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Procedia Manufacturing 42 (2020) 434–441

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

International Conference on Industry 4.0 and Smart Manufacturing (ISM 2019)

Internet of things and industry 4.0 applied in the delivery system for the bicipuma bike-sharing system in UNAM-Mexico.

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Abstract

This paper analyzes the delivery of units by the users of Bicipuma so that the accomplishment of this task is done quickly and efficiently for the modules with the highest demand. The aim of the proposal is to create a delivery system by aids of simulation in which the times required are minimal, improving the quality of service to users.
Also describes the development of a system for the loan service of BiciPuma bicycles implementing elements of Industry 4.0 such as automation and the internet of things (IoT) that allow reducing bicycle losses and the number of accidents caused due to carelessness when traveling along the cycle path. In addition, an App is proposed that allows the user to be informed about the existence of bicycles in the different stations and the service conditions of the stations.

Keywords: delivery; management,;simulation; IoT,;App´s

1. Introduction

The term Industry 4.0 refers to the so-called Fourth Industrial Revolution, driven by digital transformation, based on the connection between physical and digital systems, equipment interconnectivity, real-time data monitoring through the use of sensors, control and maintenance of remote machinery The four main engines of Industry 4.0 are: Internet of Things (IoT), Industrial Internet of Things (IoT), cloud-based manufacturing and intelligent manufacturing (Vaidya, 2018).

A transport system that favors cities is that of bicycle lending, this system has also been favored with Industry 4.0, for example, in Russia bicycles are equipped with a sensor system that at the time of returning the bicycle to the rental station, this system transfers the information on the technical condition of bicycles, with the data received at the station a forecast of the technical condition of the returned bicycle is made and each bicycle that enters the rental station is assigned a rating about its technical condition in a range of 0 to 100. The information on the technical condition of parked bicycles is transferred over the Internet to the company's server bicycle rental, where the need for bicycle maintenance is analyzed [1].

1.1. History of bike sharing

Early European bikesharing systems were small scale, operated as nonprofits, and focused on social and environmental issues.

10.1016/j.promfg.2020.02.052

The first generation was called White Bikes (or Free Bike Systems) in which in a free bikesharing system, the bicycle is the main program component,another distinguishing characteristics of first-generation bikesharing were that bicycles were usually painted one bright color, unlocked, and placed haphazardly throughout an area for free use[2].

Then came the second generation with coin-deposit systems due to the problems with free bike systems (namely, bike theft) that led the city government and the City Bike Foundation of Copenhagen, Denmark, to launch a bikesharing service that was different from any previous system. In January 1995 Bycyken (City Bike) was launched as the first large-scale urban bikesharing program in Europe.

As the technologie evolved so bikesharing systems with the third-generation bikesharing that count with four components:

- distinguishable bicycles (either by color, special design, or advertisement);
- docking stations;
- kiosk or user interface technology for check-in and checkout; and
- advanced technology (e.g., magnetic striped card, smartcards).

Third-generation bikesharing programs are distinct because the incorporation of information technology has allowed bikesharing programs to track bicycles and user information. The incorporation of third-generation information technology has helped to deter bike theft, which was a major concern of second-generation coin-deposit systems.

At present, there are approximately 101 bikesharing programs operating in an estimated 125 cities around the world, with more than 139,000 shared bicycles. As the leader in bikesharing activity today, Europe currently has 19 nations that support bikesharing [3].

The Americas operate programs in Canada, Mexico, the United States, Brazil, and Chile. Asia, which represents the fastest growing bikesharing market, operates programs in China, South Korea, and Taiwan [4].

1.2. Bikesharing in Mexico

In Mexico City the growth of the demographic density has become exponential and so the need for transportation, because of that the city management needed to look for a sustainable way to help with this mobility issues, as 50% of trips is less than 8 kilometers away, the implementation of a Bikesharing program was viable.

Therefore, the Ecobici program was created as a public bicycle system within the Integral Transportation and Roads Program (2007-2012), which was inaugurated in 2010 with 85 stations served in 6 suburbs of the Cuauhtémoc town hall, that is in the downtown area of the city. In the next years, the program expanded to the historic center of Mexico City and the Polanco neighborhood [5].

Mexico City launched its Ecobici program with some 1,000 bikes in 2010, it quickly reached its limit of 30,000 annual members and started a waiting list of eager would-be cyclists. The program has quadrupled in size and remains the largest of Latin America's dozen or so programs.

1.3. Bikesharing in UNAM

Currently, the use of alternative forms of transport is booming, especially in school campuses with large volumes of people and routes, so the central campus of the Autonomous University of Mexico created the Bicycle Loan System for those belonging to the university community called: Bicipuma.

The objective of the Program is to provide the user, free of charge, the means to transfer to different educational centers and university dependencies, starting from the main accesses to the campus, to carry out their school, administrative or teaching activities, and in the free time as recreational activity. The bicycle not only allows an easy and fast displacement, but also, that the community knows different spaces of the university life is through the 5,980 meters that have of cycle path, fomenting in this way their sense of belonging, coexistence and emotional well-being [6].

Bicipuma has 14 stations or modules, 5980 meters of cycle path, 1440 unities that serve 4500 users daily [7].

The system in use for the loan of the bikes works in the following way: the system records the loan of bicycles, making it by the reading of the bar codes in the students or workers credential and one set on the bicycle; creating through this scan a database with the records of the account number to whom the loan is made, the date, time and exit module; the delivery of the bicycle is corroborated with the scanning of the in the delivery module, thus attaching to the database the delivery time and the module of delivery.

Damaged bicycles are collected every fifteen days for review and maintenance; the damage or wear of the mechanical parts is due to the constant use of the units.

The time spent by the users regarding the delivery of the units causes a delay in the service impacting its quality and operational costs associated to the maintenance of the units.

When observing this problem, the development of a proposal that uses the existing infrastructure for the improvement of the delivery service arise.

By implementing the proposals, the delivery and service times will be improved.

This optimization will not only impact at the operating level of the system but will improve the quality of service and reduce costs associated with the maintenance of the units and modules.

This article was developed in the following way: section one presents an introduction for bikesharing systems and its importance, in section two a literature review is shown. In section three the methodology used such as the data analysis, the problem approach, and the proposed solution are given. Section four shows the results obtained by the followed methodology and in the fifth section conclusions are presented.

2. Literature review

The bike sharing problem has been deeper studied in the last five years, mostly with optimization methods. In this section some papers are presented.

The Bike-sharing systems contribute towards obtaining a more sustainable mobility and decreasing traffic and pollution caused by motorized transportation. They considered the problem faced by a bike-sharing service provider who needs to manage a fleet of bikes over a set of bike stations with given capacities, to serve the stochastic rental demand over space and time. According with this problem authors proposed a stochastic optimization model for the rebalancing issue that considers the randomness of user choices and demand over a determined space(infrastructure) and time (service hours) with the two reposition systems that exist: static repositions, and dynamic reposition[8]. A case study is shown in Bergamo (Italy).

The most important factor for the success of a public bike sharing system is its ability to satisfy the varying demands of the users and so the patterns of demand that must be identified and estimated and the system must be planned and managed to maximize the level of customer satisfaction. The authors observed two key factors for this; the availability of bikes at the station and the availability of slots when the users arrive to leave the bicycle. The users must be confident that they will find bicycles to start their trips and available lockers to leave them when the trips are finished wherever and whenever they need them and proposed that for achieving such there are three phases to be considered [9]:

- Strategic level; the number of stations and their location and size must be decided.
- Tactical level; the number of bicycles in the system must be determined.
- Operational level; a bike repositioning system must be adopted for moving bicycles from stations with an excess to stations with a shortage to satisfy the demands forecast for the next periods.

The problem to be dealt with in this article is based on the second factor, the availability of slots when the users arrive to leave the bicycle and in this particular case the service time associated with it which impacts directly in the system users perceived quality and since the system is meant to provide service to a specific type of users (students and faculty members) that times must be minimized in order to aid them.

Authors also identified based on the evolutionary trends of bike sharing research into four stages. The first stage from 2010 to 2012, focused on “safety and policy” issues. From 2013 to 2014, the second stage began to investigate the “benefit, system and impact” of bike sharing programs. Furthermore, the topics were subdivided into “optimization, behavior, built environment, design, and infrastructure”, which are main research themes in the third stage of 2015. The research topics that emerged in the fourth stage (2016-2018) are “demand, rebalancing, redistribution, choice, weather, usage, public transport and attitude”. In terms of knowledge domains, core studies on bike sharing that published from 2010 to 2018 are summarized and classified into five categories in view of different generations of programs. As for the third and fourth generations of programs, the main knowledge domains are divided into: 1) factor & barrier; 2) system optimization; 3) behaviour & impact; 4) safety & health. About the fifth generations of programs, the main knowledge domains are divided into: 1) factor & barrier; 2) system optimization; 3) sharing economy.

After these papers review, and mostly the last one, it can be noticed that simulation is not been used, not only for the case of the bikes delivery, but not even for the complete system. That is why is important the use of hybrid methods that consider simulation and optimization.

In the case of our research, after making a bibliographic review of simulation methodologies and a subsequent analysis, it has been possible to develop a simulation model applied in Bicipuma delivery system. The use of discrete simulation was determined due to the fact we can define the state of the Bicipumas delivery system as the number of units in the system at a time in which the system is in state n in the instant t if at that time there are n units in the system, counting those waiting in line to receive service and those who are receiving service at that time.

The impact of Industry 4.0 has also reached the cities, starting with an intelligent transport system, for example, in an intelligent capable of detecting the movement of the vehicle, parking sensors, or data collection and distribution of its surroundings, using technologies such as RFID and App´s.

Xin and Huapu (2012) expose the application of RFID technology in the management of logistics, security and traffic, focusing on the latter. They mention as advantages its long-distance identification, large storage capacity, high reading speed and wide range of applications [10].

Swedberg (2016) describes the use of passive high frequency RFID tags on 1000 new bicycles and 120 stations of the bicycle sharing system in Montreal, Canada. He stresses that the use of RFID accomplishes two things: providing bicycle program operators with a means to provide bicycle access to users and collecting historical data for maintenance purposes. For example, because bicycles are often returned more frequently to some locations than to others, they must be moved periodically on trucks to ensure they are distributed at the proper time and place. Without RFID, this would require maintenance personnel to drive around and visually verify each station. By using RFID, the data base allows the system’s management to view which bikes are docked at each location, so vehicles can be sent to move them as needed (for example, if one station is almost full and another is empty) [11].

The German company Nextbike (2018) started in 2005 as a provider of bicycle rental systems in Leipzig, Germany. They use near-field RFID (NFC) tags to identify their stations and bicycles, allow authorized users to lend a bicycle, and verify if bicycles were returned on time. The rental systems employ payment terminals and an application for smartphones. In 2016, Nextbike owned a total of 30,000 bicycles to rent on four continents, in 18 countries and in more than 100 cities [12].

The largest Mexican bike sharing system, ECOBICI, uses electromechanical locks based on RFID to prevent unregistered users from lending bicycles [13]. User and bicycle information is sent to a central monitor through a GPRS (General Service of Packages via Radio) [14]. In Mexico City, RFID technology is also used in other public transport systems: it has been used since 2006 for the Metrobus and the Metro systems. Each user has his RFID card and read/write devices are placed at the entrances of each of the respective stations.

The RFID tag system can be used for minimizing bicycles theft. The authors found two major projects where universities use RFID to increase the integrity of individual bike ownership:

- At the University of Portsmouth, United Kingdom, a WASP program (Wireless Asset Security Protection) embeds a yellow-and-black RFID tag on the bicycles registered in the program. Students, when parking their bike in safe zones, can use mobile phones to call in their location to a server. Upon their return, they call to check out their bicycle. If the bike is moved without calling and entering a PIN code to check out, the closed-circuit cameras may zoom in on the area where the bicycle was parked [15].

- Ohio State University installed five years ago the Bug Your Bike program, through which 250 RFID 'bugs' were implanted for free on bicycles that students register in a special database. Now, the system is being updated and expanded as part of the university's transportation program. Although the university is using the system as more of a stolen bike recovery program, they hope that as more and more bicycles are registered, it also discourages bicycle thieves. Currently, the Ohio State University, the City of Columbus, and the Central Ohio Transit Authority (COTA) have teamed up to expand the campus Bug Your Bike bicycle registration program city-wide [16].

The same technology is also used in bike sharing systems all over the world as an antitheft system, there are even companies that insert chips into personal bicycles so that the user can have control of it, for instance in the Copenhagen, where the City has sponsored a pilot project implanting some of its bike-sharing bikes with RFID chips to keep track of the bikes if they are lost or stolen [15].

Several bicycle-sharing programs combine registration technology with an iOS or Android-based system Apps to share information with their users. The use of this type of Apps becomes more useful as the size of the system grows.

The Velo program in Antwerp, Belgium, includes an App that allows the user to look up in real-time in which stations there are locks or bikes available, to search for a station on a specific location, to report a defect bike, to report registration problems and to consult the usage history [17].

The Vélib' Métropole program is available in the Grand Paris metropolitan area [18]; it uses an App that lets users find available bicycles or nearby docking station. The App can also be used to choose cycle-friendly routes, see the number of kilometres travelled, buy a pass (1 day or 7 days), change the user's subscription, etc. However, as the extension of the Vélib' system is very large, both iOS and Android users complain about the problems with loading the maps (https://play.google.com and https://itunes.apple.com).

The Netbike program in Germany uses an App that gives users real time information on which stations have available bikes, can let them manage their account, exchange vouchers, as well as give their opinion or communicate directly with the customer service team. To rent a bicycle, the user enters the bicycle number or scans the QR code. To deliver it he can select the station physically or find a nearby free locker via GPS [12].

3. Methodology

The methodology used for this work is the following:

3.1. Data analysis

The data analyzed consists of the Bicipuma loan records registered during 2016 and 2017.

With the database provided by Bicipuma, the total number of loans registered during the period from 2016 to 2017, the day and month of greatest demand, the highest and lowest demand module.

3.2. Problem detection

The detection of problems was carried out first through observation and direct use of the system (field work), to subsequently conduct a series of interviews with the various actors of the system including the Director of Bicipuma module managers and modules operators.

Because of the interviews we obtained that the users find the service of Bicipuma practical even though they indicate that in some cases there´s a considerable delay in the service due to the inefficiency of the delivery system.

While the Director indicates that the system should have a better system in which the times and associated costs are minimized but without making a big investment.

Furthermore, the demand for the use of BiciPuma has increased considerably, in a comparison of February 2017 and the same month of 2018, increased by 30 thousand services.

This growth has made it necessary to improve loan systems to streamline and meet daily demand. Here are three of the problems encountered where the industry 4.0 approach supports its solution:

- Bicycle loan service automation
- Prevention of accidents on the bike path (crosswalk and bicycle system users)
- Attention to the demand for bicycles and communication with users

3.3. Determination of the study module

The study module was determined using the data analysis described in this section 3.1 even though the module is not the number one in destination demand it was selected due to its location.

The location of this module is highly important because of its proximity to one of the main entrances to the campus at the same time is located near Copilco metro station which is one of the most used means of transportation to reach the campus.

The module Medicine was selected to perform a field work in which data of variables of interest such as time of arrival and departure of the users, time in queue and time of service to be used in the simulation were collected.

3.4. Discrete simulation

With the data obtained in the field work two simulations were made: a manual simulation with queue theory using excel and a simulation discrete simulation with SIMIO software, this is to make a comparison and validate the model.

For the discrete simulation it is necessary to identify the type of distribution presented by the data collected for each variable.

3.5. Layout redistribution

With the results provided be the simulation and the second scenario a layout redistribution proposal was created so that the service can be optimized, and the automatization implemented.

3.6. Semi automatization

The new Layout proposal must be complemented with a system semi automation This system is necessary because the module operator would have to attend to different access and exit points of the module, complicating its work in an extreme way, the semi-automation proposal allows the operator to be released during the moments of loading, unloading and attention to users.

3.7. Accident preventing system

Also, several points of accidents in the highway were observed which led into another proposal, the design and construction up to the level of the presentation of a prototype for minimizing the occurrence of accidents.

3.8. Optimization of bicycles demand and communication system with the users

As the automatization proposal was developed a demand optimization, and communication with the users proposal arose, in which an application was developed.

4. Results

The results on de methodology described in sections 3.1 to section 3.5 are presented in the article "SIMULATION OF THE DELIVERY SYSTEM FOR THE BICIPUMA BIKE-SHARING SYSTEM IN UNAM-MEXICO" [19] in which the need for system optimization is observed,making so that to improve the quality of service,the new Layout proposal must be complemented with a semi-automation system. This system is necessary because the module operator would have to attend to different access and exit points of the module, complicating its work in an extreme way, the semi-automation proposal allows the operator to be released during the moments of loading, unloading and attention to users.

4.1. Semi automatization

The semi-automation proposal works in the following way:

- The user identifies himself with his valid credential before the operator, who registers it in the system and gives him access to the module towards the fast service section.
- The user goes to the fast service area, takes the next bike, presents it to the RFID reader and exits the module. These actions assign the bicycle to the user and register it in the system automatically. The exit will be made through a "turnstile" adapted to facilitate the exit of the bicycle (fig. 1).

Fig. 1. Semi automatisation (assignation- exit)

The proposed system (fig. 2) to carry out the actions described above is based on a set of components which are mentioned below:

- PLC
- Relays
- Pilot light
- Microcontroller (IoT).
- RFID system

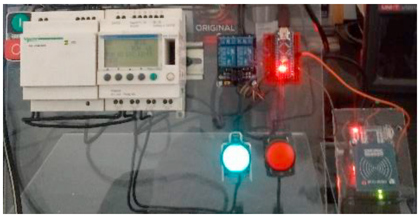

Fig. 2. Proposed prototype

This system is intended to assist the operator in the loan of bicycles. Allowing the user to access the service without having to go through the same point twice, which speeds up the loan service.

Another benefit offered by this system is that, if any user enters the module, but did not register previously and intends to extract a bicycle from the module, the system will not allow it, with this action it is intended to mitigate any attempted robbery.

Other benefits of the implementation of the semi-automation system are:

- Agility in the loan process
- Reduction of rows to apply for the loan
- Reduction of bicycle thefts
- Support to station operators
- Minimum staff required
- Better attention by station operators (for example, decomposition review or bicycle arrangement in specified areas)
- Agility at the time of collection or re-supply of units (bicycles) to the stations
- Support in the registration of units through IoT technologies

4.2. Accident preventing system

Currently, the BiciPuma system has almost 7 km of bike path, in which there are certain crossings or intersections that prove to be dangerous for users and pedestrians, lack of road culture, distractions, speeding, among other factors; promote the occurrence of accidents on the cycle path.

The points with the most recorded accidents (according to users, operators of the modules, statistics and their sighting) can be seen in Fig. 3:

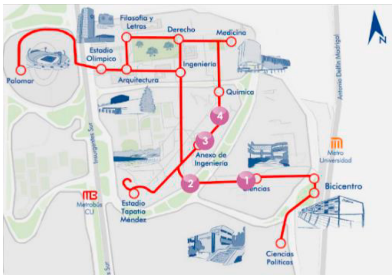

Figure .3. Areas with the highest incidence of accidents

This is because there are irregular sections of the cycle path such as: crossings or intersections with crosswalks or roads, sharp bends, steep descents, unconfined lanes, etc. This is illustrated in the photographic evidence shown in Fig. 4.

Figure 4. Bicycle tire brands due to excessive speed in sharp turns and lack of confined lane

An analysis of risks carried out in this year by UNAM students, [20] showed that these events occur mainly due to causes such as: carelessness on the part of pedestrians, crossing the road irresponsibly or invading confined lanes, lack of skill in handling the bicycle, speeding, among others. The classification of elements with the highest risk is illustrated in Figure 5.

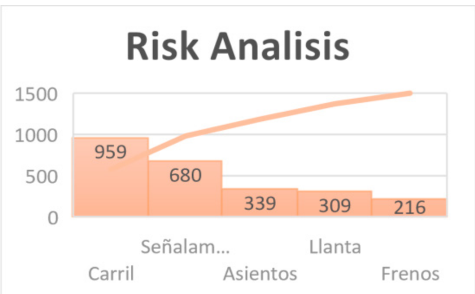

Fig. 5 Bicipuma program risk classification

One of the solutions proposed to reduce the level of risk and accidents of the cycle path was the design of a device that allows measuring and recording the speed at which bicycles approach at crosswalks (fig. 6).

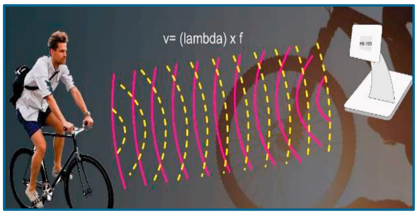

Fig. 6 Function and purpose of the proposed device

The objective of this device, in addition to detecting the speed at which user are coming up with the bicycle, it is to issue a light and audible alert that allows the pedestrian to identify if it is safe to cross the cycle path and inform the Cyclist traveling at speeding.

The following describes in greater detail what the proposed speed detection consists of an indicator light will allow you to meet pedestrians if it is safe to cross the cycle path to reach their destination. If the speed at which the bicycle travels is within the established limit (15Km / h) or the presence of a bicycle is not detected, the indicator light will be green indicating that it is safe for the pedestrian to cross (fig. 7a).

Furthermore, if the speed at which the bicycle is approaching is higher than the allowed speed limit, an audible alarm will be emitted and the indicator light will change color to red allowing the bicycle driver and the pedestrian to take the measurements precautions, that is, the pedestrian must not cross the track and the cyclist must slow down. The same to avoid head-on crashes between bicycle users in sharp turns and blind spots of the bike path (fig. 7b).

Figure 7. (a) Safe passage indicator, (b) Stop indicator

This device will be installed at the points with the highest number of accidents shown in Figure 4.

Finally, the information collected will be sent to a database linked to the IoT device (fig. 8), where the information will be stored for further processing.

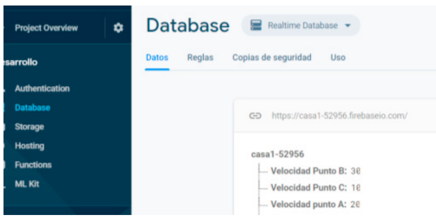

Fig. 8. Database of speed detection system

Expected benefits with the implementation of the system:

- Prevention and reduction of accidents.
- Record of the speeds at which users travel on the cycle path (at the marked points).

- With the registration of the information, the pertinent analyses will be carried out that will lead to an action that improves the safety of the cycle path.

4.3. Optimization of bicycles demand and communication system with the users

Currently, the BiciPuma system has a registration system that allows you to know which bike was lent to a certain user. However, this system, although powerful, does not meet the requirements that communication users have such as: information on the number of units per station, shortage of units, closing and opening of stations, suspension or resumption of services (rain, simulation, etc).

The proposed solution consists of an application for mobile devices named "BiciPumapp" whose objective is to support the planning of bicycle demand between the different stations and open a communication channel between modules and users

BiciPumapp groups the following functions: regulation of use of the service, emergency contact numbers of the Bicipuma administration, access to Bicipuma social networks, communication between stations, trip timer and map of the stations.

The following describes some of the functions considered important for users:

- Make known in real time the number of existing bicycles per module. The user can check the number of bicycles in each of the modules. This option allows the user to decide which module to go to (fig. 9).

Fig. 9. Available units in the station

Send notifications about the status of each of the stations (fig. 10): closed stations, lack of bicycles at the station, suspension and resumption of services and request for support to its user community.

Fig. 10. Notifications system

The notification sending function allows the user to interact with the Bicipuma system, since not only can they receive important information about the stations, but they can also support if required.

- Creation of new programs to encourage the participation of the community of users of the system. Programs based on the use of "new technologies" that encourage the participation of the user community are proposed. An example of the is the "move your bike" program, which aims to help the user community to support the distribution of bicycle demand by informing whether bicycles are required to travel between stations.

This program aims to encourage the participation of users and improve the distribution of bicycles without using the delivery truck.

The "move your bike" program contemplates rewarding the users that most support the performance of services, these consist of moving a bicycle from one station to another that requires it.

Expected benefits with the implementation of the system:

- Participation of the users.
- Reduction of the units' damage when transported by the van.
- Better distribution of bicycles to meet demand.
- Lower fuel consumption

Due to the fact that the implementation of the system linked to the application is complex because it needs the Bicipuma administration to make an investment the benefits had to be measured by the means of a simulation which was carried out by performing an analysis of the last school semester of the year 2018 that includes the months July – August (https://www.dgae-siae.unam.mx/actividades/calendarios/2017-2018-semestral.jpg, https://www.dgae-siae.unam.mx/actividades/calendarios/2018-2019-anual.pdf), and crossing this information with the statistics provided by the bicipuma page (dgsgm.unam.mx/bicipuma) on the BiciCentro PA station, it was obtained as a result that the daily number of bicycles borrowed is 829 units. The same procedure on the Science station resulted in the daily number of bicycles borrowed being 430 units. The BiciCentro PA and Sciences stations were selected due to the proximity feature they present, these stations are connected by the bike path and there are no deviations or bifurcations between them as illustrated in fig. 11; so both are ideal to promote the participation of users (take and bring bicycles between both stations) and thus reduce or dispense with the use of even the truck that distributes the bicycles.

Fig. 11. Bicipuma stations

Science station has a proximity of only a few meters with the Faculty of Sciences and its population is around 8616 students according to the 2011 - 2017 report http://www.fciencias.unam.mx/nosotros/ address / reports / Global_Report_2011-2017.pdf). On the other hand, a large the number of people of the university community that arrives and withdraws from Ciudad Universitaria through the Universidad station, which is very close to BiciCentro PA.

To take advantage of the aforementioned features, the "BiciPumapp" application notifies users about the needs between both stations, allowing users to take charge of transporting bicycles in minutes (37.2 min) as shown by the simulation results presented in fig.12.

The simulation takes the following considerations: a station of the BiciPuma system can contain up to 72 units, a conservative projection of 10% of the daily loans between both stations is proposed (based on the daily bicycle loans of both stations), time average arrival of users to the station 12.5s (measured), peak demand times 12: 30-14: 30 (statistics).

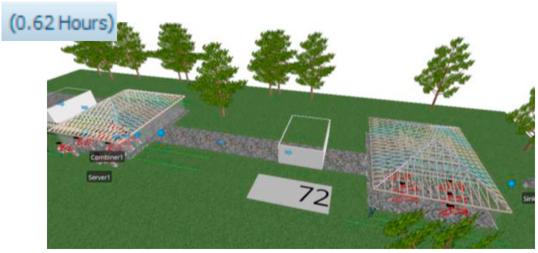

Fig. 12. Bicipuma ssimulation of replenishment with App aid.

From the above, it is experimentally proven that the use of new technologies, in this case BiciPumapp would significantly reduce the use of the delivery truck

5. Conclusions

Bicipuma bikesharing system is functional to its users, even though it is not in optimal service conditions due to the long waiting queues for service that occur during peak hours and in high demand modules which generates high associated costs and impacts directly in the quality of the given service.

By carrying out the simulation, the system problems became more evident as well as the necessity of implementing a more efficient system for the delivery of the bicycles, so the proposal of adding a second server was considered but due to the lack of resources and the cost associated with this proposal, a lower cost alternative is sought which considers the use of the existing infrastructure.

The implementation of the elements that make up the so-called Industry 4.0 allow to improve the efficiency and effectiveness of a system through communication and real-time monitoring of the data, being the user benefited from having real-time information on the existence of bicycles and service conditions of the stations. To achieve an interconnection with the entire system, it is necessary to use high-processing computing tools, small and low-cost sensors to attach them to bicycles and have databases that allow large amounts of data to be stored.

Acknoledgments

To the PAPIIT DGAPA project IT102117, UNAM for its support to this research.

References

[1] Galyom, V. Y., & Shchenikov, Y. A. (2019, May). Digital transformation of bicycle rental maintenance process. In IOP Conference Series: Materials Science and Engineering (Vol. 537, No. 3, p. 032025). IOP Publishing.

[2] Bea Alonso, M., & Pasqual i Robert, J. (2009). Los sistemas de bicicletas públicas urbanas.

[3] Shahen Susan et al. (2010) Bike sharing in Europe, the Americas, and Asia: Past, Present, and Future.

[4] Larsen Janet. Bike-Sharing Programs Hit the Streets in Over 500 Cities Worldwide (2013), Earth Policy Institute.

[5] Perez López Ruth (2016). Vínculos entre la bicicleta utilitaria, recreativa y deportiva: análisis del impacto de los programas "Ecobici" y "Muévete en Bici" en la Ciudad de México (2006-2012).

[6] L. Gomez, "Campaña: Bicipuma El Mejor Transporte en Ciudad Universitaria", El Filogisto, 2009, pp. 1-5.

[7] UNAM (2018). BICIPUMA. Dirección General de Servicios Generales y Movilidad. Retrieved from: http://dgsgm.unam.mx/bicipuma.html, 22-05-2018.

[8] Maggioni, F. (2019). Stochastic optimization models for a bike-sharing problem with. European Journal of Operational Research, 272-283.

[9] Alvarez-Valdes, Ramon & Belenguer, José Manuel & Benavent, Enrique & Bermúdez, José & Muñoz, Facundo & Vercher, Enriqueta & Verdejo, Francisco. (2015). Optimizing the level of service quality of a bike-sharing system. Omega. 10.1016/j.omega.2015.09.007.

[10]Xin , L. (2012). Study on the Use of RFID Technology in Bicycle Management. Advances in technology Springer, 367-372Vogel, P.(2011).Understanding Bike-Sharing Systems using Data Mining:Exploring Activity Patterns. Procedia Social and Behavioral Sciences,Science Direct, 514–523.

[11]Swedberg, C. (2016). Toronto expands RFID -Enable bikesharing-programm. RFID Journal., 20-30.

[12]Netbike (2018). Netbike: Original Bikesharing. Retrieved from: http://www.nextbike.net

[13] Meddin, R.(2010). North America's Newest and Largest Year-round Service Opens in México City. Retrieved from: http://bike-sharing.blogspot.mx/2010/02/north-americas-newest-and-largest.html

[14] CDMX (2018). Ecobici. Retrieved 03 08, 2018, from www.ecobici.cdmx.gob.mx

[15]Janet., L. (2013, 04 25). Bike-Sharing Programs Hit the Streets in Over 500 Cities Worldwide . Earth Policy Institute, 26-32. Retrieved from Bike-Sharing Programs Hit the Streets in Over 500 Cities Worldwide (2013), : http://www.earth-policy.org/plan_b_updates/2013/update112

[16]OSU (2018).Department of Public Safety.Retrieved from https://dps.osu.edu/bug-your-bike) [16 Velib (2018).Velib Metroplole. Retrieved from: https://www.velib-metropole.fr/en_GB

[17] Velib (2018).Velib Metroplole. Retrieved from: https://www.velib-metropole.fr/en_GB

[18]Velo (2018).Velo Antwerpen. Obtenido de https://www.velo-antwerpen.be/en/app

[19]García C.(2019). Simulation of the delivery system for the Bicipuma bike-sharing system in UNAM - Mexico. EMSS, Lisboa , Portugal.

[20]Perez, A.(2019). Implementation of an accident preventing system in the infraestructure of the Bicipuma bike-sharing system in UNAM-Mexico.SRA-LA, UNAM,México.