

The Evaluation of Home-School Itineraries to Improve Accessibility of a University Campus Trough Sustainable Transport Modes

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Abstract. Sustainable mobility is often related to the balance between supply and demand transport, including in its development in terms of connection between the behavioural and economic factors. Furthermore, the investigation of travel reason is useful for the aforementioned selection, also correlating with the different age groups and gender. There is a growing need for young people to access university campuses but the transport supply is often not adapted to student needs. This problem involves compromising not only accessible status but also sustainability and therefore the environmental, economic and social aspect. In this way, it emerges that is necessary to adapt to the growing transport services with student economic availability, travel distance and waiting times. This work explored the accessibility of a university campus (school node), through interviews considering a current transport offer and home–school reason. It was also linked to the availability of parking lots adjacent to the campus and the occupancy rates of the various neighbouring car parks were also calculated, monitoring the aforementioned areas for about a month using video cameras and sensors. The research investigated both travel distances in Euclidean and network terms and both travel times through the use of a micro-simulation tool and a linear equation. The study shows as a first research step that the shared mobility solution saves time but also highlights the critical issues of the service that should be better adapted to the students' needs in terms of rate, type of car and subscription.

Keywords: Sustainable mobility · Shared mobility · Micro-simulation · Travel time

1 Introduction

The evolution of university campuses is often linked to a growing demand for transport which is not homogeneous from an economic and social point of view, as students have different incomes or different transport habits.

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The growing need to simplify access to these areas and the need to solve the problem of congestion on closed roads has become one of the aspects that most promote the sustainability (environmental, economic and social) of universities.

The accessibility aspect is based on the interactions between transport and land use defined by different variables, such as travel time.

According to [1, 2] the choice of the different types of transport modes may be related to the different expansion of urban contexts.

The accessibility aspect is also an efficient way to assess environmental and social impacts and also the sustainability of transport and land use provisions in accordance with [3].

In terms of transport offer, accessibility can be guaranteed not only through an offer of infrastructures and services but also through a shared and integrated planning and design through I-BIM (Building Information Modeling for Infrastructures) methods that helps to improve accessibility considering aspects such as costs and safety, parameters that also affect travel time [4, 5].

There are several models in the literature that at various scales define and optimize transport processes and thus also improve travel times [6].

In order to define a specific sustainability value, this document aims to compare the different modes of transport for a specific category of demand, considering travel time, Euclidean distance and network distance in accordance with [7] considering the Kore home-to-school travel motivation defined to exemplify as "home-to-school".

The current transport offer is characterized by private cars, university DRT buses and car sharing.

Travel times were studied by monitoring socio-demographic and spatial characteristics in the first phase by interviewing a sample of university students in accordance with [8–11].

The use of micro-simulation tools allows the comparison of scenarios in standard or emergency conditions, mitigating the criticality of transport in a preventive way. The following paragraphs describe the methodology used and the results obtained with reference to the university context considered.

2 Methodology

The objective of this research is to evaluate the travel time covered by university students considering the different forms of mobility that allow them to move daily from their places of residence to the university area examined. This research has been carried out in the following steps:

- the collection of data relating to the monitored campus and surrounding residential areas (no. of students, no. of parking lots, occupancy rate, mode of transport, etc.). In this step of analysis, socio-demographic and travel habits parameters have been acquired considering closed type answers.
- the definition of an interview method and the selection of the sample. In this step of analysis we chose the sample to investigate and the method of face-to-face interview.

- the processing of the data obtained from the interviews for the evaluation of travel time through micro-simulation tools.

In this step the results obtained from the interviews allowed to know the habits of moving from home to the University, the evaluation of parking occupancy rates in the case of moving by car and the perception that each student has of the move in terms of time.

- the evaluation and comparison of scenarios that take into account the values of travel time. In this step we have selected the modes of transport by private car, car sharing or DRT bus dedicated to students, estimating for each one even partial mobility on foot.
- the description of a linear correlation for the average value of the total travel time.
- the analysis of the results in terms of distance and travel speed and comparison for each mode of transport. In this step the distances in Euclidean and network terms have been considered considering the different nodes of origin and the same node of destination.

Moreover the travel times obtained by the micro-simulation and those perceived by the students, acquired during the interview, have been evaluated and compared.

Analysis of Interview Data

The area under investigation was located in a mountain town (Enna) where Kore University is the most recent.

The University is composed of 4 Faculties, but this research has investigated in depth a part of them related to the Faculties of Engineering and Architecture and Human Sciences.

The research started from a real scenario where shared mobility is currently managed by a private company that has not considered the reduction of tuition fees.

The results of the interview highlighted the main habits of university students moving from their place of residence to the area of the university under investigation. Subsequently, using a micro traffic simulator approach, it was possible to compare the different modal choices (private car, car sharing or DRT bus) in terms of travel times. The following paragraphs provide more details on the various stages of analysis.

Interview Description and Sample Selection

The interview was based on 17 questions that could be answered either with a yes/no answer (4 questions) or with a single choice between multiple options (13 questions).

The interview was based on the acquisition of socio-demographic variables and travel habits as described in Table 1 below (Table 2).

Table 1. List of parameters included on interview linked to socio-demographic attributes

	Variable	Possible reply	Variable	Possible reply
Socio-demographic	Gender	M-F	Car ownership	YES-NO
	Age	18–21 22–25 >26	bike ownership	YES-NO
	Residence area	Santa Lucia (O1) Sant'Anna (O2) Ferrante (O3)	National car sharing experience	YES-NO
	Faculty	Engineering and Architecture Human Science	Driver-licence ownership	YES-NO

Table 2. List of parameters included on interview linked to transport habits

	Variable	Possible reply	Variable	Possible reply
Transport habits	H_S transport mode	walking by car by car sharing by DRT bus other	DRT bus use frequency	never rarely (several times a week) often (several times a day)
	Travel distance perception	0-500 m 500-750m 750-1000m >1000m	Travel time perception	5-10min 10-15min 15-20min >20min
	walking frequency	never rarely(several times a week) often (several times a day)	own car use frequency	never rarely (several times a week) often (several times a day)
	Parking frequently used closed to University	P0 P1 P2	Car-sharing Parking closed University and frequently used	CSP3 other
	itinerary frequently used	IT1 =O1/P0/P1/D IT2 =O1/P0/P1/P2/D IT3= O2/P0/P1/D IT4= O2/P0/P1/P2/D IT5= O3/P0/P1/D IT6= O3/P0/P1/P2/D	IT7 =O1/CSP3 IT8= O2/CSP3 IT9= O3/CSP3 IT10=O1/O2/BS/D	
	Free parking occupancy rate experience	OR=100% OR=90% OR=80% OR=70%	OR=60% OR=50% OR<50%	

The units selected for the interview were represented by 442 university students (IS titled) and represent about 20% of the total number of students who attended the selected faculties (titled TS).

The sample was defined on the basis of a fair distribution in terms of age and gender. All students evaluated had a regular lease or property agreement, excluding those living in the university dormitory. The itineraries analysed considered as origin (O) several areas adjacent to the University and a single destination point (D) corresponding to the part of the campus examined. In the evaluation of the itineraries, the positions of the free stalls for private and car sharing vehicles and bus stops in the vicinity of the described area were taken into account.

Micro-simulation Tool Description

The results of the interview were implemented and processed through the Cube Dynasim tool [16].

Cube Dynasim is a dynamic micro traffic simulation software based on stochastic events. It is based on car following and gap acceptance models for the assessment of moving vehicles and their iteration. The modeling of transport systems allows to compare different scenarios through the creation of layers and to use O/D matrices and traffic compositions to simulate realistic flows, to consider public transport (with PT module) by setting the relative frequency and to analyze the outputs of the time loss functions.

The transport network was implemented by defining specific arcs and nodes useful for the implementation of the O/D matrix and identifying the transport requests of university students expressed during the interview phase. The calibration processes have made it possible to make the traffic parameters more realistic on the basis of the travel habits acquired and the related perceived mobility data.

The simulation took place considering a disturbance flow within the considered transport network, recorded in value through a camera system and imported into the tool during the calibration phase. The travel time criterion made it possible to measure the time taken by a vehicle to travel along the network between an input and an output section of a specific data collector.

The model made it possible to enter not only the points of origin and destination but also the location of the stables and stops related to the Demand Responsive Transport bus (title DRT bus).

Example Evaluation of Average Linear Travel Times

The evaluation of the travel time was carried out thanks to the data obtained from the interviews, i.e. through the instrument of micro-simulation and a linear analytical estimation. This work shows a first step of investigation related to the linear value of the average travel time from an origin to the destination defined “ALTTod”. It is estimated considering a disturbance flow generated by vehicular traffic during peak hours and acquired through sensors and cameras.

In this document, the evaluation of the travel time was assessed in terms of the overall travel and also taking into account the time related to the distance between the car parks and the destination and between the destination and the bus stops from the destination. For each mode of transport, an ALTTod value given by the linear sum of several values has been defined as Eq. 1 and 2.

$$\text{ALTTod} = \sum_{\text{i,j}\in\text{Pod}} \text{tij}\ \forall \text{o, d} \in \text{W} \tag{1}$$

$$\text{ALTTod} \geq \sum_{\text{i,j}\in\text{Pod}} \text{tij}\ \forall \text{o, d} \in \text{W, Pod} \in \text{Kod} \tag{2}$$

where

t_{ij} = time rate considering each arc ij
$ALTT_{od}$ = average liner travel time to reach from origin "or" to destination d
W = set of arcs traveled
Kod = set of possible itineraries
Pod = choice of means of transport from origin or destination d
i, j = extremes of the arc

For each mode of transport it was possible to define the average linear travel time (minutes) as described in Table 3.

An "OTHER" value has been added to each of these calculated times.

This value considers the following times related to:

- unforeseen events (strikes, accidents)
- time waster due to excessive urban stops
- technical problems (no electricity, blocked level crossings, poor maintenance)
- professionalism of staff and drivers
- service management issues

This step is useful to validate the application of a modal choice model considered as a "random utility" model, within which each choice alternative is associated with a utility function.

Table 3. ALTT description for each evaluated transport mode

Transport mode	Average Linear Travel Time (minutes)	
Own vehicle	$ALTT_{odcar}$	$T_{avg\ vehicle\ recognition}$ +($T_{avg\ on\ board}$ + $T_{avg\ travel}$ +$T_{avg\ parking\ election}$) + $T_{avg\ off\ board}$ +$T_{avg\ walking}$
Car-sharing	$ALTT_{od\ carsharing}$	$T_{avg\ vehicle\ recognition}$ +($T_{avg\ on\ board}$ + $T_{avg\ travel}$ +$T_{avg\ parking\ election}$) + $T_{avg\ off\ board}$ +$T_{avg\ walking}$
University minibus	$ALTT_{od\ DRTbus}$	$T_{avg\ waiting\ time}$ + ($T_{avg\ on\ board}$ + $T_{avg\ travel}$) + $T_{avg\ off\ board}$ + $T_{avg\ walking}$

Study Area Description

Enna is a mountain city consisting of 3 large districts (Pergusa, Enna Alta and Enna Bassa). The district of Enna Alta is a residential and touristic area with many offices and shops, the streets that connect Enna Alta with Enna Bassa are very steep and do not have dedicated lanes (bicycle, bus or emergency). The district of lower Enna is residential but also home to hospitals, universities and many schools and supermarkets.

The streets of Enna bassa have a lower slope and are characterized by the presence of sidewalks that make it possible to walk.

The study was conducted considering the different modes of transport commonly used by students for home-university travel (defined with home-school motivation).

It was considered appropriate to consider that travel distance within 500 m are generally made on foot while those with a greater radial distance require the use of different modes of transport as shown in Fig. 1. In the estimation of distances, the centre corresponds to the evaluated campus, defining as the travel destination correlated to the interviewed students.

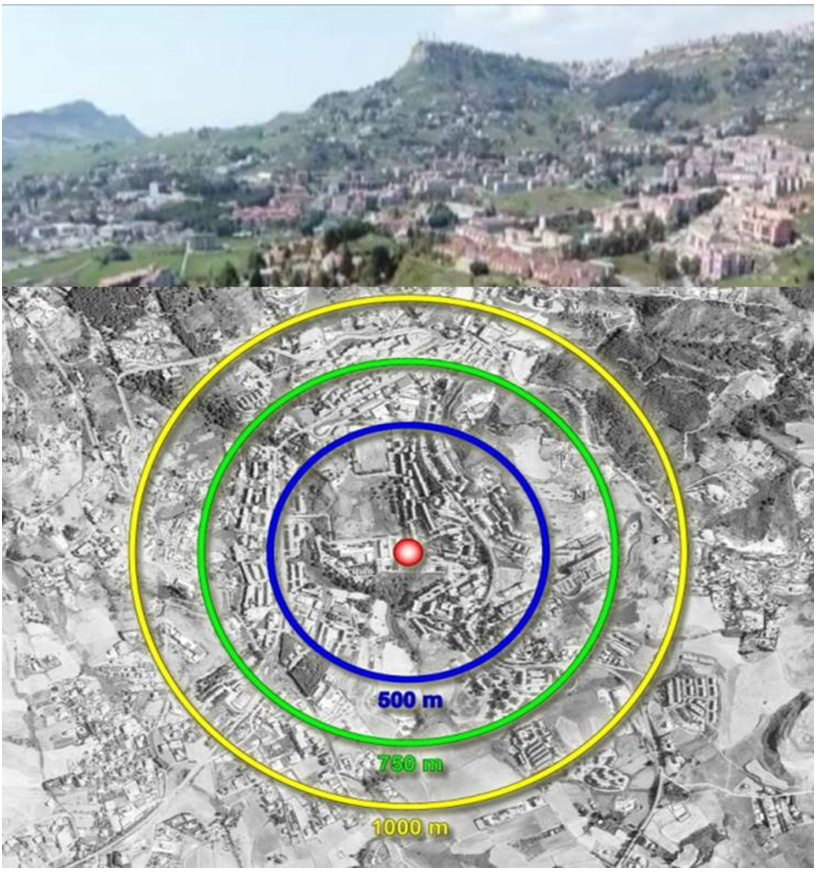

Fig. 1. Radial distance for mobility related to the monitored area

The University of Enna Kore is located between the neighborhood of Santa Lucia (O1), Sant'Anna (O2) and Ferrante (O3) while a new campus located around 3 km away in not urban area. The investigated faculties are located in the Ferrante area (O3) like described on Fig. 2 below.

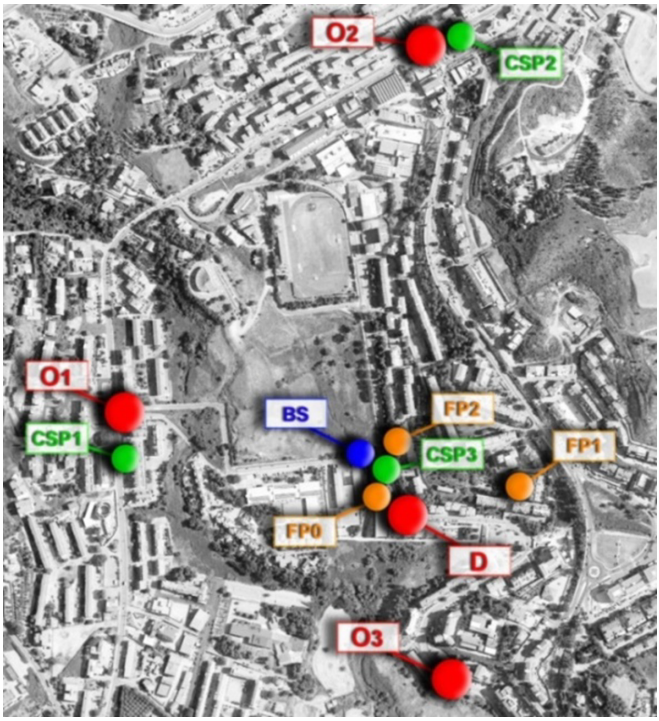

Fig. 2. Investigated main nodes of the investigated area

Estimates of travel time took into account the parking areas located near the Campus and the interview with a sample of students showed that the FP0 free parking lot reserved to enrolled students was always occupied, being undersized for the students' transport demand.

The free parking areas generally selected by students are called FP01 and FP02.

On-site surveys and interviews showed that the free parking spaces analyzed have 99% occupancy rates for Campus P0 and 85% and 75% for free parking spaces named P1 and P2 respectively. The OR values were obtained both from the respondents' opinions and from observation through the cameras.

The value of the occupancy rate refers to the time period in the morning between 8:00 and 10:00 a.m. when students generally go from school to university.

This occupancy rate varies during the day due to the movement of people living in the surveyed areas for various reasons. During this period, in fact, there is generally the absence of vehicles of non-university residents and the presence of their cars living or arriving in that area.

All the evaluated residential areas are characterized by a value equal to 90% as they are inhabited by university students and therefore the fact of not having considered the movements of non-university residents did not have much influence on the results.

To date, only two of the three areas have car sharing parking spaces less than 50 m away. In fact, the O3 has no stalls for this service.

During the selection of the parking area, students preferred to first find a place in the reserved parking lot, then aim to find a free parking space and then use paid parking as the last option.

As for the minibus, all students of the University can use this system for free by showing their university card on board.

Tables 4 and 5 show a schematization of the areas of origin/destination of the sample movements as described by the results of the interviews.

Table 4. Origin nodes and relative description

Origin	Definition	Potential transport Demand/supply	Transport mode
O1	Santa Lucia	125	Own car Car sharing Minibus
O2	Sant' Anna	109	
O3	Ferrante	200	Own car
CSP1	Car sharing (3 stalls) Santa Lucia	8	Car sharing
CSP2	Car sharing (5 stalls) Sant'Anna		

Table 5. Destination nodes and relative description

Destination	Definition	Potential transport Demand/supply	Transport mode
D	University Campus	2100 (TS)/442 (IS)	
FP0	Free parking (25 stalls) Campus	25 stalls	Own car
FP1	Free parking (20 stalls)	20 stalls	
FP2	Free parking (15 stalls)	15 stalls	
BS	Bus stop	2 bus stop origin 1 bus stop destination	Minibus
CSP3	Car sharing (3 stalls) Campus	3 stalls	Car-sharing

The selected itineraries are showed on figures below.

The origin and destination nodes of each route have been highlighted in red. The green nodes represent the car sharing stables, while the yellow ones represent free parking. Considering the Origin in O1,

Figure 3 shows the transport network defined by a graph described by arcs and nodes. The different eligible routes were IT1, IT2 and IT7 for the private and shared mobility system.

The origin and destination car parks in car sharing and the free car parks used mainly by students going to the Campus have been identified.

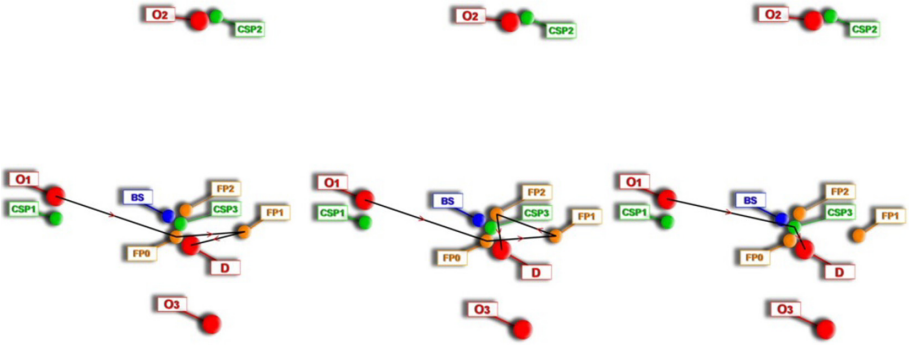

Fig. 3. Itinerary IT1-IT2-IT7 networks with O1 origin for own and car sharing

The same was also done for the O2 and O3 centroids as shown in the two figures below (Fig. 4).

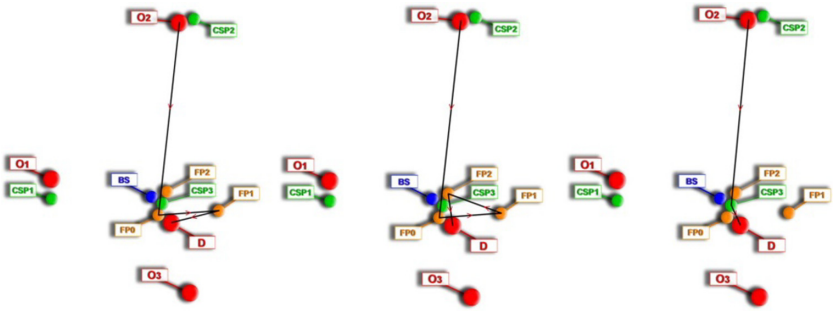

Fig. 4. Itinerary IT3-IT4-IT8 networks with O2 origin for own and car sharing

All the roads used are of a dual lane secondary suburban type with bus stops on the right (Fig. 5).

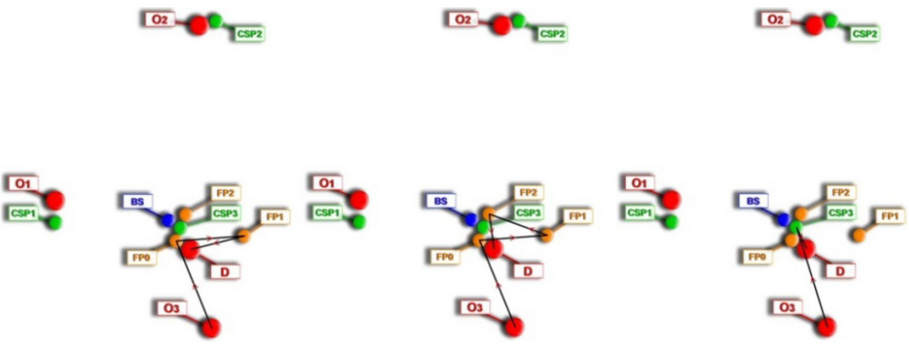

Fig. 5. Itinerary IT5-IT6-IT9 networks with O3 origin

In particular, the DRT bus service and relative presence of stops for the exclusive use of university students was assessed, with stops for getting on and off near the places of origin of the movement and a unique destination stop as shown in the figure below (Fig. 6).

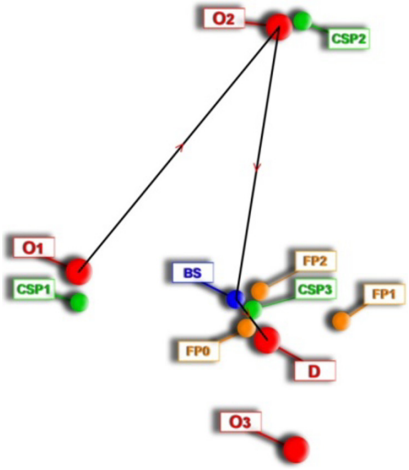

Fig. 6. Itinerary IT10 related to minibus

Table 6 shows the itineraries according to Origins/Destinations, considering the daily travel of the university students interviewed from Home to School (H-S).

A first analysis on distances was carried out considering the Euclidean measure and the network The Euclidean distances evaluated do not consider the differences in slope between the areas and the presence of main road links. All the distances of the network are greater than 500 m. Moreover, it was estimated that more than 70% of the distances exceed 1000 m, thus increasing the need to move with a motorized vehicle.

Table 6. Monitored network and itinerary details

Itinerary	Origin	Destination	Stops destination	Distance (m)	
				Euclidean	Network
IT1	O1	D	P1	481 m	1251 m
IT2	O1		P2	481 m	1974 m
IT3	O2		P1	758 m	1950 m
IT4	O2		P2	758 m	2673 m
IT5	O3		P1	294 m	1382 m
IT6	O3		P2	294 m	2105 m
IT7	O1		CSP3	481 m	620 m
IT8	O2		CSP3	758 m	1319 m
IT9	O3		CSP3	294 m	751 m
IT10	O1/O2		BS	481 m	1890 m

3 Results

Interview Results

The interviews were carried out during the month of October 2019 to 442 students living in Enna, representing about 20% of the student population of the two faculties. The sample was homogeneously composed of 49% of men and 51% of women between the ages of 19 and 25. The sample interviewed is made up of 90% of the people who have a regular lease and live in the areas surveyed, while 10% are owners of the properties where they live in the same areas.

For the medium distances (500–1000 m) it was observed with regard to the investigated sample (IS) that the distribution of transport modes reached a value of 70% for users using private cars instead 27% chose the mini-bus, and similarly 1.5% for both public transport (PT) and shared mobility (MS).

PT was not considered as a mode of transport in this first phase of analysis as it was used by a small percentage. The reason for this value is related to the free ticket and the dedicated service with a higher travel frequency and stops closer to the University. With regard to movement habits for the reason H-S was obtained that:

- considering the distance <500 m, more than 55% of the sample travels on foot, 25% by minibus and 20% by car.
- considering the distance between 500 and 1000 m, about 40% of the sample passes every day by private car while about 38% uses the DRT bus while 22% goes on foot.
- Considering the distance >1000 m about 50% go by private car and 45% by DRT bus while 5% continue on foot.

Only 3% of the sample used the car-sharing service for the H-S move once a week.

The DRT bus service allows the transfer of a maximum of 8 users and stops in every area of origin and in front of the Campus area (BS). Approximately 98.5% of the sample has not yet used H-S in Enna as the rates and the subscription are expensive.

The remaining 1.5% used MS from April 2019 to January 2020 at least once, opting for sharing with other users. In fact, vehicle sharing with other users is viewed positively by more than 85% of the sample as it allows to halve the costs of the service. In addition, about 80% of the sample has a driving licence and finally about 30% have already had experience in Italy with the car sharing service.

Microsimulation Results

The travel time estimate was made by initially considering the average travel time value for each mode of transport analyzed and comparing this value with the value perceived by the individual users expressed during the interview.

Through the use of traffic micro-simulation it was possible to accurately assess this concept of lost or gained time. With reference to the output data of the micro-simulation and the mathematical evaluation defined in the previous paragraphs, it was possible to obtain the following data from the table (Tables 7, 8 and 9).

Table 7. Interval of gain time for each itinerary

$DT_{gain\ time}$ Considering travel time on board (min)			
	P1	P2	BS
O1	62%	82%	81%
O2	71%	84%	59%
O3	66%	83%	/

Table 8. Average Linear Travel Time (ALTT) with own vehicle

T_{odcar} (sec)		$T_{walking\ avg}$ (sec)	T_{avg} (sec)	T_{avg} (min)	$T_{StudentPerceived}$ (min)
IT1	251,01	450	701,007	12	20
IT2	322,21	380	702,212	12	15
IT3	301,79	450	751,790	13	20
IT4	460,78	380	840,782	14	20
IT5	268,59	450	718,592	12	15
IT6	441,64	380	821,642	14	20

Table 9. Comparison of Average Linear Travel Time (ALTT) without own vehicle

$T_{odcar\text{-}sharing}$ (sec)		$T_{walking\ avg}$ (sec)	T_{avg} (sec)	T_{avg} (min)	$T_{StudentPerceived}$ (min)
IT7	184,189	300	484,188	8	10
IT8	236,167	300	536,167	9	10
IT9	204,301	300	504,301	8	10
$T_{od\ DRTbus}$ (sec)		$T_{walking\ avg}$ (sec)	T_{avg} (sec)	T_{avg} (min)	$T_{StudentPerceived}$ (min)
IT10	806,768	500	1306,768	22	30

Although a time saving of more than 40% was estimated, students expressed through interviews that they intend to use the car-sharing service longer, only if a revised service is implemented and reshaped to the students' needs.

The results show through a linear combination of fares and travel time that the car-sharing service is the one that allows a transfer with the shortest time. This is due to both the location of the origin and destination car parks and the absence of a time rate used to find a stall. In fact, the car sharing system implemented on the university campus provides for the presence of dedicated stalls instead for transport by private vehicle provides free and paid parking.

The most common approximation of the generalized cost of transport consists in considering two factors, namely time and cost according to

$$C_k = \alpha(ALTT)_k + \beta(AD)_k$$

Where C_k = travel cost

ALTT = average linear travel time
AD = arc distance (m)
α, β = specific parameters

It was found that a function such as the one described above can explain 60–80% of the total value of the travel choices. The unreasonable times are instead related to perceptions, variability of cost information or general errors. Therefore the next research step will be to find the values of a and b in order to assess the overall cost of the defined travel.

4 Conclusion

The sustainable development of an area with a university vocation is closely linked to preventive transport assessments that can mitigate the discrepancies between demand related to students and those working at the university and supply in terms of services and infrastructure. It is desirable to disseminate policies that can guarantee shared or public services, preferably with low environmental impact, to the growing demand for university students and allow the spread of new forms of mobility. The vision of a functional university campus is closely linked to the supply of transport that allows students to reach their destination. It is therefore necessary to extend the conventional notion of accessibility, seen as simply related to the demand for physical mobility, and take it as an indicator of the quality of urban space from the point of view of movement. Accessibility must be understood as the immediate and total usability of the built space, giving the user the management of his or her time. Accessibility is guaranteed with a positive trend through urban planning that presupposes the development of services such as parking lots or new stalls for public mobility. Survey campaigns and periodic interviews can highlight the advantages and critical points of the services provided.

The present work shows a methodology for the choice of mobility based on the concept of travel time acquired with microsimulation tools and recalculated by combining various time rates through a linear combination.

The accessibility of a university campus where car sharing services have recently evolved. The main objective is to understand the actual propensity of each student to use sustainable modes of transport, decreasing the use of private vehicles. The analysis was carried out through different phases: the first one was related to the acquisition of traffic data through sensors and video cameras considering the analysed area. The second phase was related to the acquisition of student data through the administration of questionnaires. The results were used for the calibration of microscopic models that allowed to evaluate the travel time for each mode of transport examined.

The third step was linked to the calculation of average travel times in order to compare the different modes of transport and have a first "vision" of the students' transport habits. In particular, the research considered the possibility of using the private vehicle or alternative forms of mobility such as the DRT bus and car sharing service. The evaluation of travel times with one's own vehicle considered the possibility of free parking as the first choice, considering at peak times the occupancy rates of the three observed parking areas. The synergy of local authorities with universities could lead to a mobility model in line with the sustainable development objectives defined in the United Nations Agenda 2030 and therefore to a more environmentally friendly, economically efficient and more integrated system. The work is preparatory to a subsequent evaluation of the cost of transport according to the previous equation and also to the evaluation of the probability linked to the choice of transport modes with the implementation of the logit model for a random choice of transport.

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