Solving an Interscholastic Bus Routing Problem

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Abstract

The paper discusses a practical School Bus Routing Problem (SBRP) considering interscholastic transport in university contexts. This study focuses on the incorporation of a mixed load composed of multiple schools, to emphasize the need to provide collaborative transportation SBRP solutions in university contexts. A Systematic Literature Review was developed with the purpose of exploring the mathematical optimization models that have been elaborated in the last decade, showing the research opportunities on mixed load situations. Henceforth, the paper presents a real case scenario in a Mexican city to highlight the need for a mathematical model that optimizes the transportation offer of two universities on a common urban zone, that can be replicable in similar conditions. This study exhibits the development of two of the SBRP subproblems: Bus Stop Selection (BSS) and Bus Route Generation (BRG), through the Operations Research Methodology, to construct a solution that maximizes coverage by sharing resources within schools. A sensitivity analysis that focuses on the demand, capacity and time windows variations is conducted to prove the robustness of the approach and to propose an optimal solution for the schools of the specific case.

Keywords
School Bus Routing Problem, multiple school, mixed load, university routing, optimization models.

1. Introduction
The transport sector is facing a complex challenge to carbon dioxide emissions from mobility, and, at the same time, many cities still have low accessibility to public transport services (Wimbadi et al. 2021). Consequently, researchers have pointed out that population growth and the agglomeration of economic activity will continue to gradually increase the demand for mobility and CO_2 emissions in cities. Therefore, urban transport would be needed to turn its socio-technical system around by implementing energy-efficient modes of transport and increasing the modal share of public transport.

Serrano (2021) points out that motor transport is the sector that consumes the most energy in Mexico, being the main source of CO, CO_2, and NOX particles, which causes respiratory and cardiovascular problems, chronic diseases, and early mortality. Similarly, INEGI (2022) establishes that the number of automobiles in the Mexican State of Nuevo Leon has increased substantially, so the entity currently has 1,800,000 cars, generating a 45% increase in polluting emissions. This has led to the positioning of Monterrey as the city with the second largest carbon footprint in the country, 16.6 MT CO2, according to Salazar (2022).

Wimbadi, Djalante & Mori (2021) state that urban experimentation for sustainability transitions has been evolving over the last decade, especially being influenced by universities to obtain feedback from users, learn how new technologies work, and exercise different possible ways of using technology to address sustainability issues. Specifically, Ellegood, Solomon, North & Campbell (2020) talk about the School Bus Routing Problem (SBRP), which can be described as a real-world transportation problem as well as an operations research challenge. Research has been carried out in this field in recent years. It has focused on more complex real-world problem settings, considering subtopics such as passenger numbers or travel time uncertainty to highlight promising gaps and opportunities for the SBRP, whose primary goal is to develop and deliver a reliable transportation system. of school buses that can be, simultaneously, reliable, profitable, and safe for the daily transport of students. (Ellegood et al. 2020).

Nuevo León currently stands out among the three states with the highest number of university students in Mexico, according to Uriarte (2014). For this reason, the entity appears as a potential area to deepen the investigation of the SBRP, given that, as has been established, university transportation seeks to prioritize modes of transportation that cause less damage to the environment. (Estrada *et al.* 2022).

Based on a systematic review of the literature, this paper seeks to show the importance of modeling interscholastic transport proposals and validating them with a specific case between two universities in the metropolitan area to improve the service offered with the available resources. Similarly, involve an analysis of demand, capacity, and time windows under different conditions to propose a feasible and sustainable solution for the optimization of the coverage indicator.

1.1 Interscholastic Transport

This project is inspired by previous works with collaboration of the Government and the Universities of Nuevo Léon. The collaborative works had the purpose of studying the area of university transport and generate proposals in the line of sustainability. Interscholastic transport refers to pick up students from different schools and deliver them to their respective schools while sharing resources between schools. This could enhance the efficiency and safety of school-bus operation. (Yao el at. 2016).

In accordance with the above, the University of Monterrey (UDEM) and Tecnologico de Monterrey (Tec) are universities located in Nuevo León that have developed their own Mobility Plans, with common transport objectives and strategies, such as: (a) decrease trips by individual cars, (b) promote a sustainable culture, (c) develop infrastructure and services that promote different means of transport, (d) contribute to the improvement of air quality in the Metropolitan Area of Monterrey, (e) optimization of routes to provide a greater coverage, and (f) encourage mobility proposals. For this reason, and because they share similar locations within the Metropolitan Area of Monterrey, it can be said that there is an opportunity to work on interuniversity transport proposals that benefit both communities to migrate university transport towards a sustainable mobility. Hence this work will use the universities as a case study for the experimentation of interscholastic routing.

1.2 Problem Description and Objectives

The problem consists of finding solutions for interscholastic transportation and validating them with a specific case study to demonstrate the convenience of their implementation in a real university context. The general objective of the project refers to modeling interuniversity transport proposals and validating them with the specific case UDEM-Tec to improve the service offer with the available resources by optimizing the coverage indicator.

To build the proposals, this work considers the design of a mathematical model that optimizes the transportation offer of two university districts, the design of a flexible tool for the identification and supply of the information necessary to run the mathematical optimization model so it can be used in other cases and develop a final proposal for sustainable mobility in university transport services between both institutions.

Additionally, a central hypothesis that sought to prove that the coverage indicator is increased through the sharing of resources (buses) between universities and basic research questions are posed for the development of the project, considering how sensitive the solution to variations in demand is, as well as resource capacity (buses), and what is the effect of time windows on the coverage indicator. These questions are helpful for the estimation of results that the project wants to achieve.

2. Methodology

The methodology developed to solve the problem of this work consists of following the Scientific Method as the main methodology, combining the Systematic Review of Literature and the Operations Research Methodology. These are used to identify the current situation in terms of interuniversity transportation solutions comparing methodological proposals that involve the formulation of optimization models of multiple schools, and the follow-up of the general guidelines for the implementation of Operations Research in the formulation and solution of the school routing model, respectively.

The Scientific Method is a systematic process of research that is based on interdependent parts. (Castán 2014). The stages that make up the Scientific Method in essence include: (1) Problem definition; (2) Hypotheses; (3) Data collection and analysis; (4) Experimentation; (5) Results; and (6) Conclusion and documentation.
The methodology begins with an observation phase, where initial contact is made with the research area. In this case, a systematic literature review (SLR). Subsequently, there is a hypothesis approach phase, which is based on prior knowledge, SLR findings, and data collection. The experimentation phase is then elaborated and concluded with the verification phase, both depend on the generality and systematicity of the hypothesis. (Castán 2014).

3. Systematic Literature Review

A SLR was elaborated with the objective of presenting a clear systematic review process that analyzes a specific category of the School Bus Routing Problem (SBRP) focused on interuniversity routing through the consideration of mixed load allowance mathematical models. Furthermore, to confirm the relevance of the topic in the field of study of research and application, as to identify areas of opportunity for future research.

The SBRP is a real-world problem that impacts the system of school transportation. It regards several factors such as service, costs and safety in the design and operation of transportation services for students from and to schools (Díaz-Ramírez et al. 2022; Ellegood et al. 2020). The involvement of the SBRP in transportation research has increased over the last decade developing new approaches to solve this problem. The different SBRP in literature are classified in four "sub-problems" that can be addressed either independently, sequentially, or simultaneously. Normally, a SBRP begins with the bus stop selection (BSS), this sub-problem can be solved in two different strategies known as Location – Allocation - Routing (LAR) or vice versa, the Allocation-Routing-Location (ARL) (Park & Kim 2010). After the stops have been selected, the order in which the stops are visited is named bus route generation (BRG). As the routes are assigned, they can be sequenced by bus route scheduling (BRS). Finally, an option exists where the school bell ring times adjustment (SBA) becomes a decision variable to find a more efficient solution.

The SLR approach followed was proposed by Keathley-Herring et al. (2016), which begins with the development of the search strategy, then the application of exclusion criteria, finally, the analysis of publications and the synthesis of evaluation criteria. The main findings of the review will be summarized for this work.

The search process in the selected databases (Scopus, Web of Science, Proquest, and IEEE Xplore) yielded a total of 336 articles. After specific filters and backward inclusions, a total of 49 articles were studied. The proportions are Scopus 76%, Web of Science 59%, Proquest 16%, IEEE Xplore 12%. Regarding the sub-problems considered on the corpus, it was found that the most frequently solved problem was BRG with a 35%. Studies focusing on the combination of BSS and BRG were 22%. It is worth mentioning that only 2% considered three sub-problems at the same time and only two studies the four sub-problems.

The characteristics of the SBRP considered in literature can be divided into categories, shown in Table 1, according to (Park & Kim 2010), and complemented by (Ellegood et al. 2020). Additionally, a category that involves the dynamic aspects of the problem together with the availability of real-time communications with the passenger has been added.

Table 1. Classification categories of SBRP based on problem characteristics

Categories				
Number of schools	**Service environment**	**Response Timing (New)**	**Load type (Mixed load)**	**Fleet mix**
Single Multiple	Urban Rural Both	Static Dynamic	Yes: Allowed No: Not allowed	HO: Homogeneous HT: Heterogeneous

The objective functions optimized in these types of models that stand out the most are: total bus travel time or distance, total cost and number of buses used. Meanwhile, the least common are number of shared stops, trip compatibility and maximum route length. Single and multiple objective functions are considered, resulting, as Figure 1a shows, on 35% of the corpus focusing on multi-objective or bi-objective functions. Regarding the articles that include a case study, as shown in Figure 1b it is concluded that the place with the most cases of application in real situations is China followed by the United States. However, 49% of papers do not study a specific application case using instead only randomly generated data for method validation.

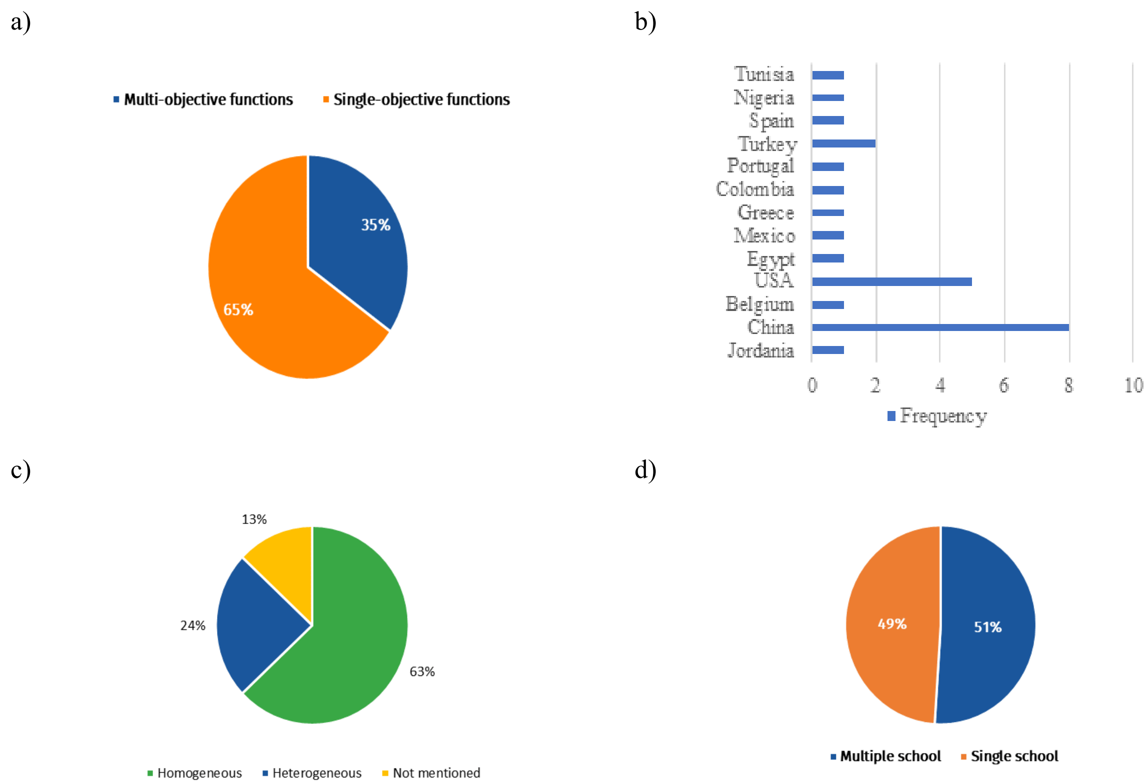

Figure 1. Results of the characteristics of SBRP: (a) objective functions, (b) application case studies, (c) fleet type, (d) number of schools.

An important resulting feature is the type of fleet (Figure 1c) considered in the models to solve the SBRP. Approaches that deal with homogeneous fleets prevail. It is assumed that documents that do not specify the type of fleet usually model considering the homogeneous characteristic rather than heterogeneity. Additionally, it was found that the works that consider heterogeneous fleets are those that simultaneously model multiple SBRP schools, due to mixed loads. Finally, the models of the articles analyzed are directed in 49% to a school and 51% to multiple schools, which is shown in Figure 1d.

The conclusions obtained from the SLR are segmented into 4 specific lines: the first refers to the consideration of the SBRP with multiple schools and mixed load on mathematical models, as it allows to produce a better use of resources. The second refers to the SBRP with heterogeneous fleets, which have demonstrated better results related to total costs and seat occupancy. In addition, the need for considering dynamic environments, by real-time data. Finally, the development of models with multi-objective functions that include indicators that satisfy real-world problems, such as environmental impact.

4. Case Study : Universidad de Monterrey and Tecnologico de Monterrey

For the case study, two universities have been selected from the metropolitan area in the state of Nuevo Leon, Mexico, the University of Monterrey (UDEM) and the Tecnologico de Monterrey (Tec) due to common transport objectives and strategies being shared, and the same student profile. Therefore, there is an opportunity to propose interscholastic transport alternatives that benefit both communities through complementary strategic routes and the use of shared resources. Also, it is important to mention that the universities share similar locations within the Monterrey Metropolitan Area, considering high schools and professional campuses. For instance, the initial potential zone is made up of four UDEM locations: UDEM University Campus, UDEM Unidad San Pedro High School, UDEM Unidad Obispado High School and UDEM Unidad Valle Alto High School; and five locations of Tec de Monterrey: TEC University Campus, TEC Eugenio Garza Lagüera High School, TEC Valle Alto High School, TEC Santa Catarina High School and TEC Eugenio Garza Sada High School.

Considering the current situation of each university, it is necessary to know key mobility data. According to a Mobility Diagnosis carried out for UDEM by Wheels in 2018, it can be said that almost 70% of the university community enters the campus at least once a day. Likewise, it was found that the daily mobility budget is $85 pesos and that 88% of the student community usually spends their free time on Campus. (Wheels Social 2018). On the other hand, in a survey conducted in 2018 on origin-destination at Tec, it was found that 51% of trips are generated within a radius of no more than 5 km from the campus and that the total daily trips generated to and from campus is 73,000. Also, it was found that the time spent on campus is 8 hours. In terms of mobility in the state, according to Wheels, it was found that 0.5 kg of carbon dioxide is emitted by public transport, and 6 kg by private cars.

Universities have specific resources to offer transportation systems to students. Therefore, there are two types of programs, paid buses, and free buses. Paid buses is a program for private transportation service with cost that connects different areas of the Monterrey Metropolitan Area with the high school units and the campuses of the universities. Similarly, the universities offer the other program that is a free private transport service that facilitate students near the districts of the universities transfer. Specifically, UDEM offers the UDEM Direct (paid buses) with a capacity of 37 students and the UDEM Circuit (free buses) with 19 students, and Tec has the Expreso TEC (paid buses) with a capacity of 37 students and the TEC Circuit (free buses) with 19 students.

Considering the fleet and the studies carried out by each university, the percentage of use of each means of transport is presented: 5.9% for Directo UDEM, 4.7% for Circuit UDEM, 6.3% for Expreso TEC and 1.6% for Circuit TEC. This information is useful because it will be taken into account for demand, one of the most important parameters in routing problems. It is important to mention that currently 27 routes are offered considering both universities, in both modes of service. Specifically, 8 routes are offered for the UDEM Direct, 8 for the TEC Expreso, 6 for the UDEM Circuit, and 5 for the TEC Circuit.

Therefore, based on the analysis of the 24 routes, it is found that most are in a specific area, which is why this area is defined as potential, covering five different schools, in the UDEM district: UDEM University Campus, UDEM Unidad San Pedro High School, and UDEM Unidad Obispado High School, and for the Tec de Monterrey district: TEC Santa Catarina High School and TEC Eugenio Garza Sada High School. By analyzing the routes offered by the Universities in their different modalities through this area of interest, in order to visualize its potential and design a joint route. As shown in Figure 2, in total, 11 routes were found with approximately 186 potential stops. (Universidad de Monterrey 2022; Tecnologico de Monterrey 2022).

4.1 Problem Classification

Considering the classification of the SBRP subproblems established by Ellegood et al. (2020), the solution to the case applied between the two university districts in Mexico: UDEM and Tec, would consist of making decisions regarding the bus stops selection (BSS) and the bus route generation (BRG). Additionally, according to Park & Kim (2010), the case problem to be solved has the following general characteristics: urban service environment, multiple schools, mixed load type and heterogeneous fleet mix.

The consideration of the quality indicator in the service to the student, translated into the distance traveled between a student residence and the respective assigned stop, and in coverage of the demand were transcendental for the generation of integral and sustainable interscholastic transportation solutions.

4.2 Demand Allocation

Prior to the generation of the bus routes, it was necessary to estimate the demand. For this, an allocation model was developed, as it is considered a classic transportation problem (Taha 2010). The stop selection was resolved following the Allocation-Routing-Location (ARL) strategy defined by (Park & Kim 2010), where the students are first grouped and then one stop per group is assigned. The purpose of the developed model would be to assign each student in the study to a bus stop considering an adequate service level.

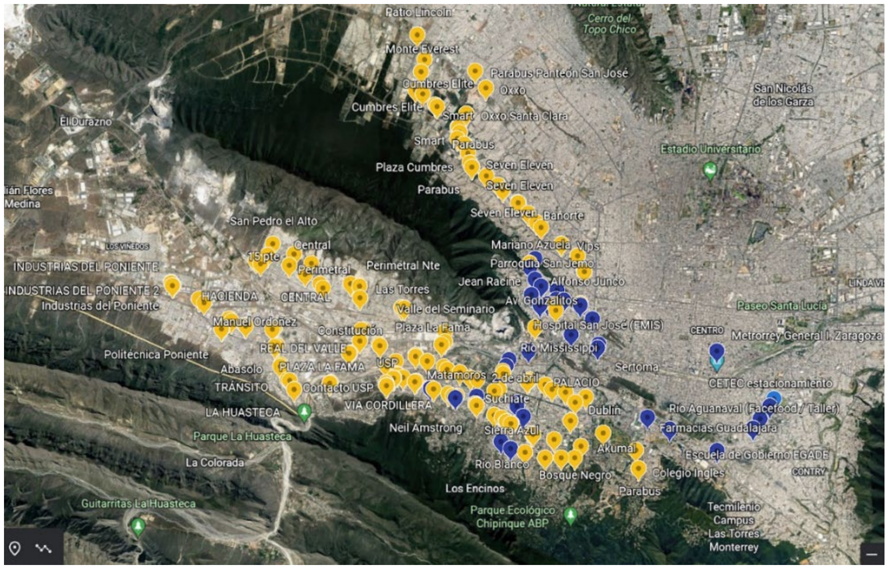

Figure 2. Map with Current Stops of the UDEM and Tec de Monterrey Routes in the Potential Zone

4.2.1 Initial Data Analysis

A database was obtained with information on the location of the population that moves in the metropolitan area of the city where the university districts of the case are in a pre-pandemic period. This was processed, to map the potential area of the case, considering the latitudes and longitudes of the polygons of the school campuses to be included in the study.

Thus, a refined database was constructed. It showed the location of the households of the users who move in each polygon that constitute the potential area of the case, with the aim of segregating the case demand by geographical area, time and school. Additionally, studies of mobility and modes of transport published in the same pre-pandemic period, with focuses on the potential areas of the study, were analyzed to complement the veracity of the demand to be estimated. (Estrada *et al.*2022; TEC 2018; Wheels Social 2018).

Once user mobility was analyzed by school zone, it was possible to eliminate one of the five schools that were initially considered in the study, given that the percentage of users within the polygon of these fifth school: UDEM Unidad Obispado High School (0.02%), is not potential considering the total number of users in the complete potential zone. Therefore, the schools to which demand would be assigned would be, for the UDEM district: UDEM University Campus and UDEM Unidad San Pedro High School, and for the Tec de Monterrey district: TEC Santa Catarina High School and TEC Eugenio Garza Sada High School.

4.2.2 Conceptualization of the Stop Selection Problem

The important aspects to consider for the construction of the allocation model are the following:

- Different time slots are considered (morning, evening and departure).
- The school bell ring times of each of the universities in each of the time slots are considered.
- Only a percentage of students who go to schools arrive by school transport (Wheels Social, 2018).
- The percentage of students who arrive by school bell ring time in each respective time slot at each school varies.

To ensure a quality service to students, it is necessary that the distance between their home and the assigned stop is between 500 and 1000 meters. Accordingly, to obtain the precise distance to be traveled by the user, the non-Euclidean distances between the household and the current stops were calculated, considering a proportion factor for the position and direction of the streets on the real map. It was possible to filter all the distances greater than 1 kilometer between the user's home and the stop, to obtain a final demand to be assigned of 4,296 to 2,236 users.

4.2.3 Bus Stop Selection: Mathematical Model

An allocation model was developed with the aim of maximizing coverage, based on the consideration of the distance between users and stops and an optimal number of stops. It was defined that a user can be assigned at most once per stop and that the demand to be assigned consists of users who live only less than one kilometer away from the stop. The optimization software used to solve the programmed model was CPLEX. This was run in the GAMS program, taking a computational time of 18.664 seconds, generating 463,000 constraints and 921,439 variables. It is worth mentioning that the model was run on Intel® Core (™) i7-1065G7 CPU. @ 1.3GHz 1.50 GHz with 16GB of RAM.

4.2.4 Bus Stop Selection: Results and Experimentation

The user assignment was made through a coverage percentage and in a distance between 500 and 1000 meters (500, 600, 700, 800, 900, and 1000 specifically) from the user to the stop, in order to estimate the number of stops to be routed to maximize the coverage, accordingly.

The model was run 54 times, for each combination of coverage percentage factor and distance between user and stop. Since the solution sought for each combination was an exact optimal solution, the method used was MIP, given its adaptability to solve this type of problem.

As shown in Figure 3, it was determined that the shorter the distance between the user's home and the stop, the greater the number of stops needed, and the greater the distance, the greater the demand satisfied.

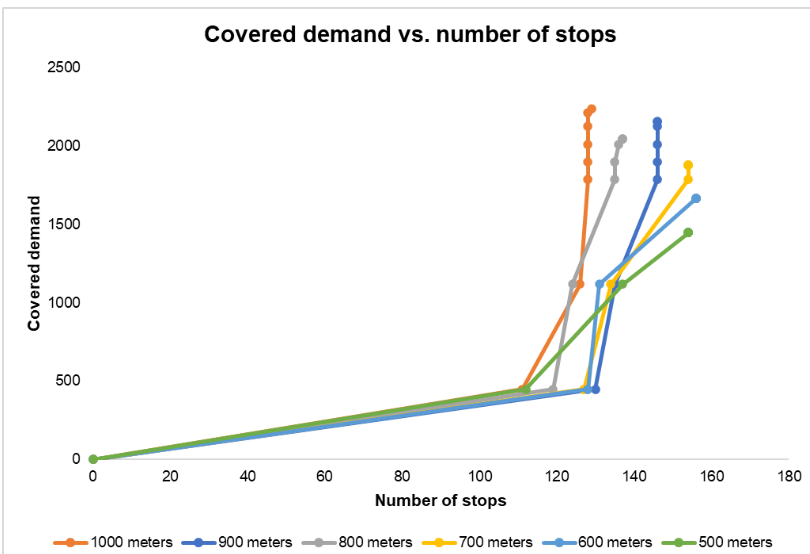

Figure 3. Relation between satisfied demand and number of stops considering different travelled distances between houses and stops

For this reason, it was decided that the distance between the user's home and the stop would be 800 meters, which would allow the number of necessary stops to be reduced to 137, to satisfy 100% of the demand that lives at the aforementioned distance.

4.3 Route Generation

With the previous model, it was possible to select the stops to which the demand would be assigned. Once the demand of users that travel to each of the potential bus stops was assigned, it was observed that only a percentage of the stops that were previously obtained had a demand of users for each school in each school bell ring time in their respective time slot. For the bus route generation problem only the stops that had a potential demand were considered.

A routing model that sought to develop transportation routes to meet supply and demand constraints (Taha, 2010) was built. Four schools in the potential zone were considered, guaranteeing the interscholastic context of the transportation problem. Some of the general characteristics of the routing problem consist of the consideration of multiple schools, mixed cargo, heterogeneous fleet and a multiple objective function, given the need found in the literature to enhance this research field.

4.3.1 Conceptualization of the Routing Problem

Prior to the route generation problem, nodes with potential demand were selected. As a result, it was defined that the distance between each node in the route should be between 300 and 2000 meters. Additionally, the travel times between nodes were calculated, using the previous distances. Subsequently, an adjacency matrix was built, which together with the above, would serve as the basis for determining the optimal route of the model.

Some important considerations for building the model were followed regarding the interscholastic route (only demand nodes should be visited), the nodes (distance between nodes can be variable within an established range), time (the actual distance between nodes is calculated using travel times), the consideration of different time slots, the demand (as it is not necessary to satisfy all the demand) or a proposed base fleet.

4.3.2 Bus Route Generation: Mathematical Model

A multi-objective function was developed to solve the routing problem, with the aim of maximizing the coverage considering the demand (users) satisfaction and the number of buses. It is worth mentioning that, according to Marler & Arora (2004), the most common approach to multi-objective optimization is the weighted sum method.

For the development of the multi-objective function of the model, the assignment of a weighted weight to each of the elements of the function was considered: the number of users and the number of buses. In particular, the weight assigned to the number of buses is related to the number of users needed to open a bus route (in the university context of the case study), to guarantee similarity in units when weighting the elements of the multi-objective function, in this case: users in the route.

The optimization software used to solve the programmed model was CPLEX. This was run in the GAMS program, taking a computational time of 14 minutes and 48 seconds, generating 183,176 constraints and 56,761 variables. The model was also run on an Intel® Core (™) i7-1065G7 CPU. @ 1.3GHz 1.50 GHz with 16GB of RAM.

5. Experimentation

A robust sensitivity analysis was conducted, focused on 4 specific lines of action: time window, demand, capacity, and weight analysis. Additionally, the computational time was analyzed, since it is an important factor to consider, given the robustness of the practical case that is sought to be solved.

The model was officially run 54 times using the CPLEX solution software in GAMS, on an Intel® Core (™) i7-1065G7 CPU. @ 1.3GHz 1.50 GHz with 16GB of RAM. To perform the sensitivity analysis, once the models were run and the solutions interpreted, the data obtained were processed using linear regressions in Minitab.

Once the analysis was held, it was found that, to maximize coverage, there is no need to consider the number of buses required, a time window of 30 minutes, and a fleet with a capacity of 19 users are enough to avoid underutilize resources. Furthermore, it was transcendental to jointly analyze the interschool routing vs. the traditional one, obtaining the following results and proving the central hypothesis initially raised, as shown in Table 2 and Figure 4.

While the transcendental routing solution manages to satisfy a demand of 48 students with 6 buses and 7 trips and an approximate route time of 53 minutes, the interscholastic routing solution manages to cover 31.25% more of the students, that is, 63 users, with half the resources, that is, 3 buses (in 4 trips) and a route time of approximately 58 minutes, below the route time established as ideal to provide a good level of service (of 70 minutes). This can be translated that, with the interscholastic solution it is possible to satisfy 16 students per trip (and bus), while with the traditional one, only 7 students can be accommodated per trip (and bus). Henceforth, it was possible to prove that *the coverage indicator is increased through the sharing of resources (buses) between universities.*

Table 2. Interscholastic Routing Solution Analysis

Interscholastic solution	Time Window (min)	Weight(users)	Coverage (users)	Route Time (min)	Number of buses	Number of routes	Computational Time (min)
Yes	30	0	63	58.4	3	4	15
No	30	0	48	52.5	6	7	39

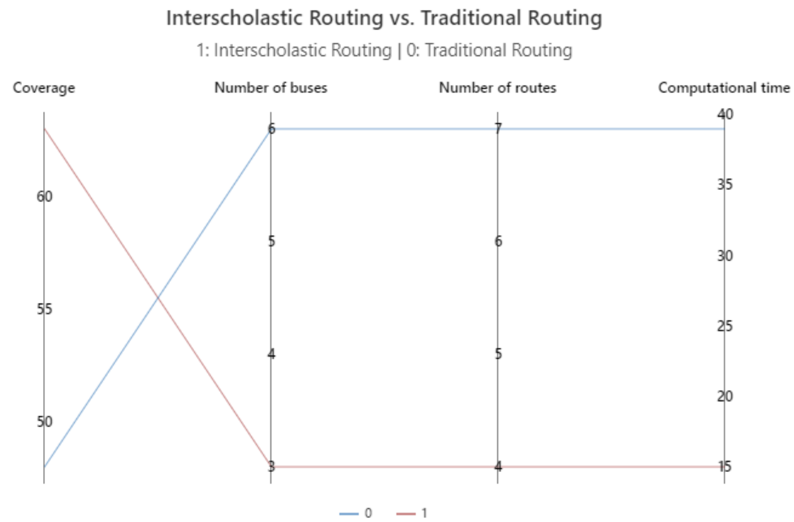

Figure 4. Comparison of traditional versus interscholastic solutions.

6. Results

It is recommended to run a pilot test with the universities involved in the case scenario with the obtained solution from the final model. The model solution, shown in Figure 5, that maximizes demand coverage uses 3 buses, making 4 trips. The buses used are 2, 7 and 8, with capacities of 37 users respectively, and they work as follows.

The first bus, number 2, departs from the TEC Santa Catarina departure node and arrives at its respective arrival node. Additionally, it can visit the demand nodes of the UDEM San Pedro High School, the UDEM Campus and the TEC Eugenio Garza Sada High School; it visits a total of 19 nodes, and picks up a total of 10 students to take them to the aforementioned destination school, in the School Bell Ring Time 3, from 8:00 a.m. The total route time of this trip is 61 minutes.

The second bus, bus 7, makes two trips. For the first trip, it departs from the UDEM Campus departure node and arrives at its respective arrival node. Also, it visits the demand nodes of TEC Santa Catarina High School, UDEM San Pedro High School, and TEC Eugenio Garza Sada High School. In general, it visits a total of 16 nodes and picks up a total of 17 students to take them to the aforementioned destination school, at School Bell Ring Time 1, at 7:00 a.m. The total route time of this trip is 54 minutes. For the second trip, it departs from the departure node, the same, from the UDEM Campus and arrives at its respective arrival node. Also, it stops at the demand nodes of TEC Santa Catarina High School, UDEM San Pedro High School, and TEC Eugenio Garza Sada High School, visiting a total of 16 nodes and picks up, also, a total of 17 students to take them to their destination school in the SBRT room at 8:30 a.m. The total route time of this trip is 54 minutes.

Finally, the third bus (number 8) makes a trip, departing from the departure node of the second school, that is, UDEM San Pedro High School, it also visits the demand nodes of TEC Santa Catarina High School, Campus UDEM and TEC Eugenio Garza Sada High School, and is capable of picking up a total of 19 students to take them to their destination school on the second SBRT at 7:45 a.m. The total route time of this trip is 65 minutes.

In conclusion, the model solution is capable of covering a total demand of 63 users (in 3 buses and 4 trips, with an average occupancy of 15.75 users) with an average route time of 58.3 minutes, which satisfies the assumptions and restrictions posed in the model, as well as with the main objective and central hypothesis of the developed research project.

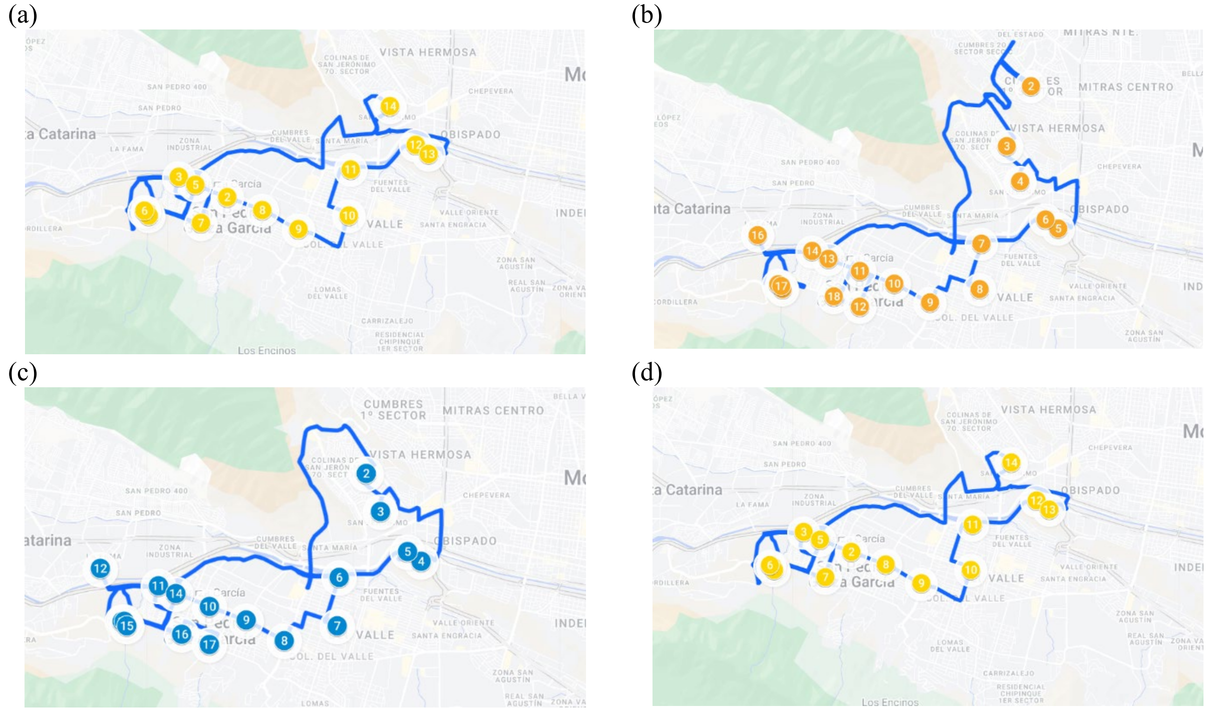

Figure 5. (a) Trip 1 to UDEM Campus at 7:00 a.m., (b) Trip 2 to UDEM San Pedro High School at 7:45 a.m., (c) Trip 3 to TEC Santa Catarina High School at 8:00 a.m., and (d) Trip 4 to UDEM Campus at 8:30 a.m.

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