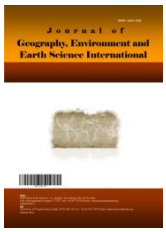

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The Bike-courier as an Energy Efficiency Instrument at the University of Guadalajara (Pilot Study)

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Introducción: The struggle and concern for climate change, the optimization of natural resources, the well-being of future generations, has permeated the public institutions of our country. In particular, the University of Guadalajara, a public body for higher education, has launched projects aimed at this direction. The year 2020 at the University of Guadalajara was declared as the "Year of the Energy Transition at the University of Guadalajara". Likewise, the Program of Austerity, Rationality and Efficiency of Institutional Resources of the University of Guadalajara was launched, implemented and applicable to the entire University Network and of a mandatory nature, to rationalize institutional spending by establishing: A decrease in energy resources through rational, responsible and sustainable use, proposing "to reduce spending on fossil fuels and lubricants by 40%, optimizing its consumption" together with a gradual transition of the vehicle fleet, "The conversion of the vehicle fleet to the electric and hybrid type will be strengthened".
Materials and Methods: Considering the above and associated with the opportunity to take as a pilot test the Transport Office of the Rectory General, it was established to replace by bike-courier the delivery of documents and light parcels in dependencies with distances less than 5 km of radius of the administrative building of the University of Guadalajara that is currently carried out using a car, seeking energy reduction, without losing efficiency in deliveries and contributing to meet the

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institutional goals of resource optimization and environmental contribution. The messaging and departure requests of the agency's operational vehicles were tracked during the year 2019.
Results and Discussion: Accounting for the annual record, only the requested trips with distances less than 5 km are those considered to be made by bicycle because they are requests for delivery of documentation, being 40.88% of these those susceptible to be delivered by bicycle, representing 2,237.54 kilometers and 187.05 liters of fuel saved, contributing to the fulfillment of the institutional goal of reducing fossil fuels by 40%. It was also evidenced that the efficiency of the bike-courier, in most cases is higher than the automotive, under the criteria and variables analyzed, using the Data Enveloping Analysis (DEA).

Keywords: Bike-messenger; energy efficiency; pilot study; University of Guadalajara.

1. INTRODUCTION

The struggle and concern for climate change, the optimization of natural resources, the well-being of future generations, has permeated the public institutions of our country. In particular, the University of Guadalajara, a public body for higher education, has launched projects aimed at this direction. The first of these is the Integral University Program of Energy Transition (PUITE) launched in the administration (2013-2018), whose objectives were: to generate clean energy by taking advantage of university spaces susceptible to install photovoltaic panels, to gradually replace the vehicle park with less polluting alternatives, and to look for areas of opportunities in the institution for energy savings that contribute to the reduction of expenditure and the best use of the public resource. The second project was to implement a series of policies of austerity, rationality and efficient management of resources, which among its measures was to stop printing invitations to events (reducing paper consumption), in addition to direct energy savings by stopping distributing such invitations, reducing the conventional vehicle fleet and replacing them with electric vehicles, together with the reduction in the cost of fossil fuels and lubricants by 40%, reducing and optimizing their consumption, the transition of the university newspaper "Gaceta UdeG" from the printed version to the digital one, as well as reducing the number of documents that are delivered in physical, digitizing them. For what was approved, by the H. General University Council name in all the institutional documents issued during 2020 the legend "Year of the Energy Transition at the University of Guadalajara".

Within the strategies, a possible area of opportunity was detected in the Office of Transport and Courier of the Rectory General (OTMRG) to carry out a pilot study to determine the feasibility of integrating the bicycle as a complement to the distribution of light messaging, within a range in which it is possible to do so without losing efficiency, compared to the car. Therefore, the objective of this work is to implement part of the energy transition in this office, without losing efficiency in deliveries and contributing to meet the institutional goals on the optimization of resources and the environmental contribution, in addition to solving the collateral problem of lack of parking and dense traffic in the downtown area when distributing couriers.

Every day millions of people to carry out their daily activities invest a lot of time in the transfers, affecting their well-being and work performance, caused by unplanned and poorly managed urban development that generates road congestion. The Metropolitan Area of Guadalajara (ZMG) is no exception, and every day it is more complicated for the OTMRG of the University of Guadalajara, to efficiently carry out the distribution of documents, transport of personnel and/or furniture, intensifying in the Centro and Minerva areas (within the radius of 5 km with respect to the Administrative Building). The increase in travel times is due to multiple factors, increase in the vehicle fleet of the ZMG, streets permanently closed by pedestrianization, reduction of speed in zones 30 (prioritizing the pedestrian and favoring non-motorized mobility), roads temporarily closed either by maintenance, demonstrations, marches, sit-ins, among others. According to data from the Planning Secretariat in its Jalisco Development Indicators Monitoring project "MIDE", the average speed of motorized vehicles in the ZMG, in the main avenues of the metropolis is 23.5 km/h in 2018 [1]. Also, the lack of parking, and the strategy to solve it is to make deliveries per couple, where one person gets out of the car and makes the delivery, while the other looks for parking or turns long enough to pick up his partner, which generates unnecessary traffic,

useless expenditure of man hours, increased energy consumption and high air pollution.

In the ZMG, air pollution is mainly caused by mobile sources of emissions, so it is recommended to discourage the intensive use of private cars, and promote the modernization of the vehicle fleet [2]. Mobility schemes that privilege private cars over other types of sustainable mobility, such as public and non-motorized transport, are a challenge in many cities around the world. It is necessary to break paradigms and remake public policies considering the bicycle as an option in the current environmental crisis and not only as a recreational medium, but also an integral part of the sustainable mobility policy, which contributes to improving the air quality, health and quality of life of the population.

The United Nations (UN), in its global report on the environment published in 2016, shows countries that encourage non-motorized means of transport, an example of this is China, where there are cities in which up to 60% of trips are made by bicycle. The Netherlands in 2016 recorded 4.5 million bicycle journeys, equivalent to 15.5 million kilometres [3].

The metropolitan territorial planning plan of the ZMG concludes that "the accelerated increase in private vehicles promotes road congestion and inefficient land use" also recognizes that there are "insufficient alternatives for non-motorized mobility, and incipient infrastructure for pedestrians and cyclists" that have an impact on poor air quality [4], corroborated by the Jalisco Atmospheric Monitoring System (SIMAJ), since the first five months of 2019 the average Metropolitan Air Quality Index (IMECA) was 112, corresponding to poor air quality [5].

The University of Guadalajara, in accordance with the austerity policies promoted at the federal and state levels and following its Institutional Development Plan 2014-2030, established as its objective the implementation of policies of saving and efficiency of spending to promote austerity and budgetary discipline of resources. To this end, it issued the agreement RG/02/2019 "Program of Austerity, Rationality and Efficiency of Institutional Resources of the University of Guadalajara" applicable to the entire University Network. In section "U" of the program, the institutional will to strengthen the rational, responsible and sustainable use of energy resources through a savings plan is reflected, projecting to reduce spending on fossil fuels and lubricants by 40% optimizing their consumption. Likewise, the conversion of the institutional vehicle fleet to electric and hybrid type is proposed [6].

Based on the above, the objective of this research is to evaluate whether the bike-courier would work as an instrument of energy efficiency, reduction of pollutants and reduction of costs in the transport office of the Rectory General, of the University of Guadalajara, and if it could replicate more offices and campuses of the same university?

1.1 Higher Education and the Promotion of Active Mobility

Many universities and colleges encourage bicycle use among their students, academics, and administrative workers, most focusing on internal mobility programs. In the United States of America there is the "League of American Bicyclists" that recognizes universities and colleges the promotion of this type of mobility, with the distinction "Bicycle Friendly University (BFU)". As of 2018, it has 193 recognized institutions, including major universities such as Stanford, or large universities such as Texas A&M with more than 68,000 students enrolled. Princenton has a "Zagster" bike-sharing program that is used inside the campus and near campus, with a $20 USD membership with free two-hour rides and additional time, with stations throughout the university complex and surrounding area, taking and returning the bike at any station. The use is not only for university students, but open to the public through registration and payment of membership [7].

Michigan State University (2014) implemented a pilot program with the intention of exploring the feasibility of launching a bike-courier service on its campus for delivery of documents, mail and other services; however the program was cancelled. The University of Illinois at Chicago had a brief period of bicycle mail delivery, but in 2014 the program was abandoned [8]. With the exception of Princeton University, all non-motorized transportation use cases for mail delivery have been within universities campuses. The case of the University of Guadalajara is different because of its network configuration, where the dependencies are distributed in all the municipalities of the state of Jalisco.

For many years, the number of cars per capita has been taken as a measure of economic

development, its increase is erroneously desirable and we have been led to believe that it is synonymous with progress. Thus, much of the space and public money is still used to encourage its growth, which favors urban models that allocate public space to this medium and not to people. The most common are policies that favor the automobile such as, avenues to improve the average speed that eliminate traffic lights not allowing pedestrians who need to cross, in some places there are pedestrian bridges that require climbing stairs and/or ramps for people with reduced mobility to cross the road. Care should be taken to ensure that the right to move easily is egalitarian and not reserved only for motor vehicles.

The ZMG like many others in the world have common problems, one of them is vehicular chaos. Every day millions of people lose valuable time in moving from one point to another, that time is directly associated with their well-being and work performance, caused by road congestion, urban dispersion, poor planning, poor public transport, reduced mobility matrix and the use of the private car for their transfers. In particular, this makes it increasingly difficult for the OTMRG to carry out requests for the distribution of documents, transport of personnel or furniture, intensifying in certain areas of the ZMG, increasing travel times due to multiple factors, such as an increase in the vehicle fleet, closed streets, low-speed roads (zones 30), temporary closures for maintenance, demonstrations, marches, sit-ins, among others. According to the Secretariat of Planning in its project of Monitoring of Development Indicators of Jalisco "MIDE", the average speed of displacement of motorized vehicles in the ZMG in the main avenues is 23.5 km/h in 2018, 22 km/h in 2017, 23.5 km/h in 2016 and 24.6 km/h in 2015 and 2014, The goal of the unit is to achieve 26 km/h. The number of cars per capita in the ZMG is 2.07 people per vehicle as of December 31, 2018, being one of the highest globally.

The Mario Molina research center elaborated in 2015 an analysis on the urban sustainability of the ZMG, from where in terms of air quality each vehicle traveled on average 43.4 km/day, with an average speed of 13 km/h, the average age of the vehicle fleet was 12 years old. One of the recommendations to improve air quality is the need to discourage the intensive use of the private car, and encourage the modernization of the vehicle fleet [2]. The high levels of air pollution in the ZMG presents an increasing rate of cardiovascular and respiratory diseases due to chronic exposure to pollutants such as PM_{10}, with an increase in pneumonia morbidity of 30 to 40% and 49% due to ozone exposure [9]. In Latin America some cities have begun to change their policies in favor of active mobility, according to data from the UN Environment, transport produces 25% of emissions in Latin America and the Caribbean.

In 2010, Mexico City started the public bicycle service "Ecobici" with 85 stations and 1200 bicycles. It currently has 480 stations and 6800 mechanical and electric bicycles, covering an area of 38 km^2, with a cost of $ 462 pesos per year and loan times at no cost of 45 minutes, coupled with a cycling infrastructure of 168 kilometers. In 2018 its users made more than 8,500,000 trips and an accumulated since its inception (30/06/2019) of 61 million trips, and a number of registered users to the same date of 310,346 [10], ceasing to emit 3870 tons of CO_2 [11]. Last year two bicycle loan companies Mobike and "Sintráfico" joined the system, where the main differentiator compared to "Ecobici" is that it is not necessary to leave them at any station, since it has an anchorless system called Free-floating bike sharing (FFBS). At the end of the trip it is placed in a place where it does not get in the way and when the blockade is made, the trip is terminated.

Locally, the ZMG has a bicycle rental system called "MiBici" which was designed to complement mobility needs, fulfilling Objective 4.9 of the National Development Plan 2013-2018, in strategy 4.9.1 that marks a line of action to promote the use of mass transport with complementary pedestrian transport measures, use of bicycles and rationalization of car use [12], the project also aligns with the Sustainable Mobility category of the Jalisco State Development Plan 2013-2033 which specifies the need to have safe, efficient and quality transport alternatives; and the need to implement public bicycle loan programs [13]. "MiBici" is operated by the company BKT bici pública S.A. de C.V., the stations, bicycles and communication and monitoring technology was acquired from the company Public Bike System Company [14]. "MiBici" began on December 1, 2014 with 86 stations and 860 bicycles in the downtown area of the ZMG, and is the second most important bicycle loan system in Mexico, until July 2019 it has grown threefold, to date it has 286 stations, 2500 bicycles, its range has an

area of 1100 ha, 63,907 users and a total of 9,812,000 trips. The average duration per trip is 12.5 minutes and the busiest hours are 8:00 and 18:00 hr where the number of trips increases 21.87%. The most demanded station is the GDL-049, the annual cost in 2019 was $ 404 pesos with free use of 30 min from Monday to Saturday and 45 min on Sundays [15].

According to the Institute of Statistical and Geographic Information of Jalisco (IIEG) from January to December 2019, in the "MiBici" System 4,646,578 trips were made, with the group of 25 to 29 years old being the one that used it the most, on average/day 12,730 trips were registered [16]. Fig. 1 shows the geolocation of the anchor stations of the "MiBici" system with representation of small circles. The blue ones are the GDL-048 cycle port located in the administrative building of the General Rectory and the GDL-049 cycle port, the one with the highest movement of both destination and origin trips.

The ZMG has 224.8 km of cycling infrastructure [17], of these 123 km are confined bicycle paths, the interconnected sections is 36.24 km composed of the Federalism, Washington, La Paz, López Cotilla and Agustín Yáñez bike paths. With the bike paths of Ávila Camacho, Revolución, Niños Héroes and 8 de Julio, they will add another 28.34 km to the network of interconnected sections [18]. Fig. 2 shows the cycling infrastructure, the green dashed lines are confined and exclusive lanes for cyclists, the blue dashed lines are streets with cyclist preference, those that are shared with the car where the cyclist has preference to circulate, and small gray polygons that delimit zones 30, with infrastructure that forces to circulate at that speed to reduce serious accidents.

Fig. 1. Stations of the public bicycle rental service called MiBici, own elaboration with uMap tool. Available in: http://umap.Openstreetmap.fr/es/map/bicimensajeriaudg_327598 #13/20.6763/-103.3304

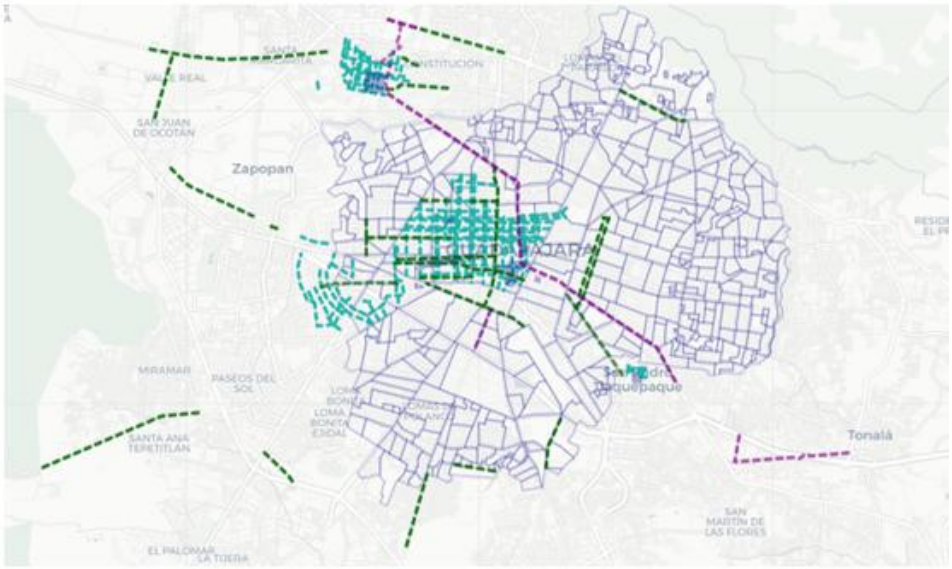

Fig. 2. Current cycling infrastructure (preferential and confined lanes), own elaboration with uMap tool. Information available at: http://umap.Openstreetmap.fr/es/map/bicimensa jeria-udg_327598#12/20.5841/ 103.2887

For its part, the University Network of the University of Guadalajara is made up of six thematic university centers specialized in a disciplinary field and a multi-thematic one of regional structure, all based in the ZMG, nine regional university centers of an interdisciplinary nature within the state, a Higher Secondary Education System with 178 campuses distributed throughout the state of Jalisco and a Virtual University System, that offers studies in the distance modality, with a presence in 109 of the 125 municipalities of the state, that is, with coverage of 98.4% (Fig. 3). The Rectory General and dependencies of the central administration are located in the central building whose address is Avenida Juárez 976, Colonia Centro, Guadalajara, Jalisco. It is in this place proper where the transport office is based, and is the point of origin and completion of all trips without distinction of the requested destination.

Fig. 3. Higher and upper secondary education campuses of the University of Guadalajara, Own elaboration with Power BI tool, available in: https://app.Powerbi.com/view?r=eyJrIjoiNjJiYTEyMDQtYzM3ZC00NDE0LTg1ZDYtZDQyOThmODcwYTgzIiwidCI6ImVmYzAwYjhkLTY

1.2 Transport and Courier Office of the Rectory General

The transport and courier office of the Rectory General (OTMRG), attached to the General Services area of the same dependency, has as its objective the "Transfer of staff of the Rectory General, special guests, delivery of courier." and has the following structure: eight people in delivery and courier work, one performs delivery tasks on foot and in emergency situations by car. Two of them collaborated voluntarily during the pilot test in the delivery of bicycle couriers. To carry out the sending and collection of couriers properly, the applicant generates a courier request, using the "Courier Delivery" format FF-ORG-SG-TYM-06, or a "personnel transport request" format FF-ORG-SG-TYM-07, or be requested by email or telephone call. Once the request is received, it is determined if it is a service of delivery of documents or transfer of personnel, identifying if the destination is within the same building, or if it is a local or foreign destination, it takes turns to who will carry out the service and the delivery is made in the corresponding dependency or address, collecting the signature as acknowledgment of receipt and delivering the completed courier order for archiving. When it comes to a personnel transfer service, vehicle and driver are assigned; the time and date are programmed. At all times and regardless of the type of service, the transport personnel fill out the "vehicle departure order" with license plate number, model and economic number of the vehicle used, initial and final mileage, name of the driver, date and time of both departure and arrival, and itinerary, which consists of the places or dependencies visited. For the performance of its functions, there are 12 cars, one electric, two for passengers (for 15 and 8 people), two cargo, and the rest sedan type.

The bicycle is the fastest and most efficient way to make trips, provided that the maximum length does not exceed 5 km, taking as a reference an average speed of 16.4 km/h compared to the average speed of a car at peak hours of 15 km/h [19]. In the publication "2018 Global Traffic Scorecard", Guadalajara occupies the 320th position of the most congested cities in the world, with an average speed of 16 km/h in the downtown area, in 2018 181 hr were lost driven due to traffic congestion [20]. Based on this, a linear radius of 5 km was determined as a border area, taking as its origin the General Rectory building, which represents an average real distance of 5.5 km (Fig. 4). This distance was calculated by taking some dependencies located on the distribution border and selecting suggested routes respecting the direction of the road. The central point in the form of a green drop is the building of the Rectory General, the polygons with blue lines delimit the colonies of the municipality of Guadalajara, and the dotted circle is the area of possible distribution by bicycle.

2. MATERIALS AND METHODS

Courier activity was recorded for one year considering the number of working days, which was determined by the difference between the number of calendar days (365), minus non-working days (102) to calculate the number of days on which courier requests can be submitted to the year. Thus, the agency works 263 days a year. Taking into account this period, we have the certainty of recording all the events that take place annually.

2.1 Inclusion, Exclusion and Deletion Criteria

The data were obtained retrospectively from the reports for both courier and transport of personnel and furniture. Any request for courier and vehicle departure order with the formats FF-ORG-SG-TYM-06 and FF-ORG-SG-TYM-07 of "request for personnel transport" was taken as recordable information, even if it has a lack of information, or this is not clear or feasible to understand. Vehicle loan services where the participation of personnel was not required to drive the car will be excluded, regardless of the period of time, if as the vehicles assigned to the officials, limiting only the utility cars. Because the institutional goal is the reduction of fossil fuels and lubricants by 40%, optimizing their consumption, the energy consumption of the electric car was not recorded, although its activity is considered. Records where useful information cannot be obtained, or where it is impossible to infer it, were deleted. In messaging requests, those that have no date or dependency to which it is addressed. With regard to vehicle departure orders, car information is necessary: plates or economic number, initial and final mileage; and date of service. To minimize information biases in the data, it is reviewed that there is logical coherence, information is crossed when there are doubts or the applicant and/or service driver is interviewed when the event is recent. If these criteria are not met or cannot be deduced, they are discarded.

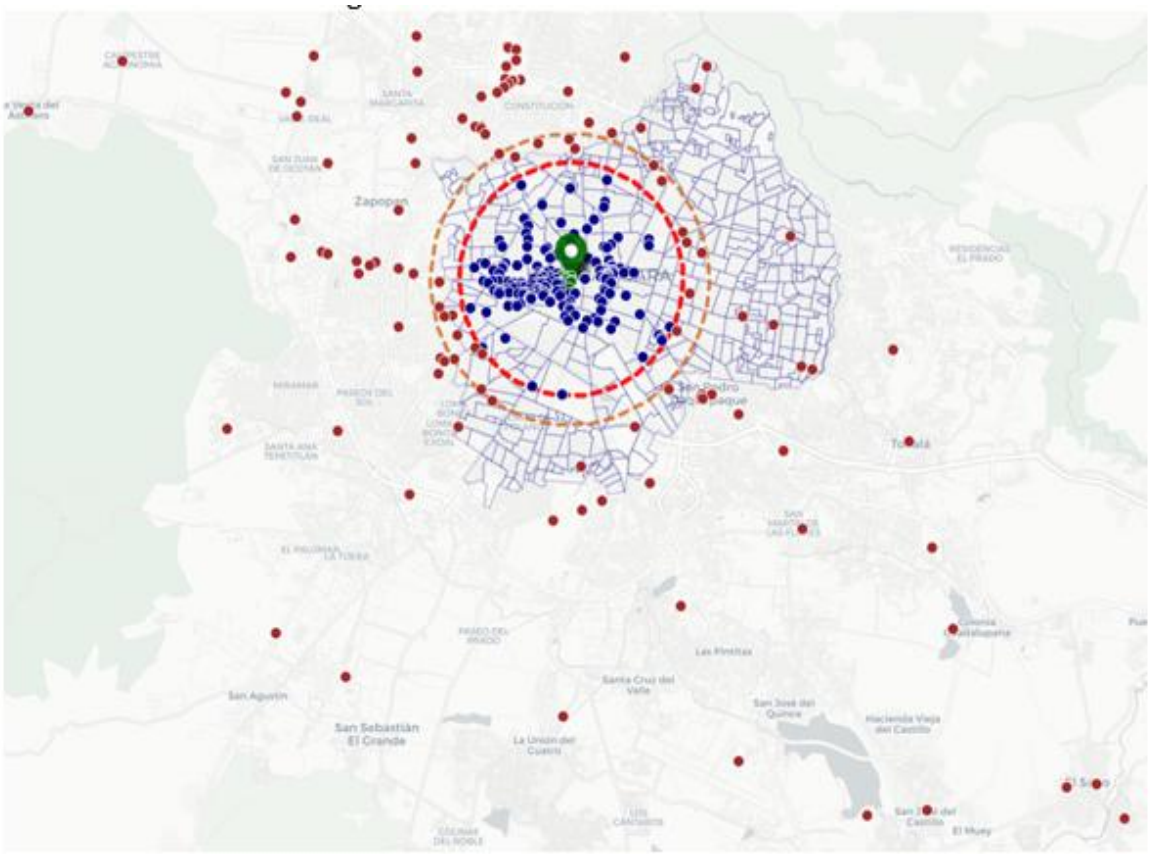

Fig. 4. Dependencies with messaging request, visualization of layers (Admon. Central, Distribution on foot, less than 5km, more than 5km, Colonies, Radius of 4km and 5km). Own elaboration for uMap http://umap.openstreetmap.fr/es/map/bicimensajeria-udg_327598#12/20.64

The human resources that participated were transport, human resources, and General Service personnel. The material resources used were: computer, travel log formats, messaging request formats, uMap an OpenStreetMap Project map software, Version 1.1.2, http://umap.openstreetmap.fr/es/, Microsoft Power BI, https://powerbi.Microsoft.com/es-es/desktop/, Wix to host files and create HTML5 websites, https://es.wix.com/, DEA Frontier Add-In for Excel http://www.deafrontier.net/deasoftware.html, open data from MiBici, https://www.mibici.net/es/datos-abiertos/, open data from the City of Guadalajara, https://datos.guadalajara.gob.mx/, Map of ZMG bike paths, GDL en Bici organization. https://gdlenbici.org/mapa-de-ciclovias-amg/ and maps of https://mapa.guadalajara.gob.mx/geomap.The economic resources were the time of the administrative staff of the offices, institutional inputs such as formats, logs, electronic equipment and two annual memberships of MiBici ($808.00).

2.2 Methodology

The first stage of the methodology is to have access to the information generated by the transport office, both courier requests and trips made, gasoline invoices, vehicle files, files and interviews with the personnel of the area, among others. The sources of information were requests for courier, transfer of personnel or furniture of the OTMRG. In the case of transfer of people or furniture is requested by phone, email or by the format FF-ORG-SG-TYM-07. In the case of documents, the format FF-ORG-SG-TYM-06 is used, the vehicle departure orders are generated by the transport personnel.

The second stage begins when the information fields have been identified, creating databases that were modified throughout the project adapting to the questions, objectives, ways of

visualizing the information and the analysis of it. Likewise, an interactive dashboard with the generated databases was created, with the aim of making visual representations of the information. For the fuel expenditure data there is no established format, but it was estimated, since in each gasoline invoice the plates or economic number of the vehicle to which it corresponds are noted, and mileage on the odometer at the time of fuel loading. In case of doubt or missing data in any of these documents, we proceed to try to obtain or clarify the discrepancy by asking directly the applicant in the courier deliveries, or who made the trip in the departure orders of the vehicles.

For vehicle departure orders, it was more complicated to obtain missing information. The missing fields were the time of departure and entry, the type of service that involves the use of the car. In order not to lose these records, the category "without type" (S/T) was created to count the kilometers that these services added. Another missing data was the destination or places where the service was requested, they registered generic names such as "address", "route", "restaurant" leaving the site of delivery or service without geopositioning. In some cases due to confidentiality the information of some exit orders was registered as "domicile". In other cases, the coordinates of the site were determined, but not the name. In these cases, it was resorted to consulting with the operator of the vehicle, to cross-information between the request for personnel transport, request for courier delivery, consulting the calendar of events in the protocol office, the calendar of requests of the OTMRG itself or the requests for delivery of courier "FF-ORG-SG-TYM-06" and personnel transport "FF-ORG-SG-TYM-07".

Databases (DB) are interconnected through interrelated fields in such a way that the information can be complemented and data representations obtained for analysis, decision making or conclusions. For the spatial presentation, an open access, open source and web application tool called uMap was used to make maps, which would allow not only to import information from open data sources but to visualize it by layers such as: places of delivery, incidents, infrastructure, perimeter in which the delivery of documents by bicycle is efficient taking into account the average speed in time of traffic congestion of the center of the ZMG, and all stations in the MiBici rental system.

Fig. 4 shows the map of the ZMG marking the radius of 5 linear km with epicenter in the building of Rectory General, in which it is technically feasible to do bike-courier we have a better appreciation of the number of destinations and their dispersion. Also, you can see red dots that are the dependencies beyond linear 5 km of the central administration building. Blue dots are destinations that are in the feasibility zone of bicycle delivery. The green dots are the dependencies in which it is delivered on foot. The blue polygons delimit the colonies and the municipality of Guadalajara. From this information, the number of dependencies outside and inside the distribution perimeter by bicycle and on foot was determined.

The number of dependencies by distribution areas, in which it is possible to deliver on foot were 41 (29 within the same building) representing 11%, by bicycle (less than 5 km) were 181 dependencies representing 49% and deliveries by car (greater than 5 km were 149 dependencies and represent 40%. Thus, almost half of the destinations to which courier has been requested are within the possible distribution zone of 5 linear km, and most are concentrated in the downtown area of the city and towards La Minerva.

Subsequently, the convenience of using the bicycle rental system "MiBici" or that the University acquires its own bicycles was analyzed. The public bicycle system "MiBici" has a good infrastructure and sufficient coverage in the distribution area, of a total of 286 stations, 105 (37%) are within a radius of 5 linear km with respect to the administrative building of the general rectory, with an average density of 2 stations/km^2 within the distribution area (Fig. 5). The number of bicycles within the area of influence is approximately 918, considering that the stations are not balanced and that the bicycles are constantly changing places, the service is available 365 days a year, with hours from 6:00 a.m. to 0:00 a.m. covering the delivery shifts in the courier. "MiBici", in its subscription includes protection with a coverage of damages to material or personal third parties so that the insurer compensates in case of mishap, legal assistance, limited medical expenses insurance whose amount is fixed by the insurer. If the bicycle were to be stolen, the deductible that the insurer dictates would be paid [21]. The option for the agency to provide workers with their own bicycles would have a higher cost, since the investment of the vehicle must be added to the

acquisition of a U-lock lock, a bicycle insurance, which covers both the cost of the same and damages to third parties, medical expenses and life insurance for the user so it would be more expensive than paying an annuity of $ 404.00 for the use of "MiBici" vehicles.

Fig. 6 shows the map of location and type of existing cycling infrastructure, the green dashed lines symbolize the existing confined bike paths, the streets with cyclist preference of water blue, purple the bicycle paths confined under construction and finally the gray polygons of zones 30. The layers of the dependencies registered with messaging request in 2019 are also shown, where the central building stands out, all framed by the distribution limit of 5 linear km. The map helps us to visualize that it is possible to reach many of the dependencies easily and in some cases safely because the confined lane, together with the 30 zones helps to minimize the risk of accidents.

With this information, the geospatial feasibility of using the ZMG MiBici system was evaluated. However, a more detailed analysis of the behavior of messaging, workflow and operation of the OTMRG is needed considering more variables to determine energy consumption, economic performance and efficiency. To do this, the Microsoft tool focused on "business intelligence" was used, with the ability to provide interactive visualizations that help to be clear about the behavior of the data and better decision making.

The databases used and linked were added to the system, working in parallel with the construction of the dashboard in Power BI, the process was continuous and adapted the graphical representations of the data, such as the design of the tables in the DB, and the consistency of the data was periodically verified, as well when something strange is observed in the behavior, it is corroborated with the source of information and when it does not comply it is deleted. In total 3570 messaging requests were registered during 2019, Fig. 7 shows a graph of this behavior, by type of messaging. The first trimester has an average of 16 applications/working day, while the rest of the year records an average of 6 applications/day. The dynamics in the applications are possibly due to the change of administration and the start of the "Program of Austerity, Rationality and Efficiency of Institutional Resources of the University of Guadalajara", of a mandatory nature to the entire university network. Where the printing of invitations is limited, generate the copies strictly necessary for trades and as far as possible their sending electronically, which caused a decrease in messaging requests, favoring savings in fossil fuels and emissions of pollutants.

In percentages for the total of applications registered in 2019, 62.4% are delivered on foot, the rest by car and of these, 23.49% are within the bicycle delivery area. Leaving only the courier requests in the delivery area that have required only distribution of documents, it is necessary that 19.47% of the total requests are susceptible to deliver by bicycle. Of the dependencies that would be able to deliver more documentation by bicycle are the Coordination of Research, Postgraduate and Linkage (CIPV) with 143, followed by the Higher Secondary Education System (SEMS) with 60, the University Center for Health Sciences (CUCS) with 44, followed by the package called (DF) documentation destined to the representative office of the University of Guadalajara in Mexico City with 43 and University Center of Social Sciences and Humanities (CUCSH) with 41.

Fig. 8 in Power BI shows the dependencies within the 5 km in which it is efficient to make deliveries by bicycle filtering those in which the delivery is documentation, yielding 71 destinations. The number of times a unit requests courier service and the distance from the receiving unit, measured in km from the Building of the Rectory General, were also mapped.

Fig. 9 shows the number of messaging requests in each unit versus the distance from the building of the Rectory General up to 25 km. The figure allows to visualize the behavior, disposition and frequency of messaging in the dependencies in which it is possible to distribute by bicycle, only with transfer of documents (blue rhombuses). Thus, the agency with the highest number of applications is the CPIV with 143 per year, at a distance of 1.3 km followed by the SEMS with just under half of applications. The number of kilometers traveled per year by official vehicles is 57,630 km, the Chevrolet Express Van of 15 passengers was the one with the longest travel with 22.31%, followed by the Nissan Tiida with 19.06%. As for the kilometers per month, October was the month with the most km traveled with 13,265 km. Finally we have that

44,176 km equivalent to 76% of the total annual distance were for personnel transfer, and only 13.23% was used for the distribution of documentation.

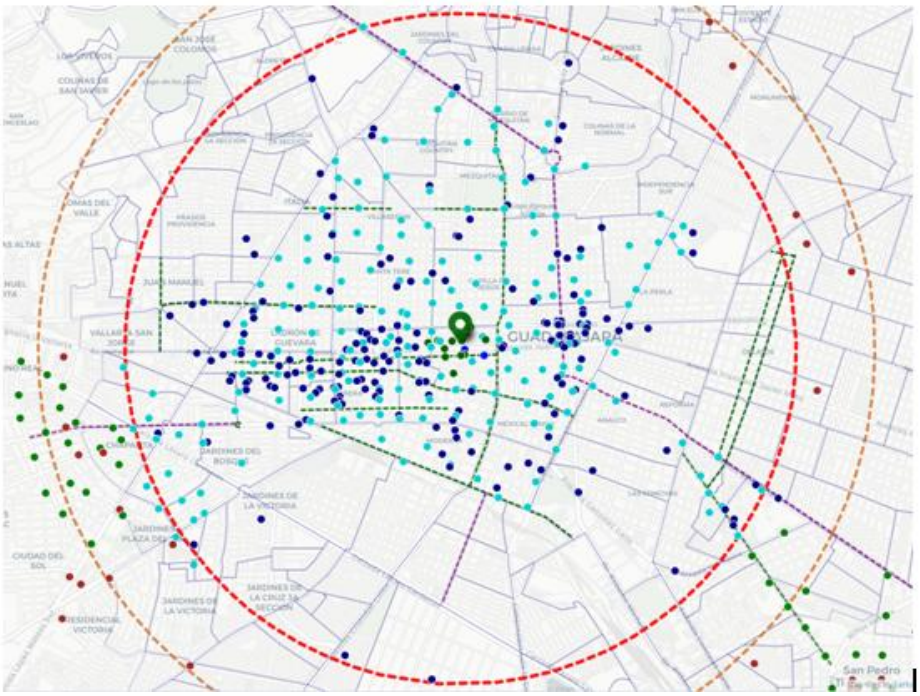

Fig. 5. MiBici stations inside and outside the bicycle delivery perimeter vs dependencies where courier service has been requested. Own elaboration for uMap http://umap.openstreetmap.fr/es/map/bicimensajeria-udg_327598#12/20.6407/-103.27 84

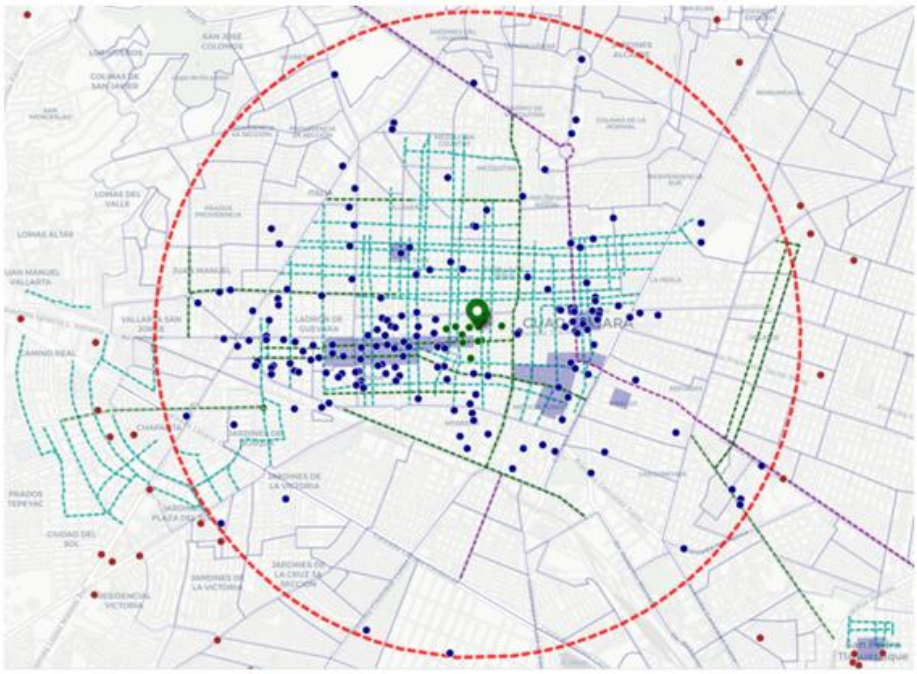

Fig. 6. Cycling infrastructure and dependencies with distribution requests, own elaboration with uMap tool http://umap.openstreetmap.fr/es/map/bicimensajeria-udg_327598# 14/20 . 6745/-103.3406

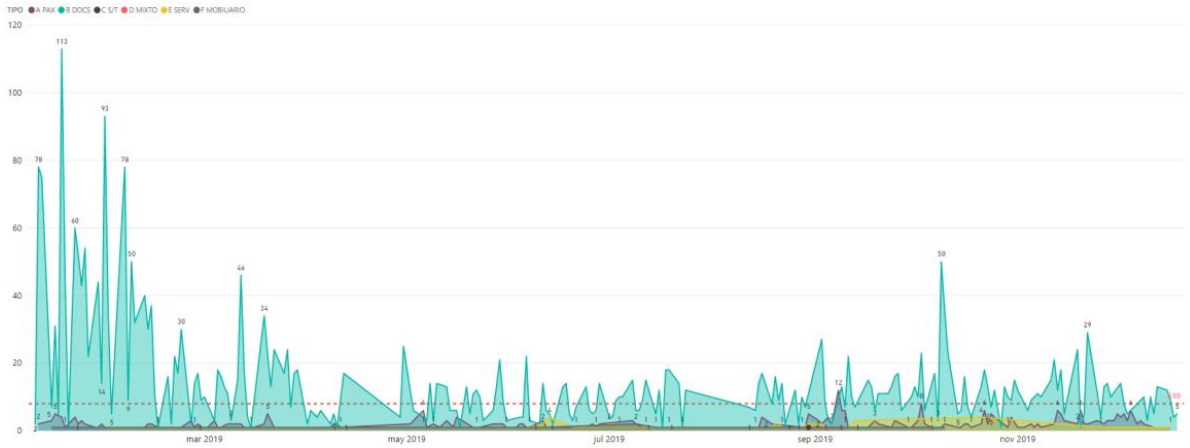

Fig. 7. Number of messaging requests registered in 2019, with detail of type of request, own elaboration with Power BI tool, available for consultation in: https://app.powerbi.com/view?r=eyJrIjoiNWRjZDQ0MzktN2UwNS00ZWNmLTgzNTgtNWU3YTlkYWYxYjVmIi

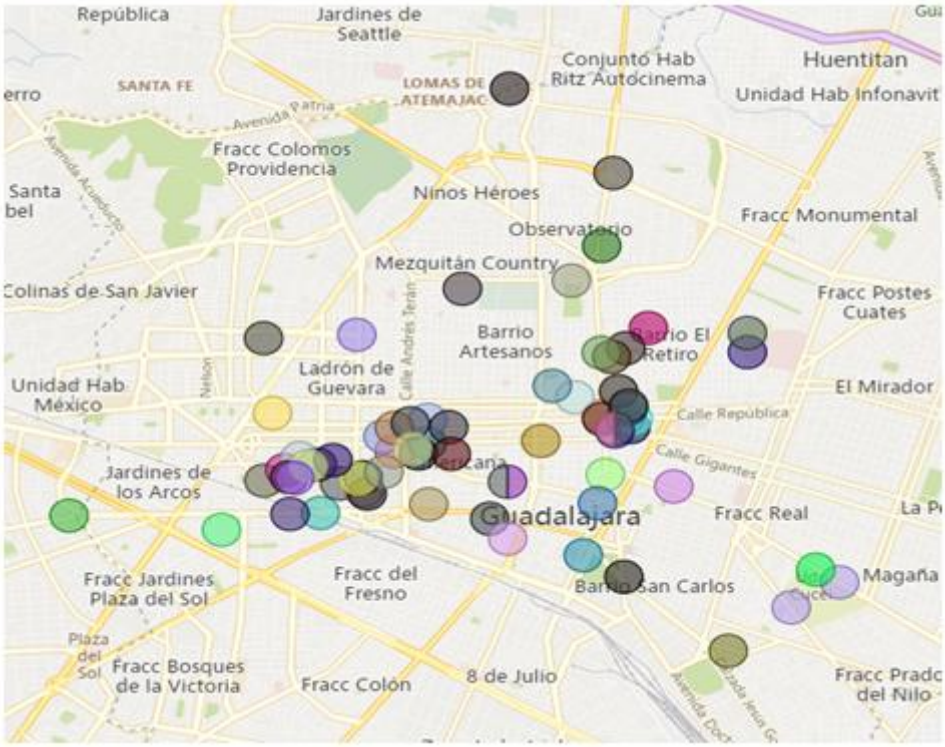

Fig. 8. Map with geolocation of dependencies within the bicycle delivery area with messaging requests of type documents. Own elaboration with Powe BI tool available in: https://app.powerbi.com/view?r=eyJrIjoiNWRjZDQ0MzktN2UwNS00ZWNmLTgzNTgtNWU3YTlkYWYxYjVmIiwidCI6ImVmYzAwYjhkLTY4ODYtNDE4YS1hNDRhLWQwODk5OGJhNGEzMyIsImMiOjR9

The data obtained from the two documents in which the information was obtained were contrasted to verify the congruence in them. Result of this comparison Fig. 10 shows the amount registered by type of service, being the first transfer of personnel, followed by documents and "C-S/T", in the mixed were registered those services or requests where any of two or more types were carried out. In the category called "E-SERV" are the trips in which the service is linked to the use of the vehicle such as fuel loading, going to the workshop, purchase of spare parts,

etc. Finally, the "FURNITURE" type concentrates the trips in which objects were taken for events of the General Rectory (awnings, tables, planks, podium, flowers among others). With this categorization, it is clear that the first two have information of the exit orders of the vehicle, one counts the km recorded by category, another the number of exit orders, and the third counts the courier requests and categorizes them.

Apparently there is a discrepancy in the data, since the largest number of km recorded in the first diagram correspond to the transfer of personnel, in turn does not keep a proportion with respect to messaging requests. For example: a transfer of personnel to the University Center of La Costa adds 324 km to the first graph, while a request to take people to a nearby dependency adds little distance, so there is no correlation between the km traveled, departure orders and courier requests. Thus, the interpretation of why the third graph seems more disproportionate with respect to the previous ones, for the category "B-DOCS". The fact that the largest number of messaging requests are recorded for the movement of documents than people, is not reflected in the first two graphs. 62.41% of document deliveries are made on foot and do not add mileage, since the receiving units are close, coupled with the fact that a single request can add great distance and that the analysis of frequency of requests with respect to mileage can be observed that the requests with greater distances were for the movement of people.

Fig. 11 shows the number of courier requests/day in which documents were delivered exclusively in the year vs the graph of the departure orders with the number of kilometers/day for personnel displacement during the same period. There is a downward trend in document delivery (dotted black line) with an annualized average of 14.38 requests/ day (red horizontal line). The average of 26.4 daily requests for documentation in the first quarter contrasts with the rest of the year with an average of 10.02 document deliveries/day. The second graph the km registered in personnel transfer/day is up (black dotted line) and annualized average of 228 km. During the first quarter the average was 140 km, while the rest of the year averaged 249 km/day.

The fuel expenditure in 2019 was $ 142,290.75 Mexican pesos, the vehicles that consumed the most fuel were the Express Van of 15 passengers 27%, followed by the Gol Volkswagen with 14.48% and the Tiida Nissan with 11.14% (Fig. 12). Fig. 13 presents, on the one hand, the evolution of the monthly mileage recorded per vehicle from the reading of the odometer of each car to which a line of different color corresponds vs the accumulated in the monthly fuel expenditure.

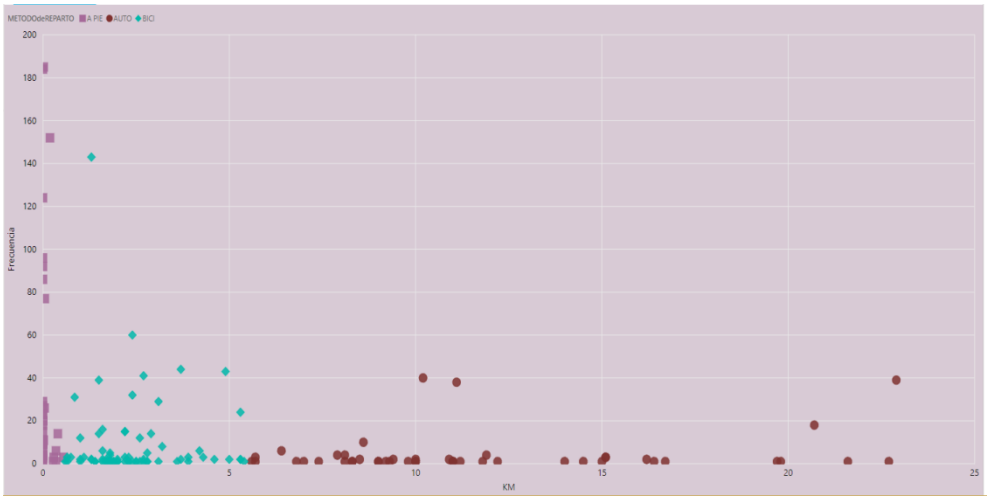

Fig. 9. Number of messaging requests in each unit, by the distance calculated from the building of the Rectory General up to 25 kilometers, own elaboration, information available online https://app.powerbi.com/view?r=eyJrIjoiNWRjZDQ0MzktN2UwNS00ZWNmLTgzNTgtNWU3YTlkYWYxYjVmIiwidCI6ImVmYzAwYjhkLTY4ODYtNDE4YS1hNDRhLWQwODk5OGJhNGEzMyIsImMiOjR9

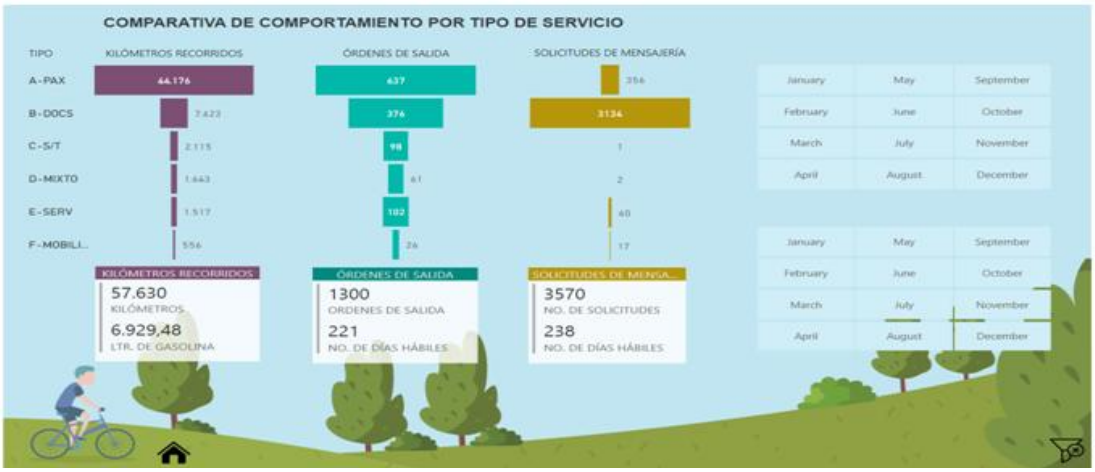

Fig. 10. Exit orders vs courier requests by type in 2019, own elaboration

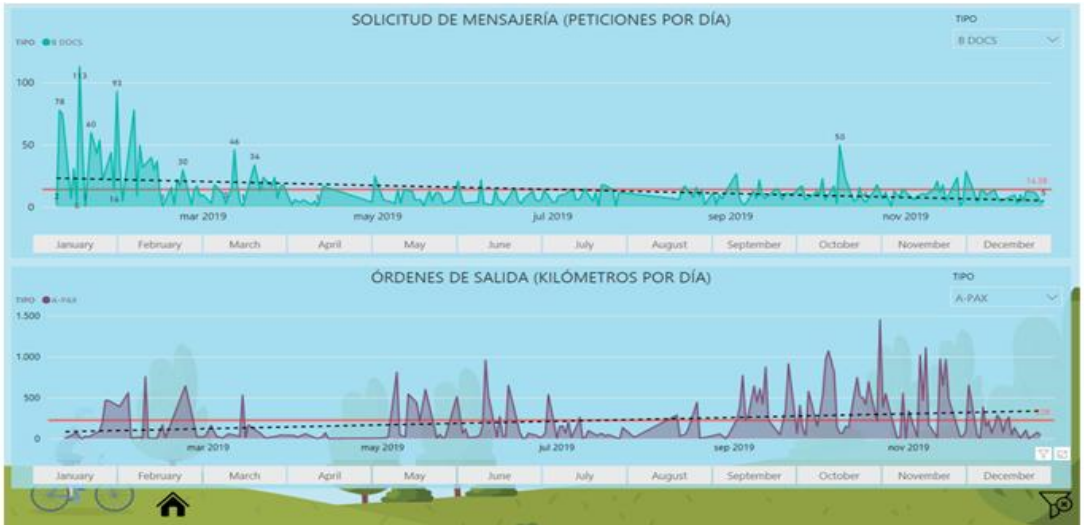

Fig. 11. Behavior comparison for messaging requests vs outgoing orders

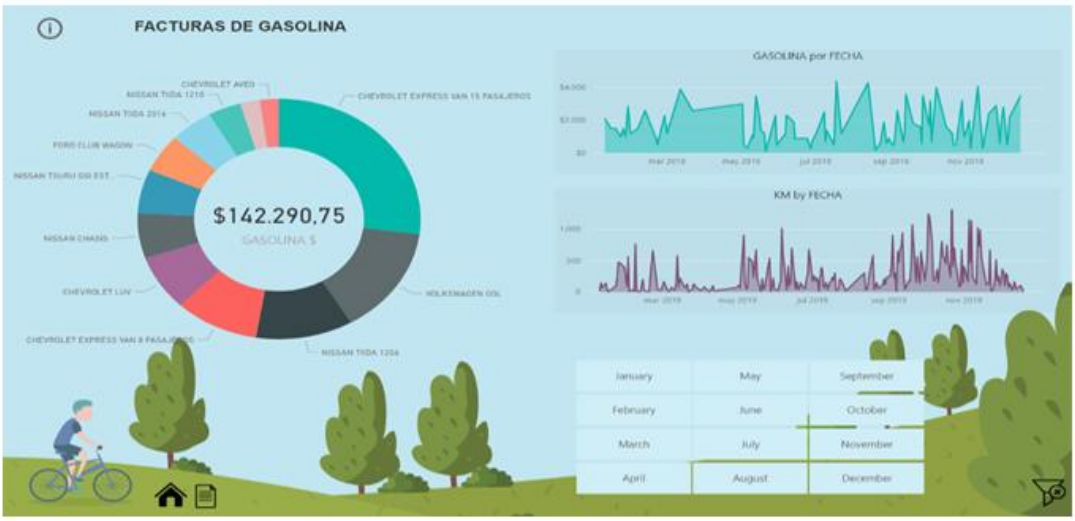

Fig. 12. Interactive dashboard with fuel consumption in 2019 and fuel consumption vs. behavior of kilometers recorded during the same period. Own elaboration

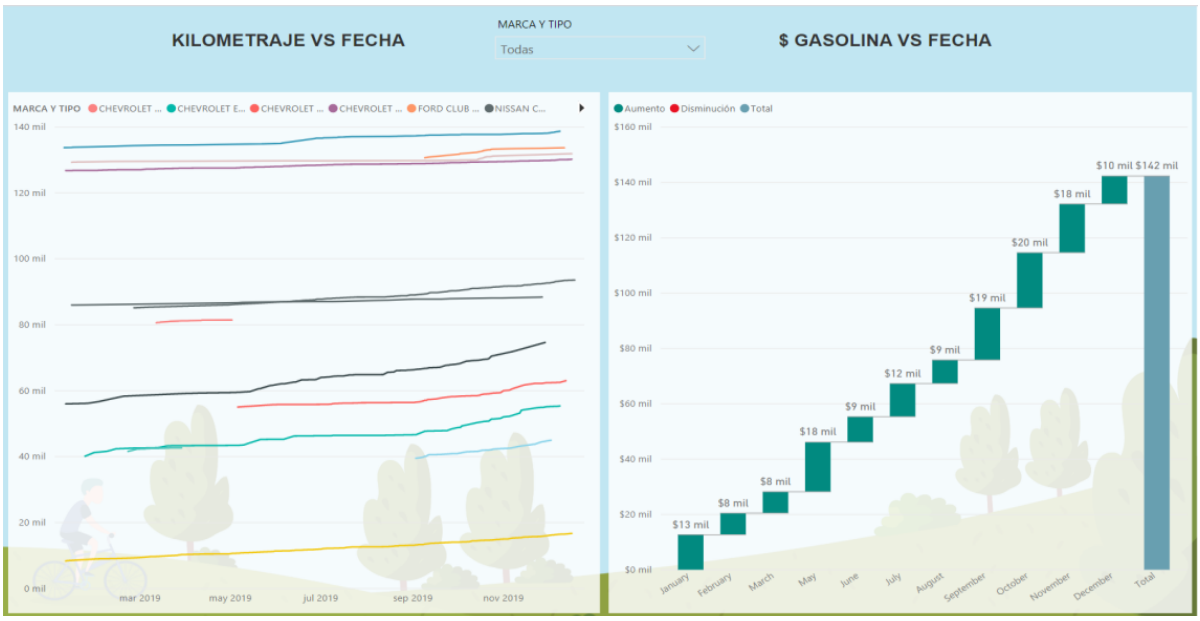

Fig. 13. Evolution of the mileage recorded per vehicle from the odometer reading of each car vs the fuel consumption per vehicle. Own elaboration

3. RESULTS

The number of days analyzed was 263 business days per year, with a total of 3570 messaging requests in 258 business days, so 98% of business days are recorded. In 2019, 62.41% of courier requests are distributed on foot, and 19.47% can be delivered by bicycle. Applying the filters of messaging requests in dependencies within the delivery range and that are documents, it can be seen that the workflow was 3.85 requests/ business day. Being the two dependencies that more documentation is sent are the CIPV and the SEMS. The frequency vs distance in which courier requests are made by dependency, filtering only those that are for delivery of documents and are within the range of distribution by bicycle shows that the number of documents requested for delivery per year in most destinations is low, being less than 20 times per year.

On the other hand, we have that of the vehicles, 76.65% of the kilometers requested were for personnel movement, and only 13.23% for delivery of documentation, of which those that are outside the distribution area have to be subtracted, leaving a very small saving margin. Fig. 14 shows the proportion of kilometers per month that are destined to deliver documentation vs any other type of service, which only 10% per month except July and August. Finally, it is estimated that with the bike-courier system it would be possible to reduce vehicle routes by 2,237.54 kilometers/year (3.88% of the total), saving $ 3,853.24 pesos ($ 20.6 pesos/liter) equivalent to 187.05 liters of gasoline, calculated from the average performance of each vehicle considering, type and model [22].

The CO_{2e} that is no longer emitted, was evaluated taking the factor of 3.49 kg CO_{2eq}/l of the "Diagnosis to achieve the certification of neutrality in GHG emissions of the University Centers of the University of Guadalajara located in the Metropolitan Area of Guadalajara, Jalisco", so that 5,727.78 kg CO_{2eq}/ year [23]. Taking as a sample not all the requests, but only the estimated trips within the radius of 5 km, it has to be that on average 1003 trips are carried out, and an accumulated route of 5,473.82 km representing 457.59 liters of fuel and an expenditure of $ 9,426.40 Mexican pesos (Fig. 15). If only the trips were taken in the possible bicycle delivery area, we can see that 40.88% of the kilometers were made for the distribution of documents. If they had not been made by car, 187.05 liters of gasoline, 2,237.54 km, and an unexercised resource of $3,853.24 Mexican pesos would be saved (Fig. 16). From this perspective it is possible to reach the institutional goal of 40% savings in fossil fuels and lubricants. It would be necessary to look for alternatives for medium and long distances, according to the different types of travel (transfer of personnel, documents, furniture).

It is inequitable to compare a human traction system vs a fuel-powered transport. The charging capacities, distance, autonomy, and speed will be infinitely greater. The only advantage offered by the bicycle is in short journeys, provided that the average speed of the city where it is intended to be implemented is low either by traffic jams, dense traffic, or limitations such as areas of vehicular restriction, zones 30, areas of shared transit, among others. For these reasons, this second analysis was made focused only on trips of any kind, registered within the perimeter of possible bicycle distribution, to visualize what their impact would be (Fig. 17).

Finally, to calculate how efficient the delivery of courier by bicycle would be compared to that made by car, The Enveloping Data Analysis (DEA) was used. This allows to handle models with multiple inputs and outputs, expressed in different units of measurement, in addition, thanks to the fact that it is a non-parametric technique, it does not suppose a functional form or a distribution. Thus, the parameters of each unit will be obtained from an average of the records in seven dependencies within the bicycle distribution area, with a range ranging from 1.3 km (CIPV), to 5.3 km (CUCEI). With two input variables: cost/km and time, and four outputs: distance saved, time saved, CO_2 not issued and number of requests. Comparing each of the variables resulting when making the delivery by car (identified with the letter "A") and the facts by bicycle (identified with the letter "B") (Table 1).

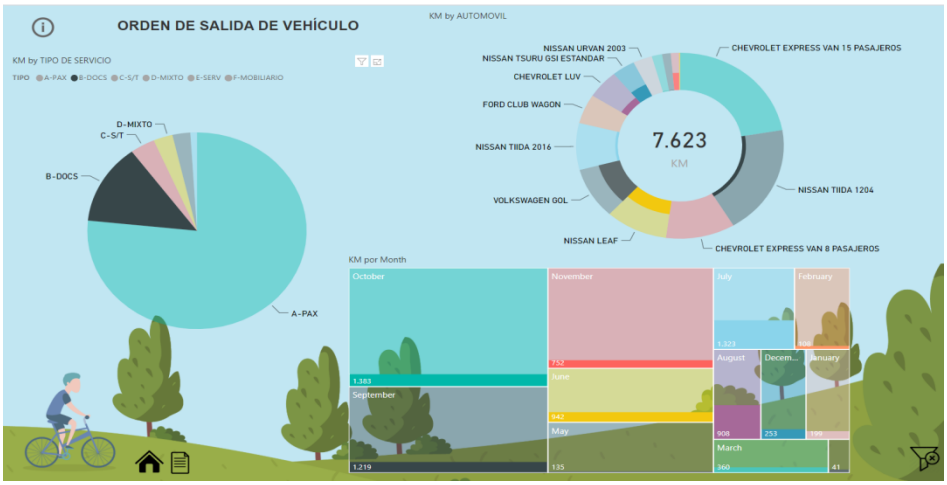

Fig. 14. Interactive dashboard that shows the kilometers traveled for the transfer of documents from the information recorded from the exit orders of the vehicles. Own elaboration available online

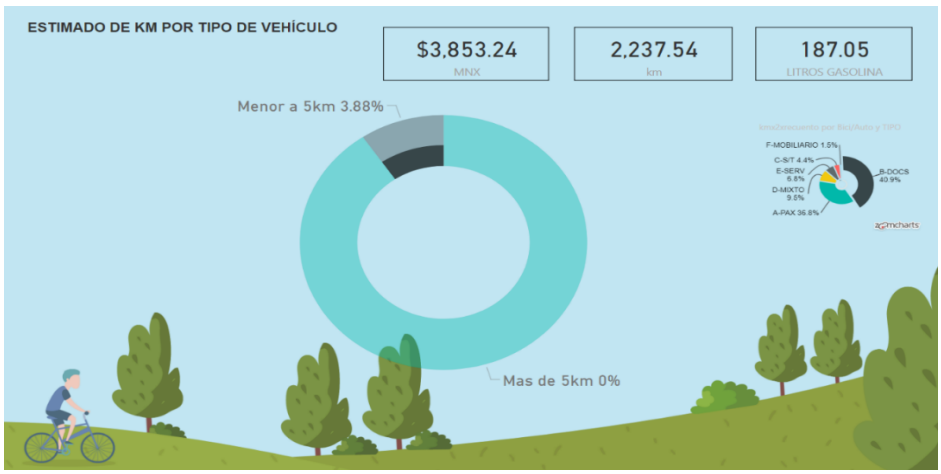

Fig. 15. Interactive board with the estimated calculation of savings with bike-messaging system, own elaboration

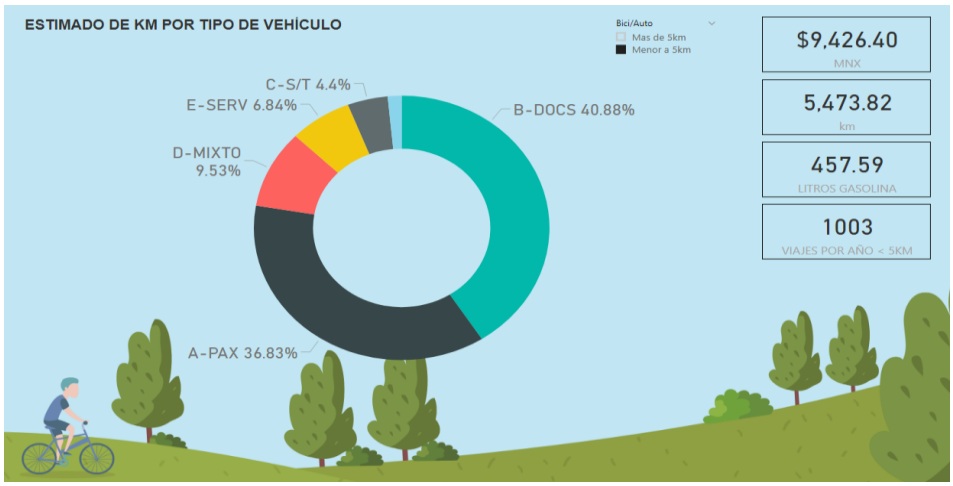

Fig. 16. Estimated km per vehicle within a radius of 5 km, own elaboration

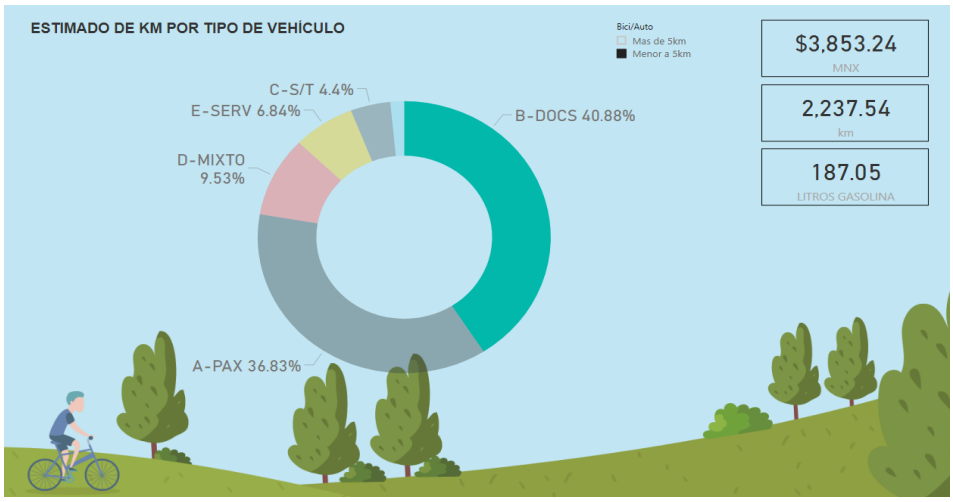

Fig. 17. Estimated km per vehicle within a radius of 5 km, selecting only the type of delivery documents, own elaboration

To determine the cost per trip (cost / trip) the calculation of the performance factor of the OTMRG in 2019 is made, taking the real annual cost of registered fuel that is $ 142,290.75 pesos between the number of total kilometers reported 57,630 km, the latter number will be subtracted from the distance traveled by the Nissan Leaf car because it is electric and does not represent a cost in gasoline bills.

$$Performnce\ factor\ = \frac{\$142{,}290.75}{(57{,}630\ km - 5{,}592\ km)} = \$2.7343/km \quad (1)$$

Finally, this performance factor is multiplied by the average distance recorded on each route.

$$\frac{cost}{trip} = \left(\frac{\$\ 2.7343}{km}\right) * \left(X\ \frac{X\ km}{trip}\right) \quad (2)$$

This same parameter is calculated for the bicycle, because there is no energy consumption with cost/liter, but an annuity of $ 404 pesos that has to be covered whether or not the system is used. The data of 2019 show that the number of working days in which the bicycle could be used is 180, we have then that the cost to use the system is 2.25 pesos/day per request for courier for bicycle delivery.

Table 1. Input and output variables per study unit for data envelope analysis

Route	Inputs		Outputs			
	Cost/trip	Time (m)	Distance Saved (km)	Time Saved (min)	CO_2 Not Emitted (g)	No- of requests
B-CEED	2.24	40.0	0,96	0,00	1592.59	14
A-CEED	19.03	31.4	0,00	8,60	0.00	14
B-CGE	2.24	30.0	0,53	0,00	1220.67	26
A-CGE	14.58	26.0	0,00	4,00	0.00	26
B-CGP	2.24	32.0	0,60	0,00	1144.38	14
A-CGP	13.67	23.0	0,00	9,00	0.00	14
B-CIPV	2.24	28.7	0,90	0,00	801.06	117
A-CIPV	9.57	21.0	0,00	7,66	0.00	117
B-Defensoría DU	2.24	42.0	0,80	0,00	1602.13	25
A-Defensoría DU	19.14	32.5	0,00	9,50	0.00	25
B-SUTUDEG	2.24	31.0	2,50	2,00	1487.69	2
A-SUTUDEG	17.77	33.0	0,00	0,00	0.00	2
B-CUCEI	2.24	95.0	1,67	32,50	3127.96	19
A-CUCEI	37.37	127.5	0,00	0,00	0.00	19

The second input variable is the average time recorded during service in each of the dependencies (in minutes). Emphasizing that it is not only the time of transfer, but that of finding parking, walking, reaching the destination, being attended, registering the document and sometimes waiting for the resolution of the procedure.

The following variables will correspond to the outputs of each DMU or decision-making unit. The first, called "Distance saved" in km, is obtained from the average of km registered in each dependency by type of vehicle $PDD_{(k)}$. The one who registers the largest number of km does not obtain any savings and for the one who registers a small number the difference between both distances is calculated.

$$PDD_{(k)} = \frac{\sum_{j=1}^{n} d_j}{n} \quad (3)$$

Where:

PDD = Average distance per destination (km)

k = type of vehicle used for the distribution of documentation

d = distance measured in kilometers

j = j-th trip

n = number of trips per vehicle type

The methodology to estimate the time saved was determined, measuring in the first instance the average number of minutes per type of trip and then calculating the difference of the averages to obtain the savings. For the amount of CO_2 not emitted, initially $PDD_{(k)}$ will be multiplied by a factor of 228,875 (g/km) that determines the average CO_2 emissions (g/km) of each vehicle taking into account make, type and model [22]. Because the bicycle does not emit CO_2, the distribution by bicycle would save the CO_2 that it would stop emitting if it were made by car.

Finally, the number of requests refers to the number of times you have requests for delivery of documents to that agency regardless of the way in which the distribution has been made. This variable aims to provide an order of importance based on the recurrence or interaction between RG and dependence. Once running the DEA Frontier Add-In for Excel with the input-oriented model with constant scaling yields (CRS) to obtain the efficiency per unit of study based on the aforementioned parameters we obtain the following table.

Table 2. Efficiency of the units analyzed from the DEA Frontier software

DMU No.	DMU Name	Efficiency
11	B-SUTUDEG	100%
7	B-CIPV	100%
13	B-CUCEI	100%
8	A-CIPV	100%
6	A-CGP	100%
9	B-Defensoría DU	97%
1	B-CEED	96%
3	B-CGE	93%
5	B-CGP	80%
10	A-Defensoría DU	75%
2	A-CEED	70%
4	A-CGE	40%
14	A-CUCEI	3%
12	A-SUTUDEG	1%

Taking into account that DEA does not offer a measure of absolute efficiency when compared with a theoretical maximum, but compares the "relative" efficiency of a unit with respect to a reference set, we have that the most efficient dependencies for bicycle deliveries are the Single Union of Administrative Workers of the University of Guadalajara (SUTUdeG), the CIPV, and the CUCEI. Instances such as the CIPV and the CGP are 100% efficient to be delivered by car. At this point we must clarify two things, the fact that the CIPV is efficient the delivery of documentation by any of the delivery methods. Remember that each unit is evaluated from the combinations of Input and Output observed, then the achievable production limit is drawing a broken line that unites all the efficient units and prolonging it parallel to the axes the border of possibilities is obtained, the units that remain below this border are qualified as inefficient units. For the CIPV, the product of the combinations of inputs and outputs of its two evaluated units B-CIPV and A-CIPV position them at the limit of the envelope, both units being 100% efficient. The second point is the fact that the bicycle delivery for CUCEI is more efficient than by car. This is because the time data in the travel logs are very high, due to multiple factors such as the time spent parking inside the university center, the waiting time to be attended, non-traceable person or waiting time in the resolution of a document and not only the delivery of it.

In the table you can see that the bicycle is still efficient between 80 to 97%, for distribution of documentation in the Ombudsman of University Rights (DEFENSORÍA DU), Center for Strategic Studies for development of the University of Guadalajara (CEED), General Coordination of Extension (CGE) and the General Coordination of Heritage (CGP). And finally we have that the last five dependencies with the most inefficient deliveries are by car (evaluated from the set of inputs, selected outputs).

4. DISCUSSION

With the data of 2019, there is a perception of what the energy transition could represent and especially the bicycle-messenger in the distribution of documentation. Something to keep in mind is that policies implemented in the "Program of Austerity, Rationality and Efficiency of Institutional Resources of the University of Guadalajara", which aims to limit the printing of invitations, generate the copies strictly necessary for the trades and send them electronically, helped to reduce the volume of work for delivery of documents.

It is also important to consider the particularity that the University of Guadalajara has as a University Network, with 189 campuses and presence in 109, of the 125 municipalities of the state of Jalisco, requires a relationship over long distances on the part of the central administration with the different university spaces. Surely the dynamics in some other central institution are very different and facilitate the implementation of the program. Due to this particularity, the results of this research can perhaps be compared with the dynamics of public bicycle lending. It was estimated that during a year 2,237.54 kilometers could be traveled by bicycle in 812 round trips if the distribution of light packages within the proposed action area is implemented, this represents an average distance of 2,756 km. On the other hand, the bicycle loan system of Mexico City "ECOBICI" its users travel on average 1.5 km per trip with a duration of 15

minutes [24], for its part the public bicycle system of the ZMG "MiBici" registers a behavior of use very close to Ecobici, with an average route of 1.46 km according to the Institute of Statistical and Geographic Information of Jalisco [16]. Although the difference between the average distances of both systems and that of the research proposal increases by approximately 1.25 km, it is completely feasible to efficiently cover travel distances of up to 7 km, as mentioned by the PROBICI research consortium in its Guide to Cycling Mobility [25]. In Barcelona Spain, the Bicing public bicycle loan system through the Methodological Guide for the implementation of bicycle systems reports an average distance traveled per trip of 3 km [26], which shows the possibility of traveling the average distance calculated in this research being effective and efficient.

As for the efficiency analysis model, it is important to consider that it is a system with a deterministic approach, that is, it will always produce the same output from the same starting conditions or initial state, which does not always happen and also does not take into account influences on the process [27]. According to Andersen & Petersen [28] another drawback of the DEA model is that it probably works better when the number of observations is about twice the sum of the inputs and outputs. In this sense, 14 decision-making units or DMU's, for its acronym in English (Data Management Unit), two for each of the seven units selected depending on the vehicle used for the distribution, two inputs and four outputs, so the requirement proposed by these authors is met. Finally, García [29] mentions that he does not consider the uncertainty that could be caused by measurement or data entry errors.

5. CONCLUSIONS

In the field of the university community within the state, the energy expenditure in hydrocarbons will be for the transfer of personnel, to distances that exceed the coverage and the type of service for the alternative transport of the bicycle. The results show that 40.88% of the kilometers were destined for the distribution of documents if only the trips are taken in a linear radius of 5 km, which is the limit defined as possible for the distribution by bicycle. In this way the institution could save 187.05 liters of gasoline, in 2,237.54 km, this represents an unexercised resource of $ 3,853.24 Mexican pesos. It is concluded that from this perspective it is possible to reach the institutional goal of 40% savings in fossil fuels.

The efficiency analysis from the variables selected with the DEA method show that bicycle delivery is much more efficient with respect to that made by car, fulfilling both premises of the hypothesis of this work when looking for "Implementing a bicycle messaging system in the transport office of the Rectory General of the University of Guadalajara will reduce energy consumption by 40% with the associated cost reduction without losing efficiency." and the institutional goals of meeting the savings parameters expected in the agreement RG/02/2019 Program of Austerity, Rationality and Efficiency of Institutional Resources of the University of Guadalajara. In whose section "U" the institutional will to strengthen the rational, responsible and sustainable use of energy resources through a savings plan is reflected, setting as objectives to reduce the expenditure on fossil fuels and lubricants by 40% optimizing their consumption [6], this will be reflected in a decrease in pollutants and is very feasible to it will replicate to more offices and campuses of the same university.

It would be necessary to look for alternatives for medium and long distances, which also adapt to the types of travel (transfer of personnel, documents, furniture) this as one of the possible lines of research, perhaps in the coming years the objective will be achieved with the replacement of motor vehicles by hybrids and electric.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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