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Proposal for an Institutional Carpooling System among Workers from the Public-Education Sector

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Abstract: Car journeys to work represent a high percentage of daily mobility. Carpooling can be an efficient alternative for managing this transport demand. Carpooling benefits are not limited to reducing emissions and energy consumption: users can also benefit in the reduction in travel costs and travel time using high-occupancy vehicle lanes, as well as reducing commuting stress. The organization of such a system is not easy to carry out individually. Institutions and companies with a high number of employees are suitable for carpooling initiatives, and the education sector holds a high number of workers. Considering the large number of teachers and the fact that many of them are regular drivers, the sector presents an opportunity to design a formal carpooling transport system. This paper presents the design of a proposal for a carpooling system among workers from the education sector in the region of Andalusia, Spain. The system yielded relevant benefits such as cost savings, emissions reductions, and a high number of potential users. The designed system can potentially improve transport conditions for workers in commuting displacements and reduce occupational traffic accidents.

Keywords: sustainable mobility; carpooling; smart mobility; sharing economy; occupational accidents

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1. Introduction

Continuous economic development has been linked to rising transport challenges, such as traffic congestion, environmental pollution, and economic costs. During a working day, a high percentage of personal travel is due to work reasons [1]. For instance, in Spain, this percent represents around 42 percent of trips, and more than 60 percent of these trips are by car [2]. This percentage increases to 79 percent when the distance to the workplace is more than 50 km. In other countries, such as the US, Canada, or New Zealand, the percentage of people who drive to work and the distance covered have increased in recent years [3]. It is remarkable that traffic accidents due to work-related travel are a significant cause of death [4]. More sustainable alternatives to the traditional individual use of private cars could improve the economic, environmental, and social impact of daily transportation to work.

Carpooling is an efficient alternative for managing transport demand [5]. It represents an effort by drivers of motor cars who agree to take turns and share rides in the commute from personal residence to the worksite [6]. Carpooling is not a new practice. Carpooling clubs were created in North America during the second World War, for example, and in the 1970s, they were a popular response to energy crises [7].

Casual carpooling has been shown to be an efficient way to save energy. In San Francisco alone, 1.7–3.5 million liters (0.45–0.92 million gallons) of fuel are conserved each year through the use of carpooling systems [8]. Carpooling benefits are not limited to reductions in emissions and energy consumption. Carpooling mitigates congestion and reduces the need for parking infrastructures [9]. Carpooling users can also benefit from reduced travel costs and travel time using high-occupancy vehicle (HOV) lanes, thus reducing commute stress. The effects of HOV lanes on bottlenecks have been studied by other authors previously [10]. More specific studies have pointed that ridesharing platforms do not always benefit HOV lane capacity [11]; however, other authors have concluded that HOV lanes promote carpool activities and boost welfare [12].

Additionally, time and monetary savings have been identified as key motivators for carpooling [13]. In contrast, some potential users hesitate to carpool because they worry about losing control of their property and personal information [14].

Factors influencing carpooling decisions are grouped into four categories: situational factors, third-party interventions, sociodemographic factors, and psychological factors (such as socialization and feeling pleasure when carpooling with others) [15,16].

The incorporation of new technologies such as smartphones, GPS, or social networks has made flexible and dynamic models of carpooling possible [17], and different authors have highlighted the effectiveness of smart devices in developing dynamic car-sharing systems [18]. However, some recent pilot experiences in countries such as the US have been discontinued due to low match rates [19].

Given that carpool users are usually colleagues or friends who have recurrent travel from home to work [20], the implementation of a carpooling system in a sector such as education, with a high number of workers and car users, and fewer destination points, could be successful. Previous carpooling experiences have shown that employer initiatives and promotion increased worker participation in carpooling clubs [21,22].

Organizations with a high number of employees are suitable for carpooling initiatives, and the education sector concentrates a high number of workers in most countries. In the region of Andalusia (Spain) alone, the number of teachers officially employed in the education sector (excluding universities) was 127,253 in 2019 (in a total regional population of 8.43 M, i.e., 18 percent of Spain's total population). Although official data regarding their travel modes to the workplace are not available, due to the peculiarities of the sector, a high percentage of teachers use their private cars to commute to work. As a consequence, the majority of occupational fatal accidents in this sector are linked to traffic accidents [23]. In particular, some contributing factors to the use of private cars in the sector can be summarized as follows: (i) different timetables during the week; (ii) possible changes in the location of the workplace each year for substitute and temporary workers; and (iii) travel to schools located in rural villages, with a lack of public transport connections. For these reasons, we believe that the education sector is particularly suitable for implementing a carpooling system. Individual management of carpooling reduces the number of potential carpool users to known colleagues. In many circumstances, although teachers are interested in sharing their cars, their options are (very) limited, and a low matching rate reduces the probabilities of success for a carpooling system [19].

The current paper presents and evaluates a design proposal for a carpooling system among workers in the education sector in Andalusia (Spain). The remainder of the paper is structured as follows: Section 2 describes the current mobility scenario; Section 3 discusses the requirements for carpooling; Section 4 provides an overview of the proposal for a carpooling system based on the scenario and requirements; Section 5 presents the main conclusions.

2. Description of the Current Mobility Scenario

2.1. Mobility Profile in the Education Sector in Andalusia

Andalusia is a region of Spain with a total surface area of 87,268 km^2. It is larger than some European countries such as Belgium, Holland, Austria, or Denmark, and is roughly the same size as Portugal. In Andalusia, the education workforce is composed mainly of primary school and secondary school teachers, with 80 % public vs. 20% private. Women account for 65% of teachers and men account for 35%. They all work in one of the 2087 schools located in the region. The majority of teachers can change their workplace each year if they agree to participate in an official yearly procedure, in which teachers are ranked based on their length of service and additional achievements. Thus, once a year, many teachers are relocated according to the results of this procedure. The distance that a teacher must cover each academic year may therefore vary.

To define a teacher mobility profile, we assessed different categories of displacement, based on the distance from homes to worksites. Previous studies have classified trips according to their distances, in categories such as short distance, long distance, or commuting [24,25]. In our particular study case, four mobility profiles emerged according to the distance of the commute to the school (Table 1).

Table 1. Mobility categories based on distances from work to home [26].

Category	Distance	Trip Time	Description
A (Neighbourhood)	lower than 2 km (1.24 miles)	5–20 min	Teacher lives near the work site and walks or goes by bicycle/scooter
B (Intra-city and inter-villages) [26]	2–15 km (1.2–9.3 miles)	10–30 min	Teachers lives in the same city or in a close village
C (Inter-cities) [26]	16–125 km (9.9–77.7 miles)	15–90 min	School is in a different city, but usually in the same province
D (Long distance)	Above 125 km (77.7 miles)	$\geq$ 90 min	School is too far to return every day

All teachers living in the same neighborhood as their schools were included in category A. They are considered pedestrians, because the distance is too short to be covered efficiently by car. Category B includes teachers living in the same city or one nearby. Category C includes workers from different cities but usually in the same province. All teachers with a commuting distance greater than 125 km were included in the last category (D). Teachers in category A are not suitable for participation in the carpooling system because the majority of them are not going to drive often. Teachers in category D usually rent an apartment or bedroom near the school, because it is more expensive and exhausting to drive than to rent. Thus, the carpooling system should focus on workers from categories B and C only.

2.2. Transportation Alternatives

Although there are no specific data available regarding the transport mode teachers use, in practice, we can suppose that they use the modes depicted in Table 2.

Walking or biking is the most ecological and cheap option, but it is only possible if the teacher’s home is close enough to the school center. Additionally, factors such as high slopes, bad weather, or lack of bike lanes can prevent the use of bikes. Public transport (bus, train, or subway) is normally available in large cities, but is not always possible for larger distances, as there may be a lack of public transport connections between home and the workplace, or these may not be suitable for arriving to class on time.

Table 2. Occupational transportation alternatives.

Mean of Transport	Advantages	Disadvantages
Walking or bike	Cost and emissions	Only short paths
Public transport	Low cost	Limited availability
Bus hiring	Low cost	Only for big groups with same timetables
Private car (one driver)	Fast and easy	High cost and emissions
Carpooling face to face	Save cost and emissions	Need for coordination
"Bla bla car" and other sharing platforms	Save cost and emissions	Returns and arrange daily with unknown people

An alternative to this would be the hiring of charter buses. A successful example of workers hiring buses can be found in a group of civil servants living in Malaga and working daily in Granada (125 km away). The bus returns every day at same time. This practice is difficult to implement in the education sector, however, because not all teachers have the same timetable. Traveling by private car with one driver is probably the most extensive practice, and is sometimes the only possible alternative. For instance, if the school is located in a rural area and the teacher does not live in the same village, there is often no alternative to the use of a private car. In this case, there is no need for any coordination mechanism. Nonetheless, the entire cost of this transportation mode falls on the driver and it is also not environmentally friendly. In some cases, teachers create carpooling groups among workmates at the same school. According to their zones of residence (city, village, or neighborhood), they create a group with people interested in car sharing. All participants input their timetables to see what timings they have in common; based on the level of overlap in timetable, they manage the possible shifts for each day of the week. The final result depends on the number of workmates with similar timetables and routes. In the previous experience of one of the authors, a teacher could save on driving between 1 and 3 days each week. The absence of transportation alternatives motivates carpooling practices, which reduce the amount of solo drivers. Then, the number of vehicles on the road decreases significantly, especially in the neighborhood of schools and high schools.

Informal carpooling among teachers from the same workplace could be more effective, but it has some important limitations. First, carpooling initiatives are not promoted officially by principals and institutions. Such groups are also generated using word-of-mouth communication among teachers interested in reducing the number of self-driving trips. Thus, it is necessary to personally know one's workmates and their place of residence. This is not always possible for schools with a high number of teachers and high levels of rotation each year from one school to another. The acquaintance between teacher groups is only integrated with teachers from one school; however, it could be possible that a teacher from a nearby school has an overlapping route and timetable with another teacher, but carpooling is not possible because they do not know of the overlap.

Nowadays, online-app-based carpooling services such as BlaBlaCar are increasing their number of users. However, such apps have some disadvantages for teachers, including dynamic timetables, which obligate arranging a single car-share per day for the entire academic year. This is not an efficient way to manage one's daily commute. Another disadvantage is that car sharers are probably not colleagues. Sharing with unknown people can be a social barrier to the diffusion of this transport mode. Another possible inconvenience is that a car may not be available to share on some days, either because nobody is traveling on the same route or because the cars making the same trip have no available seats.

3. Requirements of a Carpooling System for Teachers

The carpooling management system the authors propose takes into account the peculiarities of the education sector and teachers' specific needs. In addition to practical requirements (e.g., timetable needs and cost saving), we pay particular attention to social barriers which may hamper the diffusion of carpooling practices among teachers.

The attributes of the system are described in Table 3. The majority of these attributes have been previously studied by related works about carpooling issues.

A relevant aspect for users is travel planning. Due to their inflexible timetables, long-term planning is provided by the system [27]. Another important attribute is the high number of potential users. Critical mass of carpool users has been identified in the literature as a relevant factor to encourage solo drivers to improve carpooling [28,29]. Similarly, privacy of users is an important aspect to be considered by the system. Personal information included in the database should be managed properly according to legal issues. Furthermore, the relationship between privacy and trust has been identified in previous research [30].

Another important attribute of the model proposed is the free election of the carpoolers by the users [27]. An automatic election by the system could generate trips composed of workmates with low personal affinity. In the proposed system, the user can choose their travel meet according to their personal judgment among the available possibilities.

Furthermore, the system will not charge any cost to the users because they agree to alternate their car for the trip [31,32].

Additionally, the information of the system about costs and emissions saving would encourage the potential users to carpool [33,34].

Table 3. Requirements for a teacher carpooling system.

Attribute	Description	Previous Authors
Long-term planning	Teachers need to arrive on time every day and they need to plan their trips in advance	[27]
Critical Mass	High number of potential users. The higher the number of potential users, the easier it is to match routes with other users from the education sector may access the system	[28,29]
Privacy	Need for protecting personal data	[30,35]
Free election	Travel mates are not imposed by the system	[27,36]
Trust	Only workers from the education sector could to access to the system	[37,38]
Fee	The system will not charge any cost to the users	[31,32]
Save cost	The system will inform users on the amount of money saved for each carpooling travel	[13,33,34]
Save emissions	The system will inform users on the amount of emissions to the environment saved	[8,39]

3.1. "SENECA" Web Platform for Teachers

SENECA is a web platform designed for teachers and managed by the Education Department of the Region of Andalusia. The system integrates different aspects of teaching, academic life (e.g., student grades and attendance, course planning, timetables), and human resources issues. In Andalusia, all teachers (from both public and private schools) are registered with the platform, and they must access the platform daily for their job tasks. Thus, the user community of this platform is made up of all teachers in the region. All data necessary to run an efficient carpooling system (e.g., home address, working center address, timetables) are already recorded in this system, which also has an APP version for smartphones.

3.2. System Attributes

The requirements for a teacher carpooling system are summarized in Table 3. Teachers do not have flexible timetables, so they need long-term planning to arrive on time every day before the beginning of classes. Another important attribute of the system is the protection of the personal data of potential users. Data protection is a legal requirement, but it is also very important for users' perception of safety. To increase user trust, only workers from the education sector would be able to use the proposed system, and travel mates could be chosen by the users and not arranged without user consent. Additionally, the system would inform users about cost savings and emissions reduction.

4. Results and Discussion

4.1. Proposal of Design of a Carpooling System

The proposed system has been designed to take into account the peculiarities of the education sector and to address the previous requirements. The system runs according to the following steps (Figure 1).

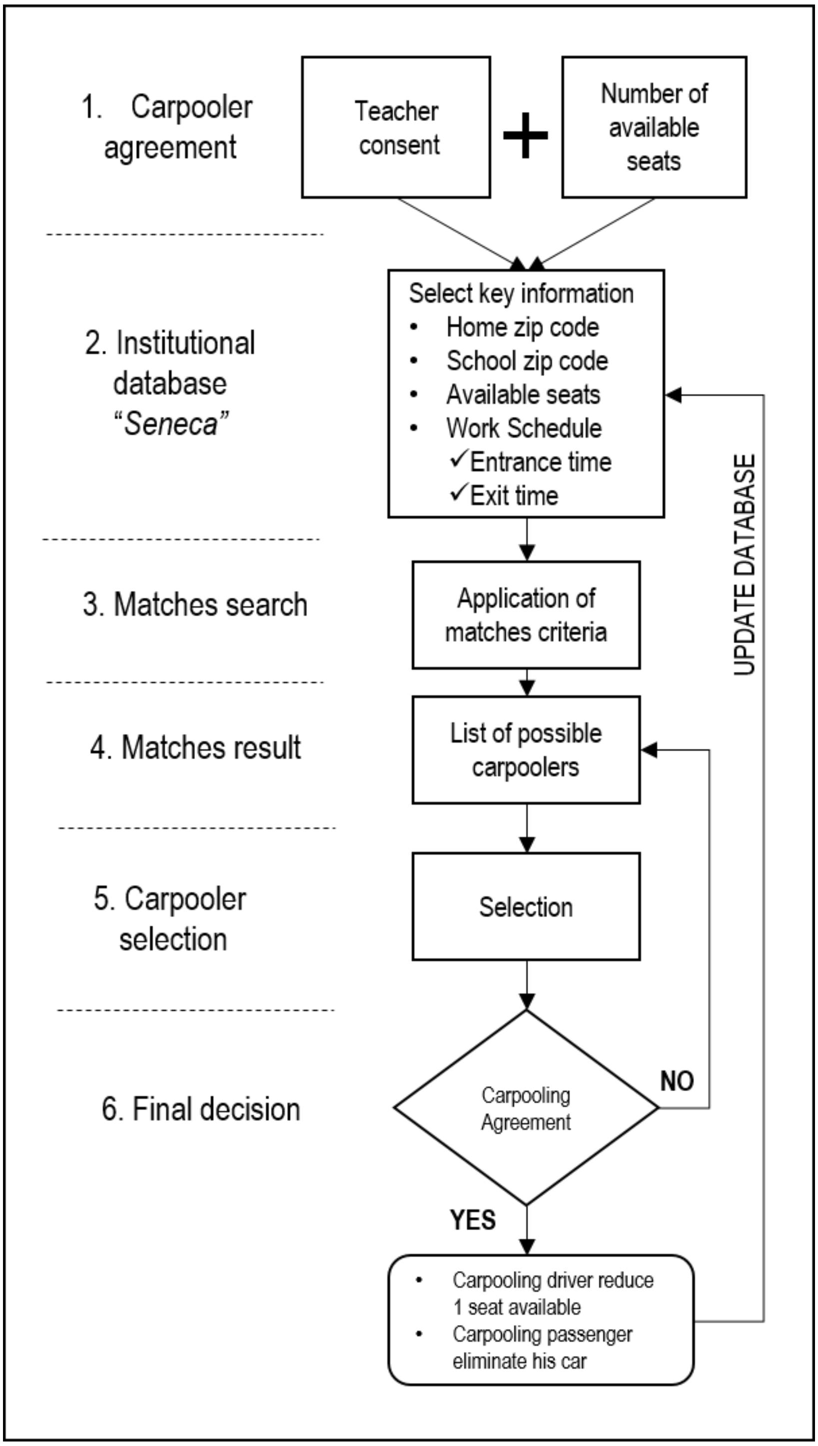

Figure 1. Carpooling proposal flowchart.

- STEP 1. Carpool user agreement: In a previously designed web platform, the worker is registered using login data from the SENECA system. In the first step, teachers interested in the carpooling system would upload a data consent to share their contact information and to be included in the carpooling system. They should also indicate the number of available seats for possible carpool users.
- STEP 2. Institutional database: Once logged into the platform, the key information required for the proposal is obtained from the institutional database and available seats are supplied by users.
  - Home or departure place zip code.
  - Working place zip code.
  - Available seats.
  - Entrance time.
  - Exit time.
- STEP 3. Match search: Some authors classify carpool trips on the basis of the types of matching between origin and destination (Furuhata et al., 2013; Morency, 2007). According to the match criteria, the platform will search for matches in timetables and zip codes. (Table 4).
- STEP 4. Match result: Based on matching criteria, the platform generates a list of possible carpool users. They are ranked by matching level.
- STEP 5. Carpool user selection: A user will select one option from the list and connect by phone or email.
- STEP 6. Final decision: If they agree to carpool, then the database should be updated. The driver will reduce one seat available, and the passenger will eliminate their car from the database for that trip.

Table 4. Carpooling match criteria.

Match Level	**Requirements**
Match 1	Same home zip code AND same school zip code AND same timetable
Match 2	Near home zip code(+1/−1) AND same school zip code AND same timetable
Match 3	Same home zip code AND Near school zip code (+1/−1) AND same timetable
Match 4	Same home zip code AND Same school zip code AND near entrance timetable (−1)
Match 5	Same home zip code AND Same school zip code AND near exit timetable (+1)
Match 6	Near zip code (+1/−1) AND near timetable (+1)

4.2. Practical Case in a High School

In a first approach, the system was checked with a group of teachers from a high school in order to obtain some preliminary results. In this example, 40 teachers were asked to participate. In the sample studied, 36 of them were habitual solo drivers for commuting, and only 23 of them (64%) agreed to be included as a potential carpooler. After agreement, the teachers provided the same personal information contained in SENECA database (Home zip code, school zip code, available seats, and timetables). All participants share the high school zip code, and some them share their zone zip code based on their home address. Afterwards, matches criteria were applied. The results from the application of cited criteria are shown in Table 5.

Due to the small size of the sample, all matching results were included, and they were not ranked according to their matching level.

According to these results, a total of 14 cars were reduced to only 4 cars. That means a reduction of 71% in the initial cars, among the participants in the pool. Considering all the teachers surveyed, the total number of 36 cars was reduced to 26 cars (28% reduction).

Although the sample is very local and small, it is reasonable to expect positive results for bigger samples of potential users.

Table 5. Results from application of match criteria.

	Match Zip	Match Zip + Timetable	Solo Cars	Carpool Cars
Zip code—Zone 1	43.48	30.43	7	2
Zip code—Zone 2	30.43	17.39	4	1
Zip code—Zone 3	17.39	13.04	3	1
TOTAL	91.30	60.87	14	4

5. Conclusions

The proposed system presents several advantages for society, organizations, and workers. In addition to the traditional benefits of cost saving and emissions reduction, the system introduces new advantages to increase the participation of workers in carpooling. First, it includes a high number of potential users. In traditional carpool groups, workers only interact with known workers from the same workplace. This makes it impossible to know whether unknown workers partially overlap along similar routes for different workplaces. The presence of more users creates more possibilities to find similarities. Second, users can arrange their carpooling trips in advance (days or weeks). This is an important advantage compared with real-time methods based on cloud computing or location systems (GPS). It reduces uncertainty about whether or not users will travel the route. Third, the timetable variability each day of the week, which is a peculiarity of the education sector, is taken also into account by the system. Fourth, the system does not arrange sharing groups, but leaves up to the users the right to accept or decline. Users can accept or decline the invitation to share their car, and they are contacted by the tool which they have authorized. Finally, the system increases trust in carpooling practices. Only registered users from the education sector can access the system. Teachers are more willing to share their cars with people belonging to the public administration—and even more from their own sector—than to share a car with unknown people.

5.1. Limitations

In small villages and schools, the critical mass of the users could not be enough to generate matches between participants. However, the match probability is lower without any system.

The system has not considered the possibility of a pay-per-trip system. This option was not included because the problem of defining a fair rate based on the high variability of fuel, insurance, maintenance, etc. In addition, it could generate role problems among work mates.

5.2. Future Research

In future research, a survey of potential users would be very useful to improve the strengths of the proposed carpooling program.

Additionally, the simulation of possible matching rates based on the official data of teachers in Andalusia could improve the estimation of the benefits related with the real implementation of the system.

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