforce [19–21]. On the other hand, rural South Africa is a case study in which researchers have proposed innovative policy reforms to support community network models to reduce the digital gap to ensure that poor people obtain social, economic, and access benefits from broadband internet [22]. Other researchers recommend the liberalization of the telecommunications sector, combined with subsidies to local entrepreneurs, to increase the rate of internet penetration in rural areas. They propose a model based on reducing the costs of providing internet services and increasing the number of access points [23]. The authors of [24] present a study that includes a brief discussion of rural connectivity trials performed in India, and they also explore the rural use case of the 6G communication system, which would suit this country's rural areas.

Therefore, and with the objective of contributing to the development of municipalities with similar characteristics, the present investigation develops strategic management matrices that allow not only the diagnosis of the socioeconomic impact of the implementation of the antennas, but also the creation, evaluation, and choice of strategies aimed at improving the results and reproducing the project in other territories.

## 2. Theoretical Framework

### *2.1. Strategic Matrix Management*

The deterioration of the environment is a matter of global order that every day acquires greater importance at the political and business levels. Therefore, many companies have shown interest in promoting behaviors framed by the concept of sustainability and the presentation of environmental results as an additional component to their finances. The authors of the above-mentioned study say that because of the need for a universal indicator to evaluate the efforts of companies to achieve environmental protection, the

International Organization for Standardization (ISO) is committed to creating international environmental standards, later called ISO 14000 and supplemented in 2004 with ISO 14001, which formalized the design and implementation of Environmental Management Systems in companies [25]. Costs have been the subject of study in various sectors and are of great importance in the decisions to be made since this will be fundamental to executing a project, but to achieve this, the organization needs to be strengthened, being part of the strategies to be developed [26].

The costs of the production process lie in the transformation of raw materials and are divided into three elements: raw materials, direct labor, and other indirect manufacturing costs. Having good cost management and an adequate system of production costs will allow better control and use of materials during the production process, and we can calculate the real cost of a good to be produced [27].

A Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis consists of evaluating the strong and weak factors that, as a whole, affect the internal situation of an organization, as well as its external evaluation, that is, the opportunities and threats. It is a simple tool that allows for a general perspective of the strategic situation of a given territory. Thompson and Strikland in 1999 [28] established that the SWOT analysis estimates the effect that a strategy has to achieve a balance or adjustment between the internal capacity of the organization and its external situation, that is, the opportunities and threats.

Once the SWOT matrix has been prepared, which lists the internal and external factors that influence the performance of an organization, the next step is to evaluate the internal and external situation of the place using the Internal Factors Evaluation Matrix (IFEM) and External Factors Evaluation Matrix (EFEM). Once the SWOT matrix has been made with its list of strengths, opportunities, weaknesses, and corresponding threats, the next stage is to make a matrix derived from the previous one: (threats, opportunities, weaknesses, and strengths), developing four types of strategies, according to what was proposed by David in 2003 [29]. The first type of strategy is Strengths vs. Opportunities Strategies (SOSs), which are applied to the internal forces of the company to take advantage of external opportunities. The second type is Weaknesses vs. Opportunities Strategies (WOSs), which seek to overcome internal weaknesses by taking advantage of external opportunities. The third is Strengths vs. Threats Strategies (STSs), which take advantage of the forces of the company to avoid or reduce the repercussions of external threats. The final type is Weaknesses vs. Threats Strategies (WTSs), which are defensive tactics that seek to reduce internal weaknesses and avoid threats from the environment.

Of the four previously described quadrants, SOS and STS are the ones that provide the greatest contribution and are therefore recommended to be used since strengths (SOS) may be increased and weaknesses (STS) may be reduced based on the application environment.

### *2.2. Connectivity*

Wireless Sensors Networks (WSNs) typically communicate by unguided means via electromagnetic waves. Transmission and reception are carried out via antennas. The transmitter may have several antennas, and there are systems that use two, three, or even four antennas. Some antennas are used for transmission, others for reception, and the same antenna can operate in both modes. Designs can also be made with intermediate antennas (reaching distances of a few meters) or repeaters (reaching tens of kilometers) [30]. Wireless Local Area Networks (WLANs) are usually located in the same building, with a coverage between 10 m and 450 m. Among the best-known WLANs is Wireless Fidelity (WiFi), IEEE 802.11 standard. Currently, there are cards and interface devices that allow connectivity up to 450 m, as long as weather conditions are favorable and there is no interference or obstacles [31].

Environmental surveillance using cameras plays a critical role in monitoring animal behaviors and promoting environmental awareness, aligning with sustainability goals. However, utilizing vehicle-mounted cameras for data collection can impact the uplink data rate, affecting sustainability efforts. The emergence of 5G networks brings improvements in high data rate services, including Internet of Things (IoT), but the heterogeneous cell coverage presents challenges for sustainable handover processes. Overcoming weaknesses in handover parameters and network destination selection is crucial for sustainable network operations [32].

This paper [33] discusses the initiatives for Smart Cities and the various aspects involved, such as governance, economy, management, infrastructure, technology, and people. As cities grow, the communication needs of Smart Cities become crucial. Wireless technologies such as WiFi, ZigBee, Bluetooth, WiMax, 4G, and LTE have emerged as potential solutions for communication in Smart City projects. However, since many of these technologies operate in unlicensed frequency bands, issues related to interference and coexistence have become more prominent. This paper presents a review of wireless technologies available for IoT in Smart Cities, comparing them and highlighting the challenges associated with their coexistence. The suitability and characteristics of each technology in different domains are considered, along with the problems arising from congested unlicensed spectrum and difficulties in coexistence.

In recent years, WiFi has evolved and has achieved universal acceptance, since it works in the 2.4 GHz band, which is almost universally available. However, it can still experience interference caused by ovens, microwaves, cell phones, and other devices. Another disadvantage of this technology is the lack of robust security in data transmission, as well as high power consumption.

### *2.3. WiFi Antennas*

Antennas are devices designed to transmit or receive electromagnetic waves in free space. A transmitting antenna transforms electrical energy into electromagnetic waves, and a receiving antenna performs the reverse function. There is a great diversity of antenna types for different applications such as connectivity for cell phones, TV, radio, etc. [34]. Nowadays, antennas occupy a physical and visual space in our environment, creating visual noise, which is why efforts are being made to integrate them into other objects so that they are not perceived. Several projects have focused on minimizing the visual impact of antennas on the environment [35,36]. This project focuses on the field of WiFi technology used to design antennas with minimal visual impact and good integration with the environment. The design of antennas adapted to the environment allows them to take advantage of the occupied surface, allowing their integration into elements of the sectors such as wearable textiles [37], automotives [38], aeronautics [39], the military [40], and rural areas [41].

There are two types of antennas used in WiFi devices.

(a) Omnidirectional. These radiate the radio frequency signal in all directions (360°). These types are the most widely used in WiFi devices and are the ones we can find in laptops, smartphones, routers and access points. Its coverage area is usually reduced compared to that of the directives.
(b) Directional: these antennas radiate the radiofrequency signal in one direction (whose emission angle is approximately 30°) or towards a particular sector (with an irradiation angle of approximately 60°). In these, we can find several types, such as parabolic, grid, yagi, or panel (sectoral). These are usually used for point-to-point links, providing the possibility of giving a broader coverage, of the order of kilometers, and for this reason, they are usually used for long-distance links.

In wireless applications, the Dielectric Resonator Antenna (DRA) is a type of antenna that utilizes a dielectric resonator as its radiating element. A Dielectric Resonator Antenna (DRA) is a type of antenna that utilizes a dielectric resonator as its radiating element. It is commonly used in wireless applications where compact size, high efficiency, and wide bandwidth are required. The dielectric resonator used in a DRA is typically made of a high permittivity material such as ceramic or composite materials. It is designed to resonate at a specific frequency or a range of frequencies. When excited with an electromagnetic wave, the resonator stores energy and radiates it into space, generating an electromagnetic field. DRA antennas offer several advantages for wireless applications. Firstly, they have a compact size, making them suitable for integration into small devices or systems where space is limited. Secondly, they can achieve high radiation efficiency, which means they can convert a significant portion of the input power into radiated energy, minimizing energy losses. Thirdly, they can provide wide bandwidth, allowing for communication over a range of frequencies [42–44].

DRA antennas can be designed in various shapes, such as cylindrical, rectangular, or spherical, depending on the application requirements. They can be used in wireless communication systems, including cellular networks, satellite communications, radar systems, and wireless local area networks (WLANs). Overall, DRA antennas offer a combination of compact size, high efficiency, and wide bandwidth, making them a suitable choice for wireless applications where performance and space constraints are important factors. Researchers are currently exploring the capabilities of DRA technology as an alternative to traditional antennas. The initial focus of this program has been on studying the fundamental properties of DRAs with various simple shapes and feed configurations. The goal is to showcase the potential advantages offered by DRAs, such as improved bandwidth and gain, as well as the development of active DRAs using ferrite materials. Additionally, efforts have been made to create compact and low-profile antennas. As part of this research, linear and planar arrays of DRAs have been designed and manufactured, with a strong emphasis on practical implementation to demonstrate the feasibility of using DRAs in an array setup [42,45,46]. DRAs possess several appealing characteristics that make them highly desirable for various wireless communication applications: 1. High radiation efficiency: DRAs exhibit a high radiation efficiency of approximately 95. 2. Size and bandwidth control: DRAs offer a wide range of control over their size and bandwidth, allowing for tailored designs based on specific application requirements. 3. Design flexibility: Various shapes of resonators, such as rectangular, cylindrical, or hemispherical, can be employed in DRAs, providing design flexibility to meet different needs. 4. Integration with existing technologies: DRAs can be seamlessly integrated with different existing technologies by utilizing a variety of feeding mechanisms, including probes, slots, microstrip lines, dielectric image guides, and co-planar lines. 5. Radiation patterns: DRAs are capable of radiating broadside or conical-shaped patterns, allowing for versatility in meeting diverse coverage requirements. 6. Tolerance error resistance: DRAs are less susceptible to tolerance errors compared to microstrip antennas, particularly at higher frequencies.

These features make DRAs highly versatile elements that can be adapted to numerous wireless communication (WiFi) applications through careful selection and adjustment of the design parameters.

In this project, dielectric resonator-type antennas with cylindrical geometry are used. Four designs have been developed for use in applications working in different WiFi bands. To achieve the optimal antenna designs, matching, radiation pattern, and transmit and receive power were analyzed. The theoretical parameters were calculated analytically and then adjusted through different simulations. In these simulations, the effects of varying the dimensions of the cylinder such as radius, and height, as well as the effect of varying the position and dimensions of the antenna feed, are seen. Additionally, manufacturing materials with different characteristics, limitations, and costs are considered. Finally, a prototype of a cylindrical dielectric resonator-type antenna is constructed. Recycled (low-cost) materials were used for this purpose. The resulting antenna has good matching and radiation pattern characteristics, resulting in an antenna of reduced size and cost, which is a good candidate for wireless communications [47].

## 3. Methodology

This research was divided into four phases, as shown in Figure 1.

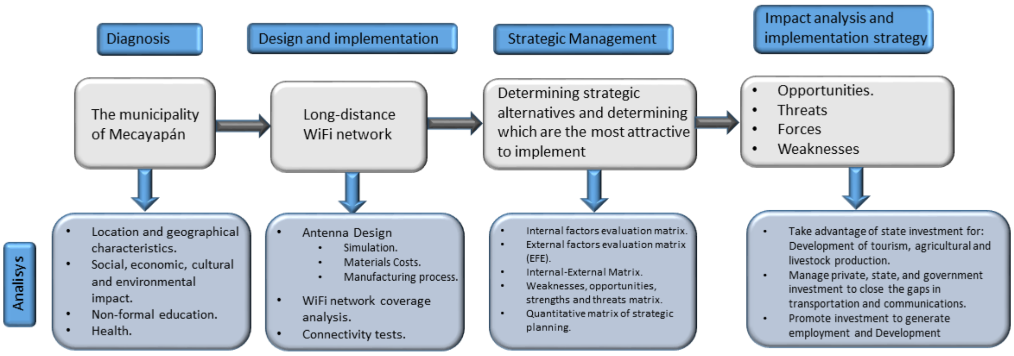


**Figure 1.** Phases of our research.

The first phase (called Diagnosis), consists of a qualitative–descriptive study, which provides information on the political–administrative, social, cultural, and environmental conditions, referring to the municipality of Mecayapan, Veracruz. The second phase, which corresponds to the design and implementation, is based on a study of the characteristics of dielectric resonator-type antennas, with the aim of proposing a design with the best adaptation results, building a prototype of an antenna.

In the third phase, based on the diagnosis and following the methodology proposed by David [29], were identified internal and external factors that may affect the success or failure of the roll-out of the antennas in Mecayapan, which were evaluated through an Internal Factors Evaluation Matrix (IFEM) and an External Factors Evaluation Matrix (EFEM) and developed in order to diagnose the impact of the application of the antennas. In both matrices, each factor is given a weight, according to the relative importance it plays in the project's success, so the greatest impact on antenna application has the highest weights, while those that have a lower impact have a lower weight. The total of all weights in each matrix will add 1.0. Subsequently, a score between 1 and 4 was assigned to each of the factors in order to indicate whether the factor represents a major weakness (1), a minor weakness (2), a minor force (3), a major force (4), a greater threat (1), a lesser threat (2), a lesser opportunity (3), or a greater opportunity (4). Therefore, the first ratings refer to the application of the antennas, while the score values in Step 2 refer to the municipality. Lastly, the weight of each factor was multiplied by their respective score to determine a weighted score for each variable, and weighted ratings of each variable were aggregated to determine the weighted total.

Furthermore, with the information provided by such matrices, it is possible to generate viable and effective alternative strategies through the Internal–External Matrix (IEM), which is based on two key dimensions: the weighted totals of the IFEM matrix on the "x" axis and the weighted totals of the EFEM matrix on the "y" axis. The matrix of Strengths, Weaknesses, Opportunities, and Threats (SWOT) allows identifying critical points and formulating strategies.

Finally, the strategy to be carried out is determined through the application of the Quantitative Matrix of Strategic Planning (QMSP), which is made from information obtained directly from the EFEM matrix, the EFIM matrix, and SWOT. In a column contiguous to the critical factors for success, the respective weights assigned to each of the factors of the EFEM matrix and the EFIM matrix are recorded, and the upper row of the QMSP consists of alternative strategies derived from the SWOT. Subsequently, Attractiveness Ratings (CA) were determined as numerical values indicating the relative attractiveness of each strategy in relation to each critical factor; that is, each of the factors is assigned a rating of 0 to 4 in order to indicate if the factor has no impact on the choice of the strategy (0), affects the choice of the strategy but does not influence the success of the strategy (1) affects the choice of strategy and influences its success to a lesser extent (2), affects the choice of strategy and influences its success (3), and affects the choice of strategy and critically influences its success (4). Finally, Total Attractiveness (TCA) ratings are calculated, which indicate the relative attractiveness of each of the alternative strategies, considering only the impact of the adjacent factor critical to success, internal or external; higher summations indicate more attractive strategies. To achieve this, weights are multiplied by the grades of attractiveness of each row; the higher the rating of the total attractiveness, the more attractive the strategic alternative will be. Once you have the attractiveness ratings by column, you add up the totals. The magnitude of the difference between the total sum of attractiveness ratings in a given series of strategic alternatives indicates the relative suitability of one strategy compared to another.

The fourth phase refers to the results of the implementation of the antennas and the strategic management matrices, from which it is possible to determine an action plan aimed at improving the results and reproducing the project in other territories.

### *3.1. Diagnosis of the Municipality of Mecayapán*

In order to provide the information to allow the capacity of the territory in this investigation to be known, pre-existing diagnoses available at the local level were established as a starting point, which, although they are based on secondary information, were analyzed with the idea of forming a preliminary panorama of the current situation of the territory.

#### 3.1.1. Location and Geographical Characteristics

Mecayapan is a town with a high percentage of the Nahua indigenous population, whose language is Nahuatl, nestled on the slopes of Cerro Santa Marta within the physical and geographical environment in the southeast of the state of Veracruz. It is located between the coordinates of the Sierra Santa Marta and San Martín and those of Los Tuxtlas at 18°12′49″ N and 04°17′40″ E in Mexico, located 340 m above sea level. This municipality has an area of 315.4 km$^2$, which represents 0.43% of the state's total, and 70% is used in agriculture and livestock, 20% in homes, 3% for commerce, and 7% for offices and public spaces. To the north, it borders the Gulf of Mexico, to the south it borders Chinameca and Soteapan, to the east it borders Pajapan and the Gulf of Mexico, and to the west it borders Catemaco, Soteapan, and Tatahuicapan. It has 15 communities: Huazuntlán, Cerro de la Palma, Ixhuapan, Agrarian Plan, Los Arrecifes, La Perla del Golfo, Vicente Guerrero, El Salado, El Paraíso, La Nueva Esperanza, San Andrés Chamilpa, Encino Amarillo, El Rubí, El Naranjo, and Arroyo Texizapan. The closest cities to the municipal seat are Acayucan, Jaltipan, Chinameca, Oteapan, Cosoleacaque, Minatitlán, and the City of Puerto de Coatzacoalco. A map is shown in Figure 2.

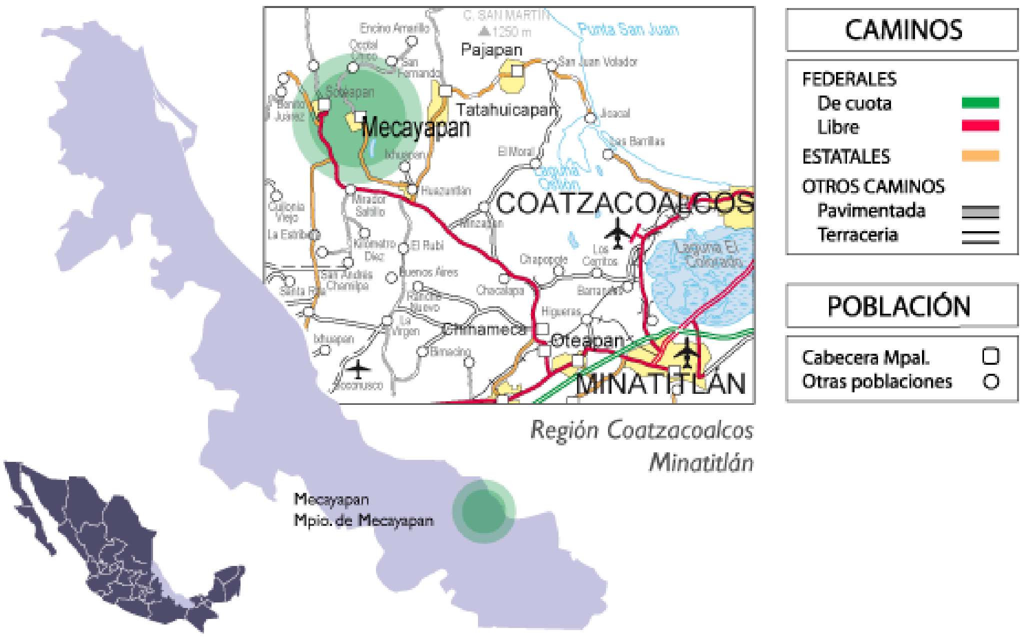


**Figure 2.** Geographical location of Mecayapan [48].

The weather in Mecayapan is warm sub-humid regular, the most humid of the climatic subtypes. The average annual temperature is 23 °C and ranges between 18 and 26 °C. There is abundant rain in summer and early autumn, with less intensity in winter. The range of rainfall is 1900–4100 mm. The soil is the luvisol type, which is characterized by accumulating clay in the subsoil with a dark hue, and it is not very susceptible to erosion.

The analysis of geographical and weather characteristics allows identifying important limitations concerning the access of telecommunications in the area, given the geographical location of the municipality of Mecayapan, in addition to the fact that telecommunications and ISP companies do not bet on investing in them, especially due to almost zero internet penetration. On the other hand, the satellite connection program that the Mexican government has is of a deficient character.

#### 3.1.2. Social, Economic, and Environmental Activities

Mecayapan has many natural resources. For example, rivers and lagoons are tourist attractions for locals and visitors. Tourist activity is active in certain seasons of the year. The flow of visitors, most of them former inhabitants of this place or the surroundings, who arrive to visit relatives or for recreation. However, in recent years, such tourism has been decreasing. The main tourist attractions are Huazuntlán, Tonalapan, Los Tres Mangos, Los Mangos, Minzapan, part of the reef coast, and Perla del Golfo. It is known that thanks to information and communication technologies, potential tourists can consult the attractions of the website to visit, so the lack of the internet in the municipality is a critical factor.

Even if the main economic activities of the municipality of Mecayapan are the small commercial establishments in the municipal head and the main towns, livestock and agriculture are the most important economic activities, which, if made known at the regional, national, and global levels, could generate investment interest towards this municipality. In this context, increased access to telecommunications and internet in the municipality would improve production, food quality and farm management, because all this technology applied in agriculture allows collecting and analyzing data to create a cleaner, sustainable, and environmentally friendly industry.

Businesses that stand out are small grocery stores, fruits, and vegetables, stationers, pharmacies, hardware stores, butchers, tortillerías, and taquerías, among others. Seasonal fruits are sold throughout the year: mangoes, oranges, guavas, custard apple, sapote, mamey, bananas, plums, and guanabanas. These products are distributed in nearby towns. However, business dynamics are almost nil because the municipality has not promoted the development of small- and medium-sized enterprises due to the lack of program support. We note that the current situation is quite precarious, because, since the municipality does not have numerous companies established, it will hardly generate employment for its inhabitants. It is worth mentioning that the municipality has a gasoline/gas supply station and a hotel that houses tourists.

#### 3.1.3. Infrastructure

According to Institute of Statistics and Geography (INEGI, for its acronym in spanish) data for 2015, 64 homes in the municipality of Mecayapan had internet service, which represents 1.4% of the total population. Computers are available in 143 homes in the municipality, which represents 3% of the population. Although there are a good number of homes that have cell phones, it is not specified if they are smartphones, that is, if they have the technology to connect to a WiFi network [49].

This diagnosis corresponds to the fact that telecommunications companies have privileged maximizing the return on traditional infrastructure investments and delaying the massification of new high-speed broadband access technologies in those localities where their performance would be relative.

In terms of transportation, there are paved federal trunk roads, paved state feeder roads, and surfaced rural roads, as shown in Table 1, and in terms of means of transportation, the population uses cars, trucks, vans, and motorcycles as its main means of transportation, as shown in Table 2. Regarding housing infrastructure, there are 4704 inhabited private homes, not all of which have access to basic services, and few have access to goods and information and communication technologies, as shown in Table 3.

**Table 1.** Road network in Mecayapan [49].

| Type | Lenght (km) |
|---|---|
| Total in the municipality | 45 |
| Paved federal trunks | 7.8 |
| Paved State feeders | 21.5 |
| State jacketed feeders | 0 |
| Paved country roads | 0 |
| Coated rural roads | 8 |

**Table 2.** Motor vehicles (2016–2017) in Mecayapan [49].

| Type | Public | Particular | Total |
|---|---|---|---|
| Cars | 44 | 377 | 421 |
| Passenger trucks | 0 | 0 | 0 |
| Trucks and vans cargo | 40 | 378 | 418 |
| Motorcycles | 0 | 16 | 16 |

**Table 3.** Infrastructure in Mecayapan [49].

| Indicator | Houstings |
|---|---|
| Inhabited private houses | 4704 |
| Availability of piped water | 4137 |
| Drainage availability | 3717 |
| Availability of electricity | 4587 |
| Availability of toilet | 3832 |
| With floor of Cement | 3812 |
| With floor of firm Land | 796 |
| Wood, mosaic and other coatings | 73 |
| Car or truck | 324 |
| TV | 2548 |
| Fridge | 2147 |
| Washing machine | 2147 |
| Computer | 143 |
| Radio | 1401 |
| Landline phone | 184 |
| Cell phone | 1710 |
| Internet access | 64 |

Under these conditions, perhaps the impact of the implementation of the antennas is not considered to have a direct impact on the population; however, from telematics, the reproducible antenna model would make it possible to reduce marginalization and to promote an increase in the level of development of the locality.

#### 3.1.4. Cultural Identity

In Mecayapan, since pre-Hispanic times, the predominant ethnic settlement until today are Nahuas, Zoque Popoluca, and a minimal part that corresponds to the north of the municipality that is populated by mestizo people (Perla del Golfo, Arrecifes, El Salado, Vicente Guerrero, etc.).

A tradition of this area is a regional fair in honor of the saint Santiago Jacobo, patron of the town, which is celebrated on 12 May of each year, with popular dances, fireworks, religious acts, mechanical games, horse races, ribbon tournaments, and sports. On 31 May, the day of the Loving Virgin is celebrated. Moreover, 15 December is the day of the Virgin of Juquila, and 1 and 2 November are the days of the faithfully departed, in which they are offered what they liked the most in life and placed in a suitable place. As for music, Jaranas are typical of the municipality, together with Son Jarochos, the Danzón, and the Décimas. In terms of crafts, we find pottery and weaving for personal use as the main activities of the municipality. Furthermore, regarding its gastronomy, what stands out the most is mole and barbecue as traditional foods.

Following the reflection, it must be taken into account that the internet is a space in which communities develop their identity and culture, and in turn, allows establishing links and collaborations with other cultures, strengthening personal feeling and sharing and getting to know other cultural realities. In this sense, the implementation of the antenna would allow increasing communication not only within the community, but with other communities.

#### 3.1.5. Non-Formal Education

Statistics show that more than a quarter of the population above 15 years old is illiterate, specifically 26.92% (this number is worse in the case of women: 34.78% of women and 18.58% of men are illiterate). The percentage of the population of schooling is lower at 5.09% (in this case with fewer differences between genders: 4.63% for women and 5.57% for men). The maximum level of education is high school.

The university or technical schools do not have schools or facilities to develop training about data networks. However, in the municipality, there is a person who works as a teacher in this field who teaches small groups of people. For example, in 2015, 72 students were trained (26 men and 4 women).

In this sense, sustainable antennas offer education the possibility of increasing the accessibility and dissemination of information, not only enabling the generation of knowledge among their community, but also, bridging the digital divide and generating a network across the region.

#### 3.1.6. Health

Health care and coverage are provided throughout the municipality; however, there are major deficiencies that require a greater effort in terms of infrastructure in this sector.

One of the most felt demands of the population is the lack of medicine in health centers, as well as an increase in the number of people in health centers. Other problems in the sector are the lack of maintenance of the health infrastructure in rural areas, as well as the absence of doctors in health centers during weekends, holidays, and vacation periods. There are 8 medical units in the municipality, which represent 0.5% of the total medical units in the state and have a total of 42 doctors. In 2010, the percentage of people without access to health services was 37.6%, which is equivalent to 6516 people.

While the internet does facilitate the flow of information among medical professionals, it also contributes to disease prevention by enabling the population to have greater access to health data.

### *3.2. Design and Implementation of a Long-Distance WiFi Network*

For the design and implementation of a long-distance WiFi network, it is necessary to simulate the antenna, analyze the cost of materials and the manufacturing process, as well as to design and implement the link and carry out coverage tests.

#### 3.2.1. Antenna Simulation

Before the implementation, some simulations were carried out to define the most optimal antenna design based on the possible materials and shapes. We used 4nec2 software version 5.9.3 for those simulations, a Windows-based tool for creating, viewing, optimizing, and checking antenna geometry structures [50].

Of all of them, the use of a recycled satellite dish with a cylindrical antenna was chosen because it combines good performance and the use of easily accessible and low-cost materials. Figures 3 and 4 show the radiation pattern and the propagation pattern respectively.

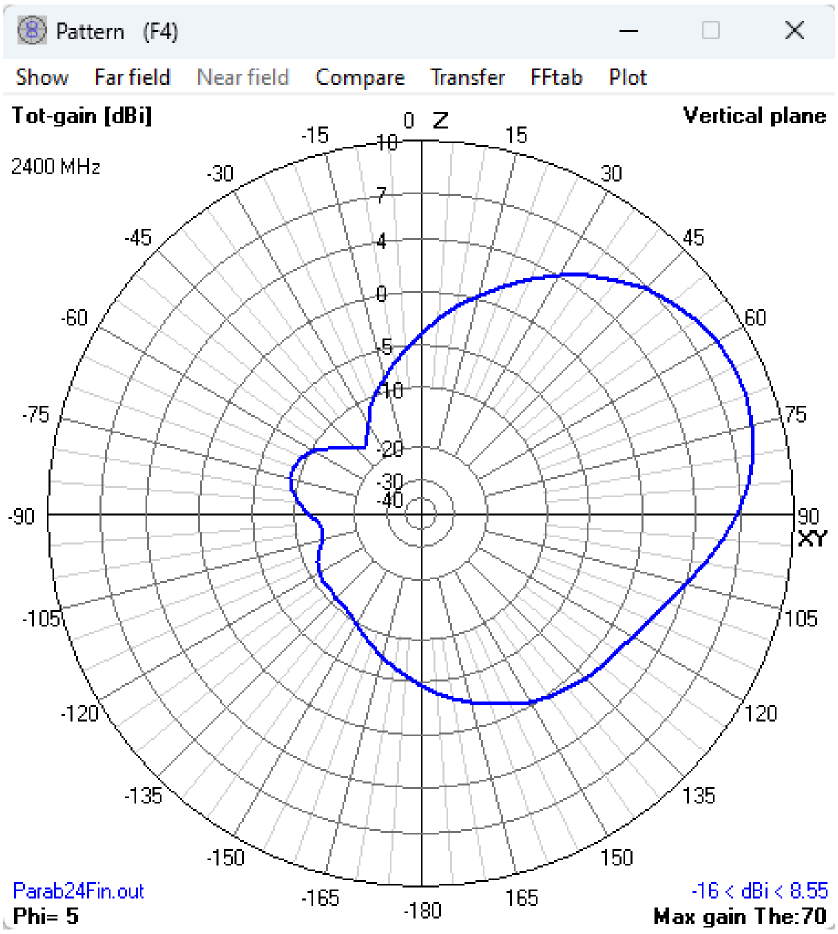


**Figure 3.** Simulation of antenna radiation pattern using 4nec2 [50].

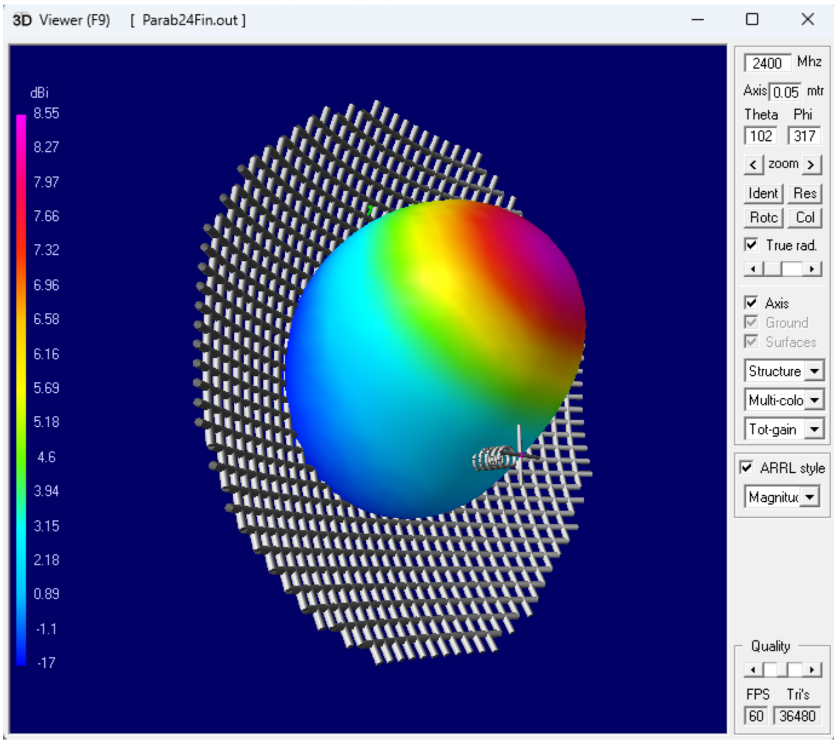


**Figure 4.** Simulation of antenna propagation using 4nec2 [50].

#### 3.2.2. Material Descriptions

Three main materials are used to construct the antennas: PCV, copper, and a parabolic plate:

- PVC (Polyvinyl Chloride):
  - Density: 1.38–1.42 g/cm³;
  - Electrical conductivity: Insulator (non-conductive);
  - Dielectric constant: 3.0–3.2 (at 1 MHz);
  - Loss tangent: 0.01–0.03 (at 1 MHz);
  - Melting point: 100–260 °C (depending on the type of PVC);
  - UV resistance: Moderate to good (depending on the formulation).
- Copper:
  - Density: 8.96 g/cm³;
  - Electrical conductivity: Very high (one of the most conductive metals);
  - Resistivity: 0.0168 μΩ·cm (Temperature Coefficient at 20 °C);
  - Melting point: 1085 °C;
  - Thermal conductivity: 401 W/m·K;
  - Corrosion resistance: Good (forms a protective oxide layer).
- Parabolic Plate (typically made of metal, such as aluminum or steel):
  - Material properties would depend on the specific metal used;
  - Aluminum is commonly used due to its lightweight and good conductivity;
  - Density: 2.7 g/cm³ (for aluminum);
  - Electrical conductivity: High (for aluminum);
  - Melting point: 660.3 °C (for aluminum);
  - Reflectivity: High (parabolic shape allows efficient focusing of electromagnetic waves.)

These properties are general characteristics and can vary depending on the specific grade, composition, or manufacturing processes of the materials used [51,52].

#### 3.2.3. Materials Costs

The materials used are easy to obtain, and some are common use. For the development of this project, the use of recycled materials was prioritized. However, some materials were purchased to build the antenna, as can be seen in Table 4 and Figure 5.

**Table 4.** Cost of materials for the implementation of the antenna.

| Materials | Cost |
|---|---|
| 3/4″ PVC pipe | 1.25 |
| 3/4″ PVC elbow | 0.25 |
| WiFi-USB adapter | 12.00 |
| Copper strip | 1.00 |
| 3/4″ PVC plug | 0.25 |
| Screw 1 | 0.25 |
| Can of soda | 1.50 |
| Enameled copper wire AWG 12 | 3.00 |
| 10 m of RG174 cable (optional) | 12.00 |
| 10 m of coaxial cable | 5.00 |
| TOTAL | 36.50 |

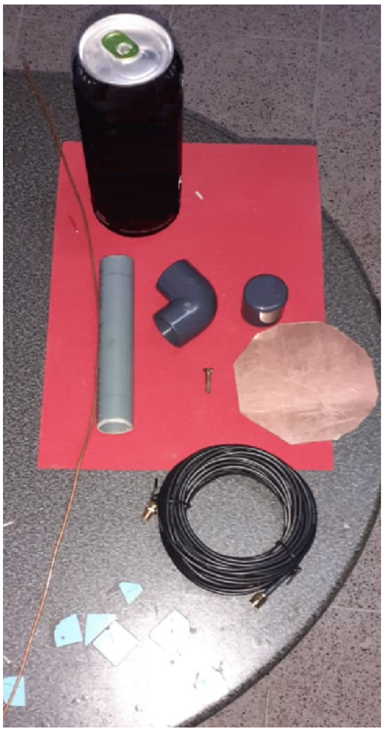

**Figure 5.** Materials for the implementation of the antenna.

3.2.4. Antenna Elaboration Process

The first step to build the antenna is to make the base. For this purpose, 3/4″ PolyVinyl Chloride (PVC) pipe is cut to 13.5 cm. Of this measure, only 10 cm is needed, but the remaining 3.5 cm must be considered for the elbow and the plug, as can be seen in Figure 6.


**Figure 6.** The base of the antenna, which is made up of the PVC tube and has the elbow and the plug mounted; recall that the space must be 10 cm.

The second step is to cut the rigid American Wire Gauge (AWG) 12 cable to an approximate length of 60 cm. The cable has an insulating cover, which must be removed. This copper wire is rolled up on the PCV tube, which represents the dielectric. The distance between each turn of the winding is 2 cm. The cable is bent at one end in an L shape, forming an angle of 90°. This fold must be 3 cm, and it is inserted into the PVC tube on the elbow side. Then, the cable is wound, making each turn coincide with the 2 cm marks on the tube until the plug is reached, as can be seen in Figures 7 and 8.

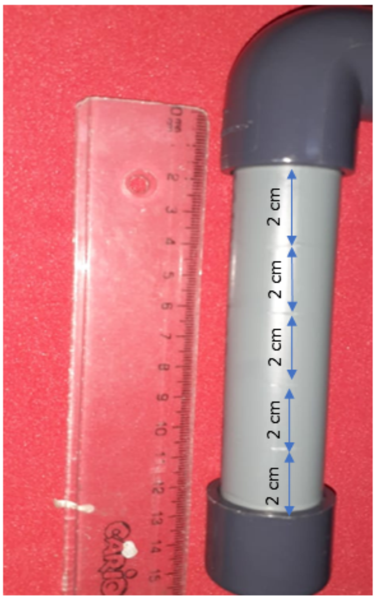


**Figure 7.** We proceeded to mark the 2 cm in the tube to pass the cable.

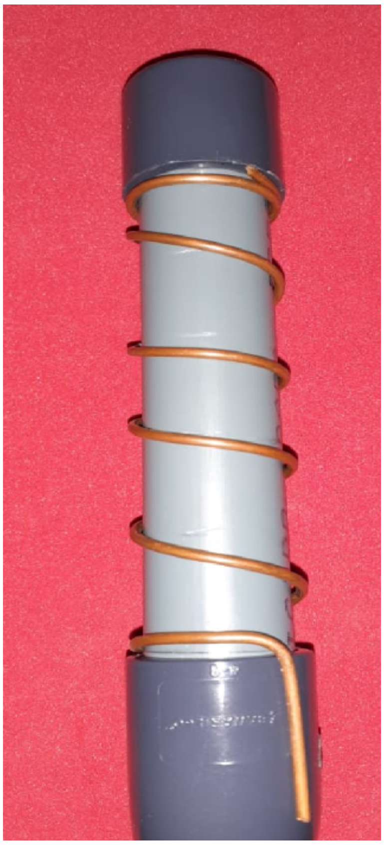

**Figure 8.** The dielectric is mounted at the base of the PVC pipe, trying to pass through the marked places at a distance of 2 cm.

The third step is to cut a copper sheet in a circular shape with a radius of 10 cm (these sheets are rectangular). Then, we proceed to measure the center of the sheet to make a hole through which the PVC tube passes, right next to the hole tube. Next, we make a small hole for the cable of our winding to pass, taking into account that the cable does not touch the cooper. It is important to isolate the part of the cable that passes through the hole, as can be seen in Figure 9.

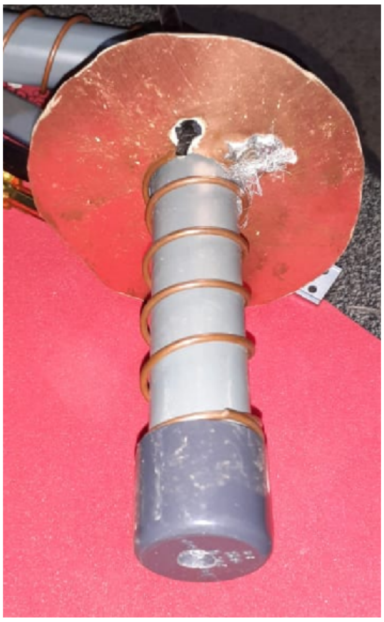

**Figure 9.** Copper sheet already with two holes made to pass the PVC tube and the cable.

The fourth step is to cut, with scissors, the base of a soda can. With a nail, the center of the base of the can is marked to make a hole with a drill (see Figure 10). A screw is placed in the hole to fix it to the tube. This structure is the receiver/transmitter of the antenna.

**Figure 10.** Base of the can that will go at the end of the antenna.

The fifth step is to fix the bottom of the can to the top of the tube with a screw. In this step, the antenna is finished (see Figure 11).

As a sixth step, the end of the cable is sanded to remove the coating. Then the coaxial cable is soldered. The central part of the coaxial cable is soldered to the antenna cable, and the mesh of the coaxial cable is soldered to the copper foil. This procedure is carried out with a soldering iron and tin.

The seventh step is to adapt the SubMiniature version A (SMA) connector of the WiFi-USB, Universal Serial Bus (USB), with the connector of the coaxial cable. The most viable option is to use a pigtail cable, which has a coaxial cable adapter at one end and an SMA connector at the other end.

The eighth step is to mount the antenna on the arm of a satellite dish that is not being used (see Figure 12).

Once the antenna is fixed to the satellite dish, the possible WiFi networks that could cause interference with the link to be established are verified. This procedure is performed with a laptop without placing the designed antenna (see Figure 13).

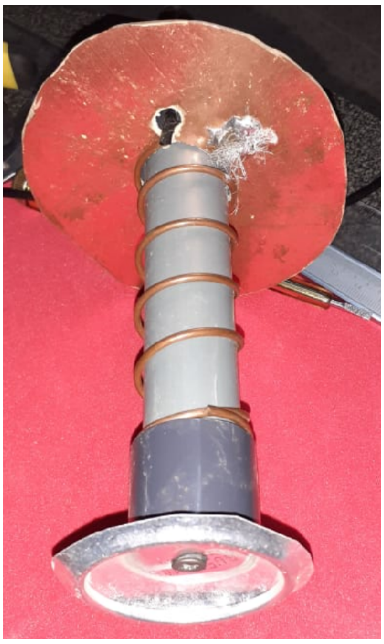

**Figure 11.** Antenna implemented with the base of the can screwed into the end of the plug and the copper foil welded.

**Figure 12.** Antenna, highlighted with red circle, mounted on the arm of a satellite dish.

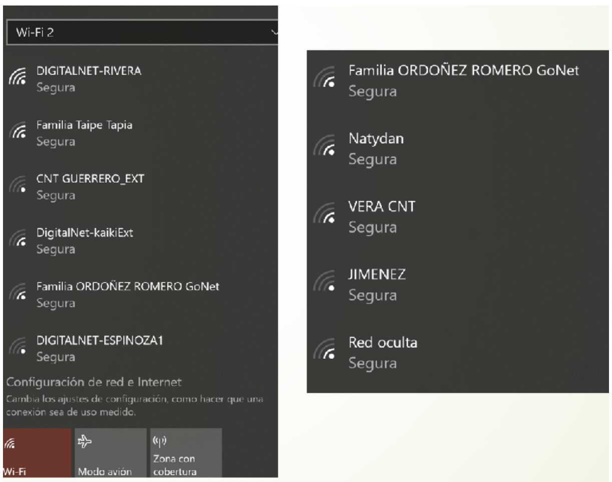


**Figure 13.** WiFi networks received by the laptop with the implemented antenna connected.

As we can see in Figure 14, without the connected antenna implemented, only two networks appear: one is the network of the author's house, for which the router is 5 m away, and the other available network is that of their neighbor, for which the router is 4 m away from where the author's laptop is located.

The next step was to connect our implemented antenna to our laptop to be able to observe the number of available WiFi networks. We saw that the number of networks increased thanks to the greater coverage that our antenna gave us.

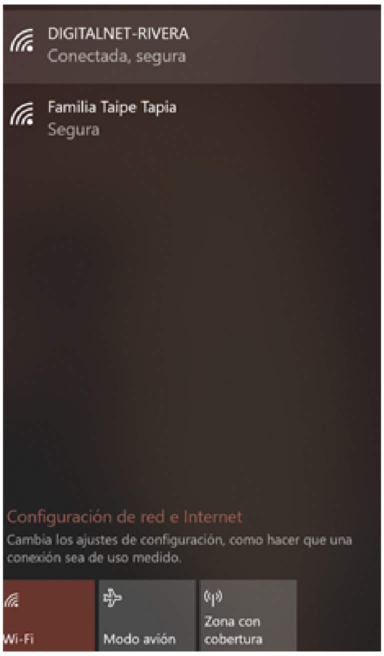


**Figure 14.** WiFi networks received by the laptop without connecting the implemented antenna.

With the help of Google Earth, we took the measurement of the most distant known network that we could visualize on our laptop, which is called "DigitalNet Kaiki ext". When measuring the distance from community health center to the Ignacio Zaragoza Elementary School, where this network is known, we gave a range of 100 m in a straight line (see Figure 15).

### 3.2.5. Network Planning

Another fundamental aspect in the design of a long-distance WiFi link is to have a line of sight to ensure that the reception signal has enough power since the attenuation at 2.4 or 5 GHz is high. This situation implies having an infrastructure on which to place the antenna, such as houses, bridges, buildings, or towers. For this purpose, the approximate cost of the towers must be analyzed (see Table 5). For network planning, the following must be taken into account:

- Location of the antennas;
- If towers are required, their location and height;
- Network topology;
- Type of antenna to use for each link;
- Transmission powers;
- Operation channel.

The long-distance WiFi connection proposed (30 km) for the population of Mecayapan can be seen in Figure 16. It consists of two 18-m towers. The first tower will have an antenna built with recycled materials to transmit the internet signal, and the receiving antenna will be able to provide the service with an Ethernet connection.


**Figure 15.** Coverage distance with the antenna connected from community health center to the Ignacio Zaragoza Elementary School.

**Table 5.** Towers.

| **Tower Height (m)/Weight Tons** | **18/4** | **24/6** | **36/8** | **48/12** | **60/18** |
|---|---|---|---|---|---|
| Cost (USD) | 150.00 | 1050.00 | 1350.00 | 1200.00 | 5500.00 |

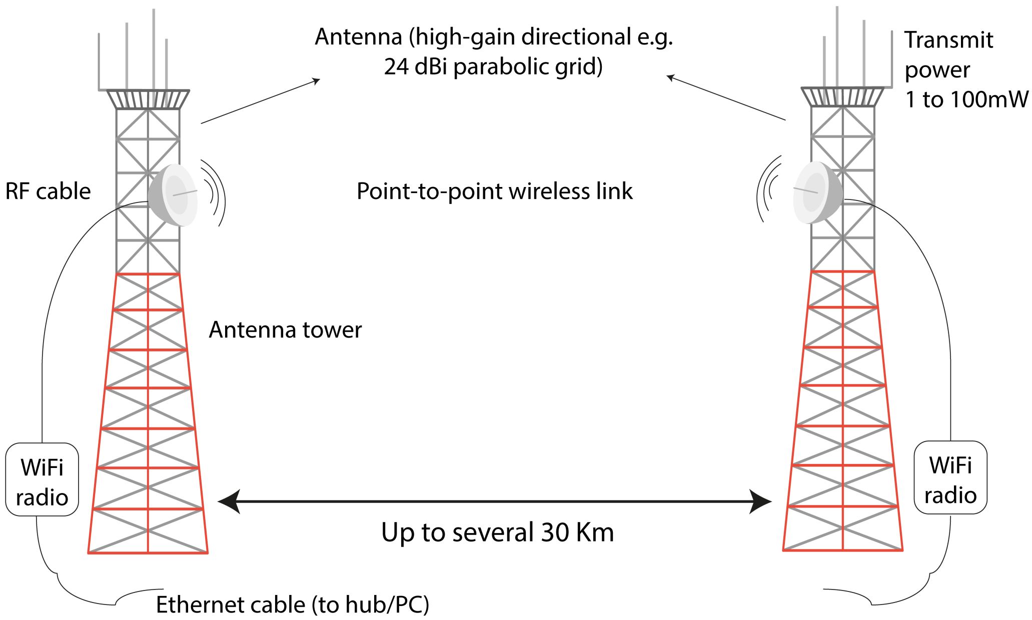


**Figure 16.** The long-distance WiFi connection proposal (30 km) for the population of Mecayapan, created by the authors, inspired by [53].

3.2.6. Implementation Budget Calculations

The cost of the project to install the long-distance link in the municipality of Mecayapan is USD 4869, and cost details are shown in Table 6. The budget for home internet distribution amounts to USD 9.60 for each home, considering that the project covers the installation of 100 homes at a total cost of USD 960.00. It should be taken into account that the price of the materials varies according to the purchase place; these values are shown in Table 7.

**Table 6.** Cost of the project to install the long-distance link in the municipality of Mecayapan.

| Material | Amount | Unit Value (USD) | Total (USD) |
|---|---|---|---|
| Router | 1 | 369.60 | 369.60 |
| Cabinet for wall mounting of 9 rack units | 1 | 155.40 | 155.40 |
| 305 m coil cable, black shielded for outdoor Cat5e | 2 | 173.88 | 347.76 |
| Container with 100 RJ45 Cat connectors | 1 | 38.64 | 38.64 |
| Cloud controller for centralized equipment management | 1 | 115.92 | 115.92 |
| 1000 VA/600 W UPS 120 input, 1 RU rack | 1 | 463.68 | 463.68 |
| Dual-band AC IP67 radio | 1 | 171.36 | 171.36 |
| Omnidirectional antenna 5 GHz frequency of 13 dBi | 1 | 193.20 | 193.20 |
| IP 66 steel enclosure for outdoor use | 6 | 96.60 | 579.60 |
| Kit with 6 m telescopic pole with installation accessories | 6 | 173.88 | 1043.28 |
| 2 × 2 MIMO subscriber antenna with integrated 23 dBi antenna | 6 | 96.60 | 579.60 |
| Outdoor UnifFi access point detachable MIMO 2 × 2 antennas | 6 | 135.24 | 811.44 |
| TOTALS (USD) | | 2184.00 | 4869.48 |

**Table 7.** Budget for home internet distribution amounts (USD).

| Description | Units | Unit Price | Total Price | Benefited Homes | Total Cost |
|---|---|---|---|---|---|
| USB WIFI adapter | 1 | 4.50 | 4.5 | 100 | 450.00 |
| RG58 coaxial cable | 6 | 0.50 | 3 | 100 | 300.00 |
| SMA connector | 1 | 1.50 | 1.5 | 100 | 150.00 |
| Transport | 2 | 0.30 | 0.6 | 100 | 60.00 |
| TOTAL (USD) | | | 9.60 | | 960.00 |

### *3.3. Strategic Management Matrices*

In relation to the results obtained from the diagnosis and the proposal for the design of the homemade antenna with recycled material, the following strategic management matrices were developed, which allow objectively determining various strategic alternatives and determining which antennas are the most attractive to implement, as well as replicating the project in territories with similar characteristics. The strategic management matrices include an Internal Factors Evaluation Matrix (IFEM) and an External Factors Evaluation Matrix (EFEM), which provide us with basic information to formulate strategies, at the same time allowing us to know the weaknesses, strengths, opportunities, and threats with respect to Mecayapan.

#### 3.3.1. Internal Factors Evaluation Matrix

Internally, Mecayapan has several positive internal factors (strengths) that it can take advantage of to overcome and improve weaknesses by using strategies that help generate a solid internal position, as shown in Table 8.

**Table 8.** Internal factors evaluation matrix. Where Q is Qualification.

| Critical Factors for Success—Strengths (S) | Weight | Q | Weighted |
|---|---|---|---|
| (S1) Tourist attractions such as spas in water tributaries and the Sierra de Mecayapan. | 0.025 | 3 | 0.075 |
| (S2) Support from the public entity of the municipality | 0.2 | 4 | 0.8 |
| (S3) Agricultural and livestock production, which are the main activities | 0.1 | 3 | 0.3 |
| (S4) High percentage of command of the Spanish language despite a predominantly indigenous population | 0.05 | 3 | 0.15 |
| (S5) Access to public and private transport, owned by their own and neighboring towns, and some public fleets. | 0.125 | 4 | 0.5 |
| **Critical Factors for Success—Weaknesses (W)** | **Weight** | **Q** | **Weighted** |
| (W1) High poverty rates, which is one of the aspects that most afflicts the municipality. | 0.15 | 1 | 0.15 |
| (W2) Lack of industrialization, since they do not have industrial equipment and machinery to process and manipulate products. | 0.03 | 2 | 0.06 |
| (W3) Business formalization, which despite the fact that there are shops, hardware stores, and butchers, they are not formalized, so they are not taxed. | 0.06 | 2 | 0.12 |
| (W4) Unemployment, which hits the municipality hard. | 0.14 | 1 | 0.14 |
| (W5) High marginalization, which includes the lag in terms of the availability of resources such as drinking water, sanitation, and education. | 0.12 | 1 | 0.12 |
| Total | 1 | 24 | 2415 |

The total score of the IFEM is a little below the average of 2.5, which means that, although the municipality of Mecayapan has the support of the public entity and has access to public and private transportation, the high rates of poverty, unemployment, and marginalization keep the territory in a weak position, which is why telecommunications companies and Internet Service Provider (ISPs) do not bet on investing in it. Therefore, strategies must be generated that promote investment in the territory and allow directing resources to improve the quality of life of the inhabitants.

#### 3.3.2. External Factors Evaluation Matrix

From the above, it is possible to distinguish five opportunities and five threats. Of these, one opportunity that stands out is the interest of the state in carrying out municipal development programs. However, the proximity of elections to change the municipal government threatens to result in the suspension and/or cancellation of social development projects. On the other hand, the vulnerability of the municipality to climatological phenomena also represents a threat to the proper functioning of the WiFi antennas, as shown in Table 9.

It is observed that the weighted total is slightly below the average of 2.5, which indicates that the municipality is not capitalizing on opportunities and is susceptible to the threats that surround it.

#### 3.3.3. Internal–External Matrix

According to the crossing of data between the results obtained in the internal matrix and the external matrix, we are centered in Quadrant V. This quadrant tells us that the strategy to be carried out is the maintenance strategy, which suggests that we increase or improve the aspects that allow the impact produced by the project to occur in the best way in the municipality of Mecayapan, as illustrated in Figure 17.

**Table 9.** External factor evaluation matrix. Where Q is Qualification.

| Critical Factors for Success—Opportunities (O) | Weight | Q | Weighted |
|---|---|---|---|
| (O1) State investment (made by the state of Veracruz in support of the development of the project). | 0.14 | 4 | 0.56 |
| (O2) Achievement of municipal development programs. | 0.12 | 4 | 0.48 |
| (O3) Government support and investment (carried out directly from the Ministry of Telecommunications). | 0.09 | 3 | 0.27 |
| (O4) Increasing the communications infrastructure. | 0.1 | 4 | 0.4 |
| (O5) Development of ecotourism (public and private incentive plans). | 0.05 | 3 | 0.15 |
| **Critical Factors for Success—Threats (T)** | | | |
| (T1) Vulnerability to weather phenomena (due to the geographical location of the municipality) | 0.15 | 1 | 0.15 |
| (T2) Migration of residents to other municipalities, cities, etc. | 0.025 | 2 | 0.05 |
| (T3) Economic losses due to climatic situations (purchasing power of people). | 0.11 | 1 | 0.11 |
| (T4) Suspension and/or cancellation of social development projects. | 0.125 | 1 | 0.125 |
| (T5) Pollution and over-exploitation of natural resources generated mainly by agriculture, mining, and livestock that encourage the felling of trees | 0.09 | 2 | 0.18 |
| Total | 1 | 25 | 2.475 |

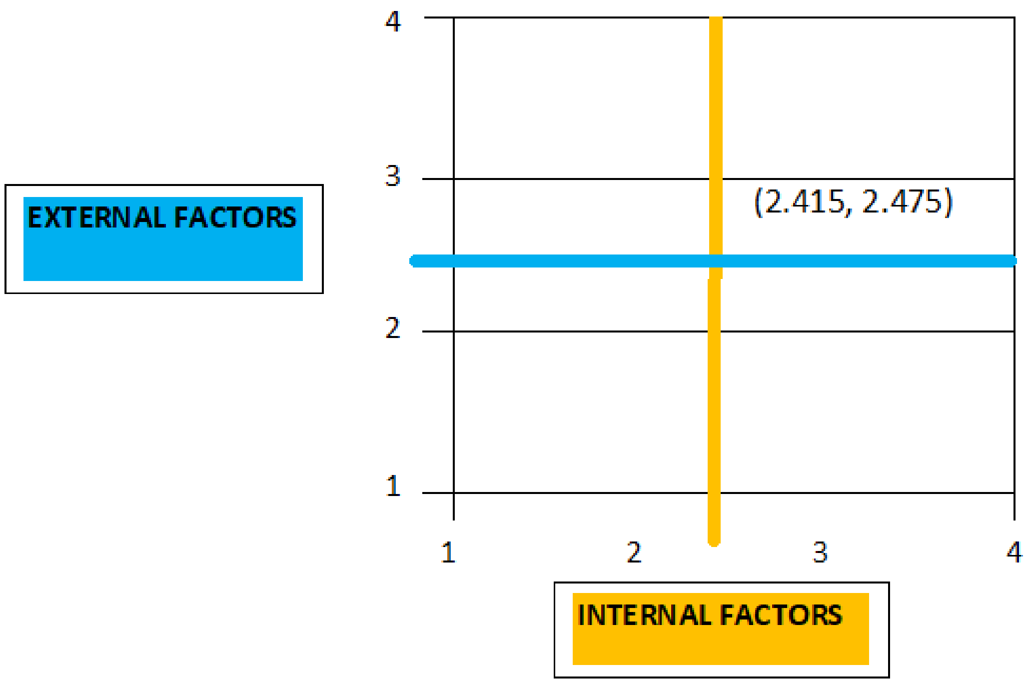


**Figure 17.** Internal–External Matrix.

In this sense, increasing or improving the aspects that allow the project to have the best impact in the municipality of Mecayapan is the most recommended strategies, according to the quadrant.

### *3.4. Strengths, Weaknesses, Opportunities, and Threats Matrix*

Considering the retention and maintenance approach suggested in the IE matrix, it is possible to establish improving the conditions of the municipality of Mecayapan as the main objective so that the project achieves a real impact. Under this approach, and from the crossroads of the opportunities and weaknesses of the environment with the forces and threats present within Mecayapan, strategies are proposed in the SWOT matrix, aimed at improving socioeconomic conditions, as well as infrastructure, according to the needs of the project, as shown in Table 10.

The Pareto principle applied to strategic planning tells us that planning should focus on a strategic number of actions that allow the goals to be achieved to a large extent [29]. In this sense, it is necessary to prioritize strategies in which we have positive elements (opportunities and strengths), since they are directly aimed at achieving the objective, and consider the other strategies as complementary. In this sense, the strategies that are considered to favor the generation of the greatest impact of the project are as follows.

- Take advantage of state investment for the development of tourism, seeking to attract a greater number of visitors. (O1, O5, S1).
- Manage private, state, and government investment in order to close the gaps in transportation and communications. (O3, O4, S5).
- Promote public and private investment to generate employment and development in Mecayapan. (O1, O2, W2, W3, W4).

**Table 10.** SWOT Matrix.

| | **Strengths** | **Weaknesses** |
|---|---|---|
| Opportunities | · Take advantage of state investment for the development of tourism, seeking to attract a greater number of the of visitors. (O1, O5, S1)<br>· Improve the main development programs to increase agriculture and livestock production. (O2, S3)<br>· Manage private, states, and government investment to close the gaps in transportation and communications. (O3, O4, S5) | · Allocate state resources to social impact investments allowing to improve the quality of life of the inhabitants. (O1, O2, W1, W5)<br>· Promote public and private investment to generate employment and development in Mecayapan. (O1, O2, W2, W3, W4)<br>· Schedule training aimed at small entrepreneurs, guiding them to formalization. (O2, W3) |
| Threats | · Generate regulations to promote agricultural and livestock production in a responsible manner, in terms of the use of natural resources. (S2, S3, T5)<br>· Improve the living conditions of the inhabitants to mitigate the risks of weather effects. (S2, S4, T1, T2, T3) | · Direct the resources of the municipality to improve basic services (health, education) and employment to reduce the emigration of the inhabitants. (W1, W4, W5, T2)<br>· Formalize local businesses to improve tax collection to mitigate the effects of project suspension due to lack of financial resources. (W2, W3, T4) |

Quantitative Matrix of Strategic Planning

To be able to determine the relative attractiveness of the previously proposed strategies, the following Quantitative Matrix of Strategic Planning (QMSP) matrix is developed, which allows the various strategy options to be valued and their execution to be prioritized, as illustrated in Table 11.

- Strategy 1: Take advantage of state investment for the development of tourism and agricultural and livestock production.
- Strategy 2: Manage private, state, and government investment to close the gaps in transportation and communications.
- Strategy 3: Promote public and private investment to generate employment and development in Mecayapan.

**Table 11.** QMSP Matrix.

| Key Factors / Strategy | | Strategy 1 | | Strategy 2 | | Strategy 3 | |
|---|---|---|---|---|---|---|---|
| Opportunities | Weight | CA | TCA | CA | TCA | CA | TCA |
| O1 | 0.14 | 4 | 0.56 | 4 | 0.56 | 3 | 0.42 |
| O2 | 0.12 | 3 | 0.36 | 2 | 0.24 | 4 | 0.48 |
| O3 | 0.09 | 2 | 0.18 | 4 | 0.36 | 3 | 0.27 |
| O4 | 0.1 | 2 | 0.2 | 4 | 0.4 | 3 | 0.3 |
| O5 | 0.05 | 4 | 0.2 | 1 | 0.05 | 3 | 0.15 |
| Threats | | | | | | | |
| T1 | 0.15 | 2 | 0.3 | 2 | 0.3 | 1 | 0.15 |
| T2 | 0.025 | 2 | 0.05 | 0 | 0 | 2 | 0.05 |
| T3 | 0.11 | 2 | 0.22 | 1 | 0.11 | 2 | 0.22 |
| T4 | 0.125 | 2 | 0.25 | 4 | 0.5 | 3 | 0.375 |
| T5 | 0.09 | 5 | 0.45 | 0 | 0 | 2 | 0.18 |
| Strengths | | | | | | | |
| S1 | 0.025 | 4 | 0.1 | 3 | 0.075 | 3 | 0.075 |
| S2 | 0.2 | 4 | 0.8 | 4 | 0.8 | 4 | 0.8 |
| S3 | 0.1 | 4 | 0.4 | 4 | 0.4 | 3 | 0.3 |
| S4 | 0.05 | 2 | 0.1 | 2 | 0.1 | 2 | 0.1 |
| S5 | 0.125 | 2 | 0.25 | 4 | 0.5 | 3 | 0.375 |
| Weaknesses | | | | | | | |
| W1 | 0.15 | 3 | 0.45 | 4 | 0.6 | 3 | 0.45 |
| W2 | 0.03 | 2 | 0.06 | 3 | 0.09 | 3 | 0.09 |
| W3 | 0.06 | 2 | 0.12 | 2 | 0.12 | 4 | 0.24 |
| W4 | 0.14 | 1 | 0.14 | 2 | 0.28 | 4 | 0.56 |
| W5 | 0.12 | 2 | 0.24 | 4 | 0.48 | 3 | 0.36 |
| Total | | | 5.43 | | 5.965 | | 5.945 |

According to the matrix, the strategy that generates the greatest impact for the project and that allows the project to spread in other territories is to manage private, state, and government investment in order to close the gaps in transportation and communications. Taking this into account, in the medium to long term, it will be necessary to optimize the transport infrastructure, through the creation of new roads or highways, in order to generate greater spatial mobility between Mecayapan and the other territories in the area.

## 4. Impact Analysis and Implementation Strategy

Even though this is the fourth industrial revolution, the municipality of Mecayapan has lagged and has not received its benefits, which is due to variables such as age, level of schooling, income, ethnicity, and geographic location. The analysis showed that the geographical characteristics and the rugged topography of the municipality are some of the factors that make it difficult for the various internet providers to access the area, which means that only 1.4% of homes have internet access and 36.4% have a cell phone. Therefore, the increased coverage of technologies such as the internet, social networks, mobile, and fixed telephony would allow the population to communicate with other towns without the need for contracts with an ISP. On the other hand, 91.4% of the population of the municipality is in poverty, so the lack of economic resources is another limitation for acquiring internet service. Therefore, the proposed implementation of the WiFi network, i.e., the antenna model proposed, would give most of the population the opportunity to connect not only in public places, but also in their own homes, through training for this purpose, of the women of the community. Furthermore, and since 73.36% of the population is of indigenous ethnicity, it could be thought that the use and exploitation of this resource would be difficult; however, 84.5% know how to read and write, and only 1.17% do not speak Spanish, which makes learning the use of technological tools and learning to enter and surf the net are not considered limitations for this population. Conversely, it is proposed that the young population, which has knowledge of the use of Tics, could be the one that teaches and trains those who do not have this knowledge, and in this sense, everyone could take advantage of internet access. It is worth mentioning that future work within this project could be on how the same young population could become involved and develop materials and courses in their own indigenous language, benefiting the original cultures. Economically, 54.1% of the Economically Active Population belongs to the primary sector, and 35.4% is dedicated mainly to handicrafts and garment weaving. Therefore, increasing internet access in this sector would make it easier for them to promote their products, generating a virtual market for goods and services by taking advantage of this tool. Finally, it is important to highlight that, in order to implement the long-distance WiFi network, private, state, and government investment must be managed in order to close the gaps in transportation and communications. It is necessary, in the medium term, to optimize transport infrastructure by improving access roads and creating new ones, in order to generate greater spatial mobility between Mecayapan and the other markets in the area.

## 5. Conclusions

The comprehensive diagnosis of the situation in Mecayapan has provided valuable insights into the municipality, revealing deficiencies across multiple development areas. This analysis validates the statistical data and highlights that the high poverty rates reflect the inadequate execution of projects aimed at reversing this situation. To address these challenges, it is crucial to promote economic and social initiatives in Mecayapan that capitalize on new technologies, such as the internet, social networks, and mobile and fixed telephony. These tools enable communication with other regions and facilitate the promotion of local products, creating a virtual market for goods and services.

Through the utilization of the Quantitative Matrix of Strategic Planning (QMSP), various strategies were evaluated. Notably, the main strategy identified involves managing private, state, and government investments to bridge the gaps in transportation and communications. In the medium to long term, optimizing transport infrastructure by constructing new highways and establishing a small airport becomes imperative to enhance spatial mobility between Mecayapan and other markets in the area.

The implementation of a long-distance WiFi network with wide, open-access coverage will significantly benefit the population of Mecayapan. It will contribute to improving social inclusion, reducing poverty rates, and ultimately enhancing the quality of life for its residents. By leveraging technological advancements and connectivity, this project aligns with the United Nations' sustainable development goals and serves as a catalyst for positive change in Mecayapan. It enables economic development, grants access to educational resources, facilitates effective communication, and fosters the adoption of sustainable practices.

Looking ahead, our future endeavors will concentrate on undertaking similar projects in various regions of Mexico and the Amazon region of Ecuador. The objective of these initiatives is to replicate and build upon the outcomes and strategies achieved in the presented project. By doing so, we aim to make further contributions to the socioeconomic development and long-term sustainability of these areas.

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## Abbreviations

| | |
|---|---|
| WHO | World Health Organization |
| ICTs | Information and Communication Technologies |
| ISO | Organization for Standardization |
| SWOT | Strengths, Weaknesses, Opportunities, and Threats analysis |
| IFEM | Internal Factors Evaluation Matrix |
| EFEM | External Factors Evaluation Matrix |
| SOS | Strengths vs. Opportunities Strategies |
| WOS | Weaknesses vs. Opportunities Strategies |
| STS | Strengths vs. Threats Strategies |
| WTS | Weaknesses vs. Threats Strategies |
| WSN | Wireless Sensors Networks |
| WLAN | Wireless Local Area Networks |
| WiFi | Wireless Fidelity |
| QMSP | Quantitative Matrix of Strategic Planning |
| INEGI | Instituto Nacional de Estadística y Geografía (National Institute of Statistics and Geography) |
| PVC | Polyvinyl Chloride |
| AWG | American Wire Gauge |
| SMA | SubMiniature version A |
| USB | Universal Serial Bus |
| ISP | Internet Service Provider |

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