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Data-based understanding and optimization of sustainability of university mobility: two case studies

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Data-based understanding and optimization of sustainability of university mobility: two case studies

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Abstract. Recently, Italian universities started to collect data on the mobility choices of their communities, in an effort to move towards more sustainable forms of transport. Two examples will be detailed here. First, to foster a significant shift from car to sustainable transport in commuting, car parking space inside university locations will be allocated using individual "sustainable accessibility" indices favoring people that have real difficulties in adopting more eco-friendly modes of transport. To this end, we harness all available data on public transport services as well as road traffic to assess how fast and comfortable commuting sustainably is compared to traveling by car for any specific individual from home to university. The whole process will be web-based, allowing for fast batch computation of such indices for large numbers of people. Second, since university mobility management includes agreements with suppliers of mobility services (such as sharing), offering incentives for their use, we try to shape such agreements based on a community consultation to determine what are the sharing services subscription arrangements most appealing to interested users, thus maximizing their potential.

1. Introduction

The University of Turin (UniTo) is a large athenaeum (around 85,000 individuals) scattered among over one hundred locations in the metropolitan area. The residential area covered by its community is also very extensive, since the Piedmont region has only one additional university center (UPO), smaller and offering a more limited range of fields of study. In 2018/19, 41% of UniTo students came from outside the province of Turin, while 34% were domiciled in the province but outside the capital.

UniTo aims to improve its overall environmental sustainability, within the framework of the *Italian University Network for Sustainable Development* (RUS), and in 2016 created a specific branch, the *Green Office*, dealing with issues concerning energy, food, public procurement, waste, climate change and *mobility*. Its home city of Turin, moreover, is a critical context, lying in the Po valley, one of the most polluted areas in Europe (Horálek *et al.*, 2016), and is among the worst cities in Italy in terms of air quality, with a higher car modal share than its neighbors Milan and Genoa (ISFORT, 2021).

Due to its sheer size, the impact of daily home-university journeys at UniTo strongly contributes to shaping the mobility of Turin and the metropolitan area, with significant repercussions on road congestion, air pollution and use of public space. One of the main problems concerns the parking of arriving private cars. While UniTo has no direct competence on the management of the road network and public transport services, it does have its own parking spaces whose management can potentially be used to implement policies to discourage the use of private cars when there are efficient transport alternatives. The demand for internal parking spaces is also growing due to the progressive extension of public areas with parking fees, which make parking inside university structures more attractive. In this context, the SUSTAIN project (*Specific User Sustainability Through Accurate Index Number*) aims to encourage sustainable mobility choices in a targeted and innovative way, leveraging the allocation of parking permits for internal parking spaces. Obviously, the availability of a safe and cheap parking space is a significant incentive to choose the car as unimodal means of transport, especially in high-density urban contexts. SUSTAIN will be presented in Sec. 2-7.

Another context in which a university can assert an influence on mobility choices is to arrange for monetary incentives to be offered to its community members when using sustainable transport services. To make this process as effective as possible, after soliciting initial proposals from the full range of sharing mobility firms in the city, a survey was conducted to inquire about expectations and desires of the community on every detail of the related subscriptions: price, duration, type of shared vehicle, etc. Results from the survey were finally returned to the firms, so as to enable them to fine-tune the final agreements. The whole process and its first results are described in Sec. 8-9.

2. The new “Luigi Einaudi” Campus: a case study

In 2012, the new "Luigi Einaudi" Campus (CLE) was activated; it is today one of the main seat of the University aggregating many thousands of people. To comply with current legislation, CLE includes a large car park (500 units), to avoid overcrowding the neighborhood with parked cars of people coming to the campus. This remained largely empty for years (also due to the monthly fee of € 10 - low but not free); things changed considerably in 2017 with the introduction of parking fees (more than 6 times the cost of the internal one) in the surrounding area. It became therefore necessary to define how to manage the allocation of permits selectively, based on criteria linked to sustainability as far as possible. This case is not only relevant in itself, as the creation of already planned new structures with attached parking will create similar contexts, as will do the reorganization of the parking spaces of existing offices, now managed with heterogeneous and often inconsistent rules.

Finally, sustainable innovation regarding car parking management has a strong potential outside university as well, as it could be adopted and used for the management of public - or even private - spaces in contexts where this is a scarce resource, such as dense metropolitan ones.

3. Project SUSTAIN

Starting from these premises, the project aims to establish innovative and rational criteria to promote sustainable mobility in the university, recognizing the diversified mobility needs of individuals, with heterogeneous levels of actually achievable sustainability. The best results will derive from a combination of choices and opportunities based on the use of all available data, optimizing overall sustainability without excessively penalizing less eco-friendly travel arrangements in the most difficult cases. The guidelines of the project are therefore:

- *Equity*: allow access to parking to those who have a real need to travel by car, discouraging others;
- *Efficiency*: obtain the needed information in a simple, fast and convenient way from a web platform;
- *Extensibility*: define and implement criteria that can be easily extended to different contexts.

The goal is therefore to create a system of disincentives to use the car "door to door" based on a *sustainable accessibility index* that involves all the relevant information (the origin-destination matrix and the travel options available) and can be obtained using web resources largely available.

For any origin-destination, the index will summarize the comparative advantage of traveling by car compared to the best multimodal solution combining active mobility, public transport and sharing. It will be computed by a customized version of the existing open source routing engine (OpenTripPlanner) that the Piedmont Region uses for www.muoversinpiemonte.it, its *info-mobility* platform, that delivers the best public transport solutions available for any origin-destination.

The algorithm should not be limited to comparing travel times, involving all features of the sustainable travel options in term of comfort and commitment: e.g. the length and mode of the first and last legs of the journey as well as the number and duration of intermediate connections with respect to a reference "ideal" connection time (e.g. too risky if less than 10 minutes, too long if more than 15 minutes). In addition, the frequency during the whole day of similar solutions could be considered, as well as their average characterization such as speed. In conclusion, the index will therefore represent a measure of the overall comparative quality of the journey from home to university with the least possible use of cars, versus one made entirely with one's own car.

Parking permits will normally be awarded to those with a low value of the index (i.e. a low level of sustainable accessibility), whose car journey is significantly faster and more comfortable than the best sustainable option. Those who, on the other hand, can travel by active mobility plus public transport as fast - or even faster - than by car, will generally not be granted the permit[1]. Obviously, the lack of parking permit does not imply that you cannot come to the campus by car; however, it does entails some disincentives: paying the higher fees of public parking lots, a possibly bigger distance between the car park location and the campus, as well as a longer time to find a place for your car.

4. Customizing the routing engine

To fulfill the needs involved by the computation of the sustainable accessibility index, the routing engine should provide uni-modal or multi-modal travel solutions between any two points in the region combining walking, cycling, rail, bus/tramway/metro services, or even limited car use: in some cases a fully sustainable travel option may not exist, but allowing car use for the first 5-10 kilometers as the first leg could allow you to connect to the public transport network and complete the journey in a sustainable way (as long car is limited to the first leg, no car parking at university is required).

It is also necessary to allow calibration of relevant parameters, such as the maximum distance covered on foot, by bike and by car, and the waiting time - as well as the distance to be covered on foot - for connections between public transport services. The number of travel solutions provided by the engine, referred to a user defined arrival time, should be adjustable if more than one is available.

For each proposed path, the output will provide the following data: total estimated travel time; number of sections; mode used in each section; connection times; length of active mobility stretches.

In addition, it will produce an assessment of how frequent are similar solutions throughout the day, and the average values of the same parameters for all solutions throughout the day.

The customized routing engine will interact with users applying for a parking permit through a web-based layer that will allow them to precisely specify their home location on the map; it will also perform the geo-referencing of the point in space, providing the input for the routing engine.

5. A preliminary version: the isochrone approach

During 2019-20, given the need to start regulating car access to the Campus parking lots, a simplified, preliminary version of the methodology was implemented and put into action. In this (see Fig. 3), users applying for a permit were asked to first locate their home on a dedicated web page showing a map rendition of Turin and Piedmont; the same map was then painted in two different fashions: with isochrones colored in terms of travel times to the Campus by car, and by the multimodal solution provided by the routing engine combining active mobility and public transport. In the isochrone maps, each different color indicated a 15 minutes span.

Finally, applicants would forward to the university staff, together with their personal details, the two colors where their home seat was located in the isochrone maps, so that a simplified version of the index could be computed on this information alone. The flaws of this initial process are self-evident: the index is based solely on the duration of journeys, ignoring all other possible factors listed in Sec. 4, and the time difference itself can considerably biased: for example, with fifteen minutes spans going, say, from 15 to 30 and from 30 to 45 minutes, the index for a person with a 29 minutes car journey and a 31 minutes sustainable journey (i.e. where the sustainable alternative is strongly competitive) will

1 The full process of permits allocation will actually be based on the sustainable accessibility index, but on family management needs (such as having young age children etc.) as well. Such cases are however rare for students, for whom the accessibility criteria will therefore be more decisive. Last, some advantage will be granted to eco-friendly (e.g. electric) cars.

share the same index value with a colleague whose times are 16 minutes for the car journey vs. 44 minutes for the alternative (where on the contrary traveling by car is significantly faster). Other drawbacks are there as well: for example, as can be seen in the example in Fig. 3, the shape of the isochrones are quite unrealistic, since the standard routing engine has a fixed limit to the distance covered by the first leg on foot, and when a home is further away than such limit from the nearest public transport node, no journey solution is provided and the maps remain undefined (grey).

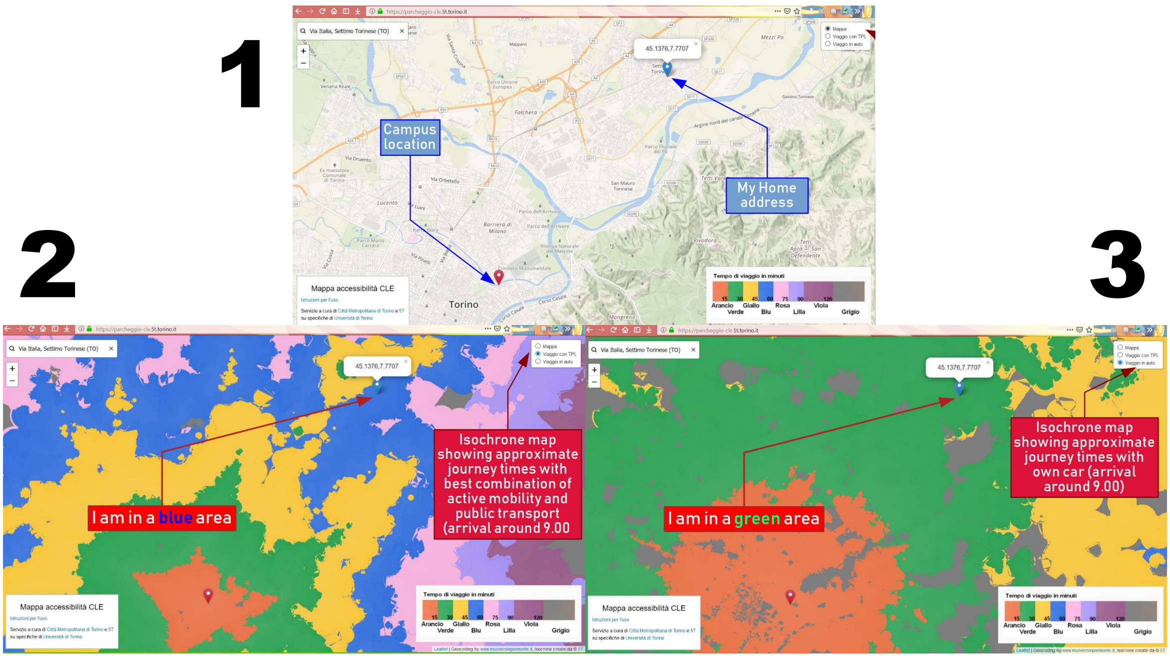

Figure 1. *The three steps of the preliminary procedure to compute the index*

6. Computation and calibration of the sustainable accessibility index

The final version of the index will get rid of these flaws, as its values will involve the exact timings for both travel alternatives, and the customization of the routing engine should avoid cases where no solutions exist due to a too long first leg: in such instances the sustainable solution will include an initial car leg, ending at the nearest public transport node. The index definition however will be more complex: moving from the sole information on journey times to the whole array of data listed in Sec. 4 implies combining heterogeneous values, with no natural metric, to be weighted subjectively. Also, its extreme values (i.e. *maximum* and *minimum* sustainable accessibility) are undefined. Some degree of subjectivity is even implied in the routing engine customization: for example, on a certain journey a long first leg by car could result in shorter times when compared with a solution where a short car leg is in itself more sustainable, but involves much longer travel times: where and how do you set the limit - if any - for the car part of the journey when evaluating the most sustainable solution?

After having defined a reasonable weighting system, to establish the final metric and set the extreme values a preliminary calibration process will be performed, using a pilot survey on a small sample (some 200 cases), starting with an arbitrary metric, checking the actual extreme values for the sample, as well as the variability induced by the involved factors, possibly adjusting their relative weights, and finally rescaling the metric so that extreme values are close to a normalized (e.g. 0 to 1) range. The chosen metric will have to be examined also with regard to its discriminating power: an index ranging from zero to one, but with actual values in the population concentrated between 0.4 and 0.6 in 95% of the cases will not help in distinguishing significantly most part of the population.

7. Further considerations

One of the strengths of the project lies in its *scalability*: the initial reference to the Luigi Einaudi

Campus is in fact coincidental, as the use of the accessibility index can be extended to other branches where UniTO owns parking spaces operated in makeshift ways lacking in terms of equity and/or efficiency. In addition, the involvement of local authorities (both the Metropolitan City of Turin and the Piedmont Region are partners) in the project reflects the interest in the definition of a tool that can be shared on an even larger scale in any context in which public parking spaces have to be managed. In fact, this is a tool that, combined with other criteria deemed suitable in the specific case, allows for the inclusion of sustainability in an effective and targeted way in the governance of mobility, also helping local authorities that have responsibility for the actual governance of public transport systems and mobility in general to identify the priority framework in transport policies.

A further potential use of the technology lies in an assessment of accessibility that is no longer *individual* (how easy it is for the individual to reach a given location), but *structural*, i.e. how much is a given location reachable in a sustainable, but also efficient, way by the whole community that gravitates around it. In fact, having computed the accessibility index for the members of such community - or for a representative sample - the average value of the individual indices (possibly weighted in relation to various possible factors, such as periodic frequency and travel times), it will constitute a highly realistic parameter of accessibility of the structure due to it being based on the situation of the actual community that converges there, rather than on a generic evaluation of the transport services that serve it. In the same line, other statistical indicators regarding the distribution of the index values among members of the same community could offer further insights on the sustainable accessibility of the location: the standard deviation, for example, would suggest how heterogeneous - or, on the contrary, how similar - its level is in the community it serves.

8. Sharing mobility and universities: the road to success

In the last two decades sharing mobility moved from a new concept in its infancy to a consolidated reality in big and medium sized cities around the world (Fishman *et al.*, 2013; D'Urso et al., 2021; Li *et al.*, 2022). However, while its market, even though ups and downs, developed and matured, sharing mobility in university commuting in Italy has remained the choice of a very small minority. At the university of Turin, mobility surveys consistently show it to have never exceeded the 1% mark.

With the aim to increase such share in the near future, in 2021 UniTo developed a multi-step procedure to offer incentives on the purchase of sustainable mobility services. The core of the process lies in its collaborative approach, where the favorable purchase terms for such services could be modeled by the firms providing them considering actual expectations and desires of the community.

The process was structured in several stages: after the mapping of the active services in the metropolitan area of Turin, firms were invited to come forward with the best bargains (involving no financial contribution from UniTo) they could offer to the academic community.

After receiving such "draft" offers, the Green Office and the Mobility Manager carried out a survey to identify the factors that the university community considered most relevant to start using shared vehicles - or to increase their use - in daily commuting. The survey results were presented in a public meeting with representatives of the sharing mobility services; the message conveyed was "If you want to actually increase your customer base significantly, take care of what they really want". Finally, the involved companies finalized and forwarded their revised offers targeted to the academic community.

As hoped, many offers were improved also based on the results of the survey. Looking at the community expectations and preferences has thus allowed all partners involved to define more effective policies, pivoted around the central element of the online survey, helping to find the meeting point between supply and demand.

9. Sharing mobility "the university way": survey results

The online survey was aimed both toward those who had already used shared mobility services, as well as those who, while potentially interested, had not used them yet at the time of the inquiry. Three main macro dimensions were investigated: (a) *type*: what types of shared vehicles are most used, how often and by who in the community; (b) *size*: what is the current - and potential - size of the market for sharing services in the university community; (c) *improvements*: how can agreements between UniTo and service providers significantly bring the community to use (or use more) such services.

In detail, current users of sharing mobility services were asked to specify what were their means of choice (bicycle, e-scooter, moped, car) and how often they used them, while for non-users the survey tried to identify the main reasons that keep people from using them. Further, it asked whether the availability of discounts and incentives could motivate non-users to start using such services, and users to increase their frequency. Finally, it was discussed which types of facilitations were considered most relevant and what was the minimum level of monetary discount deemed necessary to change the present day mobility habits with regard to sharing services. A brief summary follows.

The sample included 3938 cases (86% students, 7% faculty and 7% staff, close to the extent of the three aggregates in the UniTo community). The sample size provides a first indication on the potential size of the sharing market in the university community: at least **4000** people are potentially interested in sustainable mobility services (the actual figure can reasonably expected to be higher, as usual with voluntary surveys). Current users of sustainable mobility services are actually a minority of the survey respondents: overall, just 20%, while more than half are potentially interested but have never tried them and the remaining 25% have tried at least once but without becoming a regular user.

Table 1. *Use of sharing mobility by role*

	Non-user (never tried)	Non-user (tried)	User	Total
Students	54.7%	25.5%	19.7%	100%
Faculty	46.1%	**28.0%**	**25.8%**	100%
Staff	59.5%	19.1%	21.5%	100%
Total	*54.5%*	*25.2%*	*20.3%*	*100%*

Among those who frequently use sharing mobility services 9% of respondents use bike sharing, 17% use e-scooters and 24% use car sharing. Group-wise, students prefer e-scooters (19%) and car sharing (24%), while faculty prefer bike sharing (11%).

The main reasons discouraging use concern the perception of greater comfort and/or safety in using one's own vehicle (as well as logistics), the difficulty in finding the means of transport when needed but also the high costs (in particular for students). A direct question also confirm that the full sample is formed by potential users, as the activation of new, more convenient deals would push 99% of current users to increase their frequency of use, and 93% of non-users to start using the services.

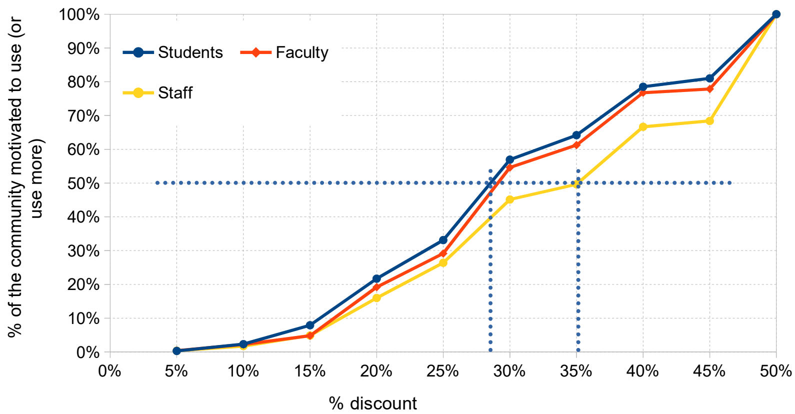

Figure 2. M*inimum discount that can motivate use - or more use - of sharing services*

Another important fact is that the majority of the public feels that sharing services fees are quite expensive; the minimum discount level capable of substantially increase the use of sharing services is in fact around 20%: below this threshold, less than 20% of the sample would change their mobility habits. A 15% discount would involve less than 10% of the sample, while to engage more than half of the university community a 30% price cut is needed (Fig. 2). Furthermore, Fig. 2 shows there are some differences between students/faculty and staff, whereas to move the latter a larger reduction is needed: to involve 50% of students and faculty a 28.5% discount would suffice, but you would need a 35% cut for the staff. Although students' financial resources are usually lower than those of staff, the economic factor alone seems to be less relevant for students, motivated also by other elements.

The vehicles of choice of new users acquired thanks to reduced rates are shown in Table 2. Some of them would embrace a single type, e.g. the bicycle by 17% of them, or the car by 12.5%; others would even adopt more types, as the 16.1% starting to use both bicycle and e-scooter.

Table 2. *Type of sharing to be adopted in case of incentives*

Bike	Bike		Bike		Bike	Bike		Bike		Bike	Bike				**62.2%**
	E-sc.			**E-sc.**	E-sc.	E-sc.	E-sc.	E-sc.					E-sc.	E-sc.	**46.4%**
		Car	Car		Car	Car	Car		Car		Car			Car	**45.5%**
					Mop.			Mop.	Mop.	Mop.	Mop.	**Mop.**	Mop.	Mop.	**22.9%**
17.3%	16.1%	**12.5%**	10.2%	**7.0%**	7.2%	7.1%	4.4%	3.4%	2.9%	2.7%	2.6%	**2.0%**	1.9%	1.9%	**100%**

E-sc.: E-scooter; Mop.: Moped

Finally, on subscription options preferences varied significantly among the three groups (Table 3): students favor more short term subscriptions, as their activity is more unevenly distributed through the year, while the opposite holds the faculty and staff. All durations, however, have their own buyers.

Table 3. *Preferred duration of subscriptions*

	Day ticket	Weekly ticket	Monthly	Seasonal/annual	Total
Student	13.3%	19.4%	**41.9%**	25.3%	100%
Faculty	7.0%	14.0%	35.1%	**43.9%**	100%
Staff	13.2%	11.1%	32.6%	**43.1%**	100%

In the end, in 2022 UniTo activated 10 agreements with sharing mobility companies (Table 4). Five companies brought the discount rate above the 20% threshold (in some cases up to 30%). All agreements do not involve any cost for UniTo as the price cuts weight exclusively on the service providers. The agreements' utilization rates will be monitored, also to evaluate the option of UniTo contributing some resources to increase the discounts.

Table 4. *Main terms of incentive for stipulated agreements*

Type	**Company**	**Main benefits**
e-scooters	Link	**30%** discount on the basic rate; discounted 24h subscription
e-scooters	Helbiz	**25%** discount on the rental and 5 free unlocks upon registration
e-scooters	Dott	**15%** discount on basic rate; credit bonus for new users and for every 50 runs
e-scooters	Voi.	1 free 30-minute ride for new members and **15%** discount on monthly passes
e-scooters	To.Tem	**30%** discount on the purchase of scooters and accessories
cars	Enjoy	discounted rental for some cars; free booking first 30 minutes; welcome voucher
cars	Share-Now	credit bonus and free membership
bicycles	Bicincittà	**20%** discount on all purchases
e-mopeds	Zig Zag	**30%** discount on all rentals; special price for the purchase of a 200-minute package
bus	Cavourese	**5%** discount on the extra-urban annual pass; **5%** discount Liguria shuttle

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