# Policies for Enhancing Mobility in Academic Campuses: The case of CERN

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## Περίληψη

Η παρούσα εργασία αναλύει τις υπάρχουσες συγκοινωνιακές συνθήκες και τις ανάγκες της κοινότητας του CERN, καθώς επίσης αξιολογεί ενδεχόμενες λύσεις για τη δημιουργία ενός βιώσιμου συστήματος μεταφορών για την κοινότητα του CERN. Για να αναλυθούν οι συνήθειες μετακίνησης και η ικανοποίηση των μελών της κοινότητας του CERN, αναπτύχθηκαν μοντέλα δηλωμένων και αποκαλυπτόμενων προτιμήσεων. Στη συνέχεια, δομήθηκαν και αξιολογήθηκαν διαφορετικές πολιτικές κινητικότητας μέσω λογισμικού προσομοίωσης. Τα αποτελέσματα οδηγούν σε εφαρμογή συνδυασμένων στρατηγικών που βασίζονται σε επιδότηση εισιτηρίων των Μέσων Μαζικής Μεταφοράς και λύσεις στάθμευσης εκτός του περιβάλλοντα χώρου του CERN. Οι παραπάνω πολιτικές, φαίνεται να οδηγούν σε σημαντικές κυκλοφοριακές και περιβαλλοντικές βελτιώσεις στο εσωτερικό οδικό δίκτυο του CERN, με το πιο αποτελεσματικό σενάριο να μειώνει τη μέση καθυστέρηση στο δίκτυο κατά 13% και να αυξάνει την ταχύτητα κατά 6,5%, ενώ από περιβαλλοντικής άποψης επιφέρει μείωση 5,13% στο CO2, 8,59% στο NOx, 10,39% στο PM και 5,26 στο VOC.
**Λέξεις κλειδιά:** *Πολυωνυμικά μοντέλα, επιλογή τρόπου μεταφοράς, προσομοίωση*

## Abstract

This work analyzes existing transportation conditions and needs of the CERN community and evaluates solutions for establishing a sustainable transportation system for the CERN community. Stated and revealed preference models are developed to analyze the travel habits and satisfaction patterns of CERN community members. Following, different mobility policies are structured and evaluated using simulation. Findings support the implementation of combined strategies based on public transportation ticket subsidization and parking solutions outside the campus. Such policies are found to provide significant traffic and environmental improvements to CERN's inner road network, pinpointing that the most efficient scenario, improves average delay and speed by approximately 13% and 6.5% respectively, while an improvement in the environmental conditions is also achieved with a decrease of 5.13% for CO2, 8.59% for NOx, 10.39% for PM and 5.26 for VOC.
**Keywords:** *Campus traffic, MNL models, mode choice, simulation*

## *1. Introduction*

Academic and research institutions worldwide are established or relocated to city outskirts or rural areas, in an effort to move away from congested city centers. Such decentralized locations offer advantages, such as additional space for facilities and infrastructure, and an environment of improved quality to members, suitable for research and academic endeavors. Throughout the years, these institutions have been transformed into independent communities (RA communities) with the size, infrastructures, and activity levels of small cities.

Constant growth of research activities in these RA communities has led to considerable increases of both incoming and in-community demand for transportation. RA communities attract on a daily basis, significant numbers of trips by their members and visitors, while facility expansion requires specialized transportation infrastructure for facilitating in-community mobility needs. To this end, modern RA campuses/communities have fully developed road, bicycle and pedestrian networks, parking facilities and in-campus public transportation services (Kaplan 2015; Longo et al. 2015).

Locating research institutions in rural areas - despite its advantages - has often proven to be problematic, particularly because of difficulties in their accessibility. Indeed, RA campuses frequently suffer from the lack of transportation options other than private vehicles for accessing their facilities, leading to extensive carr usage by their members (dell'Olio et al. 2014, Kaplan 2015). Further, car usage has a distinct negative effect on in-campus mobility, since private vehicles have to use the campus road network and therefore contribute into producing adverse environmental and health consequences (Shannon et al. 2006). Factors such as spatial sprawl of infrastructures around the campus and the concentration of activities in a limited number of facilities (meeting and office spaces, restaurants and so on) also promote the use of private vehicles and therefore provide additional barriers to sustainable in-campus mobility. These facts result in over-utilization of the campus transportation infrastructures, reduced traffic safety for pedestrians and cyclists, higher levels of air pollution and reduced mobility options.

The CERN community is a typical case of an RA community located at the outskirts of a large city (Geneva), close the French borders (with part of the campus actually within French territory). With approximately 2500 CERN staff members, 7500 users and over 25000 visitors on an annual basis, the CERN community produces a considerable number of well over 5000 daily trips to and from the site. Currently, CERN is accessible by private car and bus (connecting the site with the railway station and Geneva airport). Coupled with these impressive numbers, is CERN's policy with a clear commitment towards minimizing any environmental impacts from its wide range of research activities.

From a transportation perspective the above characteristics are a major cause of traffic congestion. As the CERN campus is segregated from the urban web and its research activities are constantly expanding, CERN community members are leaning towards private vehicles for their transportation needs. The impacts, both direct and indirect, of the degradation of CERN transportation system and campus life are depicted in Table 1.

***Table 1:** Causes and effects of the degradation in CERN's transportation system*

| **Causes** | **Direct effects** |
|---|---|
| Increased research site's activity and population | Over 5000 daily trips to and from site |
| decentralized location | favors mostly trips with private vehicles at the expense of cycling, pedestrian and mass transit transportation alternatives |
| *Indirect effects* | |
| negative effect on in-campus and around-campus mobility | negative in-campus and around-campus environmental impact |
| research community's dissatisfaction with downtown-like way of life | reduced level of service for parking, cycling and walking facilities |

As transportation systems are expected to serve community needs, their evolution has to adjust in contemporary community needs and even further to envision the future development of the community (Schneider and Hu 2015). In CERN's case, the quantitative accumulation of traffic demand in the campus facilities has already evolved in such a critical level, under which, ceteris paribus, the transportation system and campus life have been degraded as a whole.

Within this context, effective planning of CERN's research/academic community transportation system is critical for providing efficient, environmental friendly services to its members and visitors and protecting - enhancing the inherent advantages offered by its location. Such a planning should rely on the actual habits, needs and requirements of the community members and visitors and would ideally focus on developing a sustainable and environment friendly transportation system.

The scope of this work is to analyze current transportation conditions and needs of the CERN community, and to highlight efficient solutions for establishing a sustainable transportation system for the CERN community. Stated and revealed preference models are developed to analyze the travel habits and satisfaction patterns of CERN community members. Based on these models, as set of mobility policies are structured and evaluated using simulation. Traffic data is in selected locations of the CERN's inner road network are exploited for simulation calibration and evaluation purposes.

## 2. The CERN Campus

About 12,000 people work and/or visit the campus in a daily basis; about 75% of them travels to CERN from and to France and the rest 25% originates from Switzerland. A large number of facilities are established in the campus including laboratories, offices, auditoriums, a library, hotels, restaurants, a fire station, a medical center etc. Most of these facilities are located in the Swiss part of the campus which is characterized by a dense urban structure. Furthermore, there exists a number of parking areas next to different (CERN) facilities.

The Meyrin campus can be accessed by automobile from Geneva by using route Meyin (moving in parallel to the main campus northern border) or "Chemins de Franchevaux" street (south – southeast of the campus). Access from France is possible by using autoroutes D35 or D884 and their connecting roundabout with CERN or the route d' Europe and the tunnel entrance to the campus. Coupled with these impressive numbers, is CERN's policy with a clear commitment towards minimizing any environmental impacts from its wide range of research activities. Apart from private vehicles, access is possible via bus and tram. There is a 10 min bus service (bus number 56) from CERN to the nearest tram station of "Vaudagne" (tram line 14). The distance between the Vaudagne tram station and the CERN Entrance A is approximately 2.2 km. Also, CERN has established a weekday regular shuttle service to and from Geneva airport every 30 min, from 8:00 to approximately 18:00. Private vehicles are practically the best and easiest option for approaching the Meyrin Campus, since bus accessibility is limited to a single bus line (with a 10 min frequency of bus arrivals).

The mobility services offered at CERN are the following:

- CERN Cars
- CERN Shuttle Bus
- Carsharing System
- Bikeshare

Entrance to the campus from Switzerland (and also from France) is possible from three gates for personnel and visitors (Entrances Meyrin A, Meyrin B and Meyrin C) and one gate for goods (Entrance Meyrin D) (Figure 1). Entrances A, B and D are located alongside route Meyrin, while Entrance C is located next to "Chemins de Franchevaux" street. Entrance B is the campus main gate and operates 24h per day. Entrance A operates Monday to Friday from 7:00 to 19:00, while Entrance D operates again Monday to Friday from 8:00 to 12:00 and from 13:00 to 16:00. Entrance C is currently not operating. On the other hand, entrance from France is possible through the tunnel gate, which operates Monday to Friday from 7:00 to 18:00 and Entrance E (Charles de Gaulle). Entrance E in particular is open on weekdays only, as an entrance between 7:00 and 9:30 and as an exit between 16:30 and 19:00. Figure 3 indicates campus entrances.


***Figure 1:*** *Meyrin Campus Entrances.*

## 3. Survey Info and Descriptive Statistics

A total of 1104 individuals participated in the research, out of which 564 completed the entire questionnaire. The majority of the sample is male and approximately two thirds of the respondents reside in France, 27% in Switzerland and the remaining 11% inside CERN (CERN Hostel). In addition, 43% of the sample is staff members that conduct primarily scientific work (experimental and theoretical Physics). The duration of the period working at CERN varies from 2 months to 46 years, with an average of 11 years. From the above statistics we concur that the sample is fairly representative of the population of CERN staff. Moreover, the majority of the sample has at least one car available on a daily basis for his/her trips, while the respective number of motorcycles is significantly lower.

The majority of the sample (17%) is from France, followed by Germany, Italy and United Kingdom. The category Other includes nationalities with less than 1% in the overall sample, such as Canada, Israel, China, Denmark, Hungary, India, Belgium, Mexico, South Africa, Slovenia, etc. The age of the sample ranges from 18 to 84 years old, while on average the samples' age is 39 years old.

### 3.1 Mobility Patterns

The vast majority of France residents have at least one car available on daily basis which can be attributed to the lack of alternative modes serving the area. On the contrary, a significant percent (30%) of both Switzerland and CERN Hostel residents have no car available on a daily basis. the average distance for both France and Switzerland residents is relatively the same. Table 2 presents the mode choice in relation to the distance traveled and the place of residence.

France residents due to the lack of alternatives use private modes regardless of travel distances. In contrast, the share of private and public transport modes in Switzerland residents is approximately equal for distances up to 10km.

***Table 2:*** *Distance between CERN and Residence Place per Transport Mode and Residence Place*

| Switzerland Residents | | | | | | |
|---|---|---|---|---|---|---|
| **Transport Mode** | 0-3km | 4-5km | 6-7km | 8-10km | 11-18km | More than 19km |
| Private Transport | 37.5 | 45.0 | 38.2 | 40.7 | 56.5 | 64.0 |
| Public Transport Mode | 33.3 | 40.0 | 41.2 | 37.0 | 21.7 | 28.0 |
| Active Transport | 29.2 | 15.0 | 17.6 | 18.5 | 21.7 | 4.0 |
| Combination of Modes | 0.0 | 0.0 | 2.9 | 3.7 | 0.0 | 4.0 |
| **France Residents** | | | | | | |
| **Transport Mode** | 0-3km | 4-5km | 6-7km | 8-10km | 11-18km | More than 19km |
| Private Transport | 68.1 | 69.6 | 82.7 | 97.1 | 96.4 | 100.0 |
| Public Transport Mode | 6.4 | 5.8 | 3.8 | 0.0 | 0.0 | 0.0 |
| Active Transport | 25.5 | 24.6 | 13.5 | 2.9 | 3.6 | 0.0 |
| Combination of Modes | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

More than half of the respondents depart from their residence between 07:45 to 09:00 o'clock, while for their return trip approximately two thirds of the respondents depart from CERN between 18:00 to 19:00 o'clock.

The majority of the trips from Home to CERN and CERN to Home for both Switzerland and France residents are simple, meaning that no other activities take place along their commute trip. Approximately 12% of France residents and 5% of the Switzerland residents, conduct at least on stop both on their way to CERN and on their return trip from CERN to their residence place, while the percent of France residents that conduct at least one stop during their trip from Home to CERN is less than 1%.

Drop off and pick up children is one of the main reasons that respondents stop, while shopping and sports takes place only during individuals return trip. Moreover the duration of each stop may vary from 1 to 45 minutes, and on average 10 minutes/stop.

The activities that are being undertaken by France residents during their stops are similar with those of Switzerland residents. Drop off/Pick up children and shopping are the main stop purposes. Moreover the duration of each stop varies from 1 to 90 minutes, and on average 22 minutes/stop, thus compared to Switzerland residents, France residents conduct stops of longer duration.

### *3.2 Characteristics of Trips inside CERN*

In order to be able to analyze in depth mobility characteristics of in-campus CERN travel patterns, the CERN area was divided into 10 zones (Figure 3). A significant percent of the respondents conduct two to four trips per day within CERN (48.6%), while approximately 14% stated that they do not make any trips.

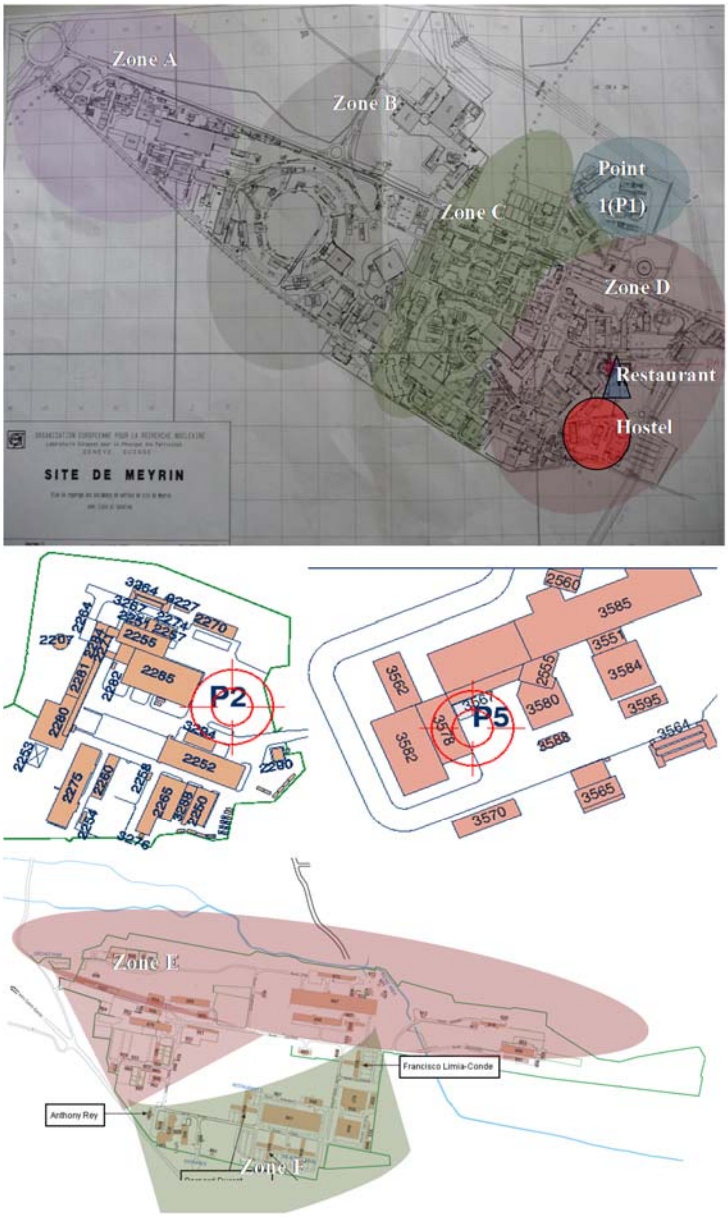


***Figure 2:** CERN Zones.*

Survey results reveal that those who are employed for scientific work (experimental and theoretical physics) and scientific and engineering work, conduct on average 3.6 and 3.3 trips per day within CERN, respectively. The majority of the trips, approximately 18.5% takes place within Zone D, followed by trips between Zone C and Zone D, as well as between Zone D and the Restaurant. Other combinations include all the O-D pairs that have less than 2% of the overall number of trips.

Approximately 60% of the trips inside CERN are pedestrian trips, while 21.5% are private car ones. However, as expected, when the distance between the origin and the destination increases, the share of walking decreases. Figure 3 presents the modal split inside CERN per O-D pair, where it becomes obvious that as the distance between the origin and the destination zones increase the usage of private car dominates (such as C-D, B-F, C-F, etc.).

### *3.3 Private Car Users inside CERN and Parking choice Behavior*

According to the survey findings, two thirds of the respondents are willing to cycle inside CERN, provided that showers and lockers would be placed in their workplaces. Moreover, the creation of bike paths, as well as of protected bike stations available around the CERN campus would also encourage a significant portion of current car users to start cycling. Approximately 60% of the respondents are willing to replace their car trips inside CERN with walking or cycling in order to exercise and less than 8% is not willing to walk due to safety concerns.

The vast majority of the respondents that comes to CERN by car (95%), park their car near their office building. More than half of the car users (56%) are not willing to walk more than 10 minutes from the parking location to their office, while approximately 9% of the sample has members of their family parking at CERN to take the TRAM to Geneva. In addition, 74% have 1-2 cars registered that enable their access to the CERN site and 5% park their car in CERN the same time with another member of their family. Moreover, 34% use CERN parking when they leave for holidays or return back to their national institutes, with an average parking duration of 8.5 days. Finally, 70% of the respondents are willing to park their car at a long term parking facility inside CERN when they travel abroad.

The majority of France residents feel happy when they use their car, while the majority of Switzerland residents find unexpected traffic delays on their usual route to work, at least twice per week. There are no significant differences between France and Switzerland residents' attitudes and the majority of both populations would be willing to cycle it there were showers and locker facilities in their workplaces, as well as bike paths inside the CERN campus.

## *4. Mode Choice Model Development*

In order to understand the mode choice behavior of CERN's staff and users, and their trade-offs of different characteristics (such as travel time, travel costs, etc.) on their choices, mode choice models were specified and estimated. Specifically, the model presented in this section corresponds to the respondents whose residence place is in Switzerland.

A discrete choice model representing individual's choice between different transport modes has been developed. This model was estimated using the total number of stated preference observations collected in the sample (604 observations) (Bierlaine, 2008). Table 3 presents the percentages of alternative choices (Dependent Variable) individuals made when responding the stated preferences scenarios. Other model structures (including Nested Logit and Error Component Multinomial Logit structures) were also investigated, but they gave poor results. The presented model was selected in the basis of statistical goodness-of-fit, as well as parsimony.

***Table 3:*** *Stated preference choices – Dependent Variable*

| Mode | Percent % |
|---|---|
| Car | 21.3 |
| Tram | 36.1 |
| Train | 42.6 |

Table 4 presents the specification table for understanding the parameters to be estimated and the way the utility of each alternative choice is specified. In this model, the train alternative is the base case for comparison, therefore, two constants are defined, one for the car (*ASC_1*) and one for the tram (*ASC_2*). The parameter ($\beta_1$) corresponds to the travel time of car alternative; ($\beta_2$) is generic and corresponds to the travel time of the tram and train alternatives; ($\beta_3$) is generic corresponds to the travel cost of all the alternatives; ($\beta_4$) corresponds to the shuttle bus frequency of the tram alternative; and ($\beta_5$) corresponds to the shuttle bus frequency for the train alternative. The dummy variable with parameter ($\beta_6$) takes the value of 1 if the public transport alternatives (tram or train) are crowded and no seats are available and 0 otherwise. The parameter ($\beta_7$) corresponds to the number of cars that are available in the household on a daily basis. The dummy variable ($\beta_8$) takes the value 1 if the individual does scientific and engineering work; 0 otherwise and dummy variable ($\beta_9$) corresponds to the individuals' age. Finally, the dummy variable ($\beta_{10}$) takes the value 1 if the individual owns a public transport card; 0 otherwise.

***Table 4:** Specification Table of Mode Choice Model*

| | *ASC_1* | *ASC_2* | $\beta_1$ | $\beta_2$ | $\beta_3$ |
|---|---|---|---|---|---|
| **CAR** | 1 | 0 | Car travel time | 0 | Car travel cost |
| **TRAM** | 0 | 1 | 0 | Tram travel time | Tram travel cost |
| **TRAIN** | 0 | 0 | 0 | Train travel time | Train travel cost |
| | $\beta_4$ | $\beta_5$ | $\beta_6$ | $\beta_7$ | $\beta_8$ |
| **CAR** | 0 | 0 | 0 | Number of cars that are available in the household on a daily basis | 0 |
| **TRAM** | Shuttle bus frequency of the tram alternative | 0 | Crowdedness | 0 | 1 if individual does scientific and engineering work; 0 otherwise |
| **TRAIN** | 0 | Shuttle bus frequency of the train alternative | Crowdedness | 0 | 1 if individual does scientific and engineering work; 0 otherwise |
| | $\beta_9$ | $\beta_{10}$ | | | |
| **CAR** | 0 | 0 | | | |
| **TRAM** | Age | 1 if individual own a public transport card; 0 otherwise. | | | |
| **TRAIN** | Age | 1 if individual own a public transport card; 0 otherwise. | | | |

The estimation result of the mode choice model for Switzerland is presented in Table 5. Based on the results of Table 5, the constant of the car alternative compared to the train one (which is the base case) is 1.33 while the constant of car is -2.58. This means that if all the other variables remain the same, individuals prefer tram, then train and finally car. The coefficient of travel time by car is negative and statistically significant, as expected. This means that if there is an increase in travel duration of one minute then the respondents' utility of this mode will be decreased by 0.18. The coefficient of travel time by tram and train is negative and statistically significant and it is lower in an absolute value than the related coefficient for car preference. The utility of tram decreases at 0.11 if the travel time increases by one minute.

The coefficient of travel cost for all the alternatives is also negative and statistically significant as expected. An increase in travel cost of one CHF will result in a utility reduction of 0.09. Moreover, as the number of the daily available cars in the households increases the probability of using car for their commute to CERN increases as well. On the other hand, as the frequency of the shuttle bus increases, the more likely individuals are to choose tram or train. In addition, if both public transport alternatives are considered crowded then individuals will most probably choose the car. Individuals that conduct scientific and engineering work are more likely to choose the car. Similarly, as the age of the traveler increases the probability of choosing public transport decreases.

***Table 5:*** *Mode Choice Model Estimation Results*

| Coefficient | Value | Robust t-test |
|---|---|---|
| ASC1_Car | -2.58 | -2,95 |
| ASC2_Tram | 1.33 | 2,04 |
| $\beta_1$ | -0.183 | -8,47 |
| $\beta_2$ | -0.11 | -8,17 |
| $\beta_3$ | -0.090 | -6,85 |
| $\beta_4$ | -0.071 | -3,11 |
| $\beta_5$ | -0.068 | -2,52 |
| $\beta_6$ | -0.552 | -3,7 |
| $\beta_7$ | 0.838 | 5,82 |
| $\beta_8$ | -1.27 | -3,97 |
| $\beta_9$ | -0.062 | -4,34 |
| $\beta_{10}$ | 1.380 | 3,2 |
| $\Sigma$ | -2.3 | -6,8 |
| **Summary Statistics** | | |
| Number of Observations | 604 | |
| Number of Individuals | 149 | |
| Initial log-likelihood | -663.562 | |
| Final log-likelihood | 415.370 | |
| Rho-square | 0.374 | |
| Adjusted Rho-square | 0.354 | |

Figure 4 presents the effect the different fare policies for tram and train respectively in the mode share. When train or tram tickets increase, there share lowers as people shift to cars. In the Tram case, if the ticket price is completely subsidized (meaning zero cost for the travelers), the probability of using it rises to 50%, while in the case of train with the same condition, the market share is approximately 36%.

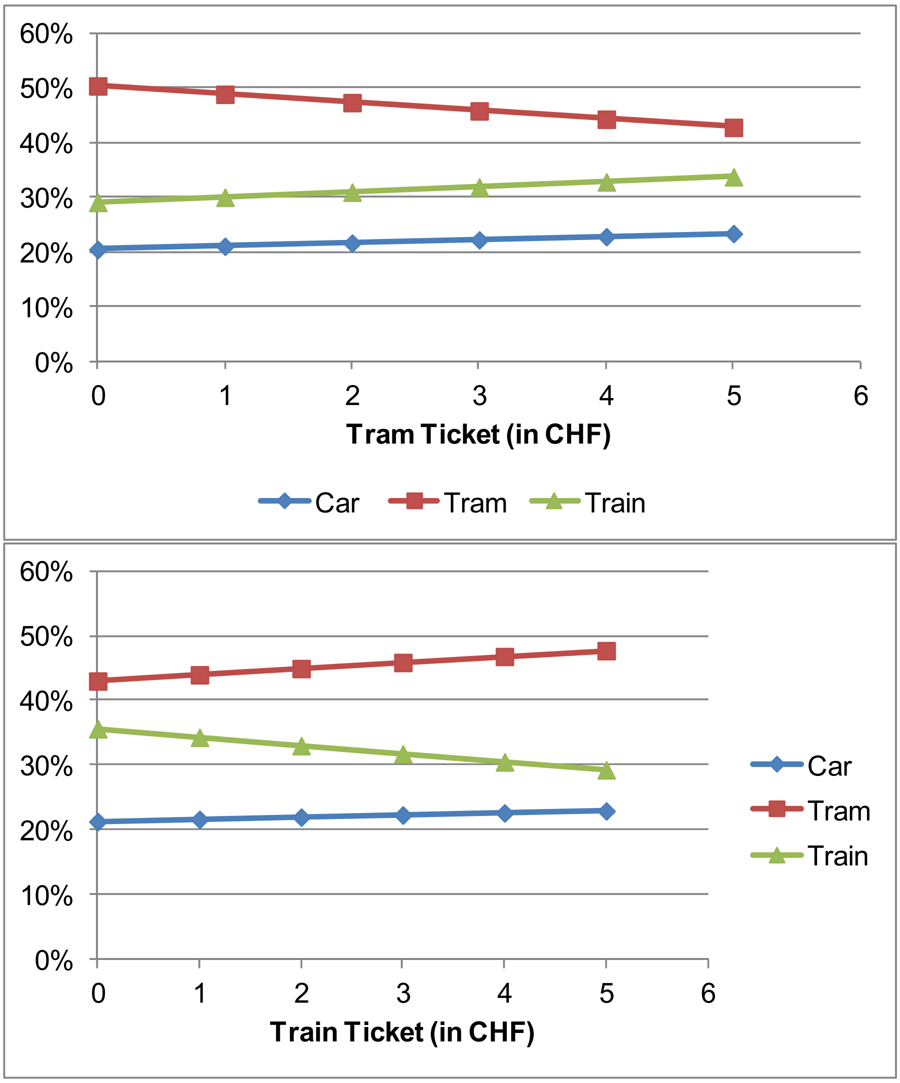


***Figure 4:** Public Transport Fare and Modal Split*

Figure 5 presents the effect of varying shuttle bus frequencies to the modal split. When shuttle bus frequency increases (either for tram or train users), the probability of choosing the respective mode rises as well. In the case of Tram if the frequency of the shuttle bus is 5 minutes the probability of choosing Tram reaches approximately 60%, which is even higher from the one observed in the case of zero cost. Similarly the train alternative may get a share of 39% if the shuttle bus headway is every 5 minutes.

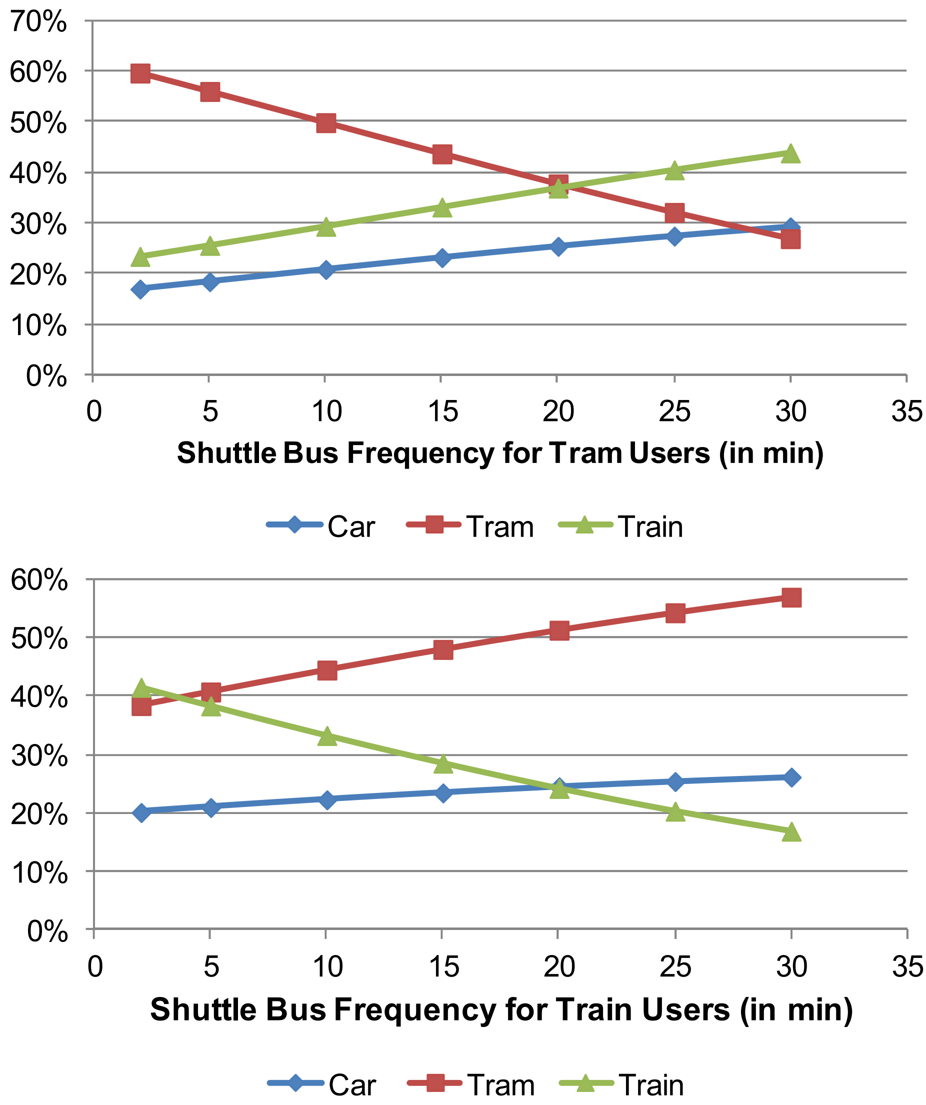


***Figure 5:** Shuttle Bus Frequency and Modal Split*

## *5. Parking Choice Model*

In order to understand the decision making behavior of CERN's staff and users regarding parking, and the trade-offs of different characteristics (such as walking time from parking to final destination, probability of finding free parking space, etc.) on their choices, a parking choice model was specified and estimated. A discrete choice model representing individual's choice between different parking alternatives has been developed. This model was estimated using the total number of stated preference observations collected in the sample (1494 observations) (Bierlaine, 2008). The data used for the model development had multiple observations from the same individual, thus it is useful to consider the heterogeneity across individuals. For this purpose a mixed binary logit model was specified and estimated. Table 6 presents the percentages of alternative choices (Dependent Variable) individuals made when responding to the stated preferences scenarios.

***Table 6:** Stated preference choices – Dependent Variable*

| | Percent (%) |
|---|---|
| Parking Inside CERN | 66.8 |
| Parking Outside CERN | 33.2 |

Table 7 presents the specification table for the model parameters to be estimated and the way the utility of each alternative choice is specified. In this model, the inside CERN parking alternative is the base case for comparison, therefore, only one constant is defined for the outside CERN parking (ASC_1).

The parameter ($\beta_1$) it is generic and corresponds to the walking time between the parking and CERN's entrance/Office; ($\beta_2$) is also generic and corresponds to the probability of finding free parking space; ($\beta_3$) is generic and corresponds to the shuttle bus frequency from/to parking place; ($\beta_4$) takes the value of 1 if the respondents currently park their car inside CERN, 0 otherwise. The parameter ($\beta_5$) corresponds to the number of daily trips an individual conducts inside CERN campus. The dummy variable ($\beta_6$) takes the value 1 if individual does scientific and engineering work; 0 otherwise and dummy variable ($\beta_7$) takes the value 1 if individual does scientific work (experimental and theoretical physics); 0 otherwise. The parameter ($\beta_8$) corresponds to the age of the respondent. Finally, $\Sigma$ corresponds to the standard deviation of a Gaussian, zero-mean error term, which has been included in the model to capture the heterogeneity across individuals.

***Table 7**: Specification Table of Mode Choice Model*

| | ***ASC_1*** | $\beta_1$ | $\beta_2$ | $\beta_3$ | $\beta_4$ |
|---|---|---|---|---|---|
| **PARKING INSIDE CERN** | 1 | Walking Time from Parking to Office | Probability of finding free parking space Inside CERN | Shuttle Bus Frequency | 1 if the respondents currently park their car inside CERN, 0 otherwise |
| **PARKING OUTSIDE CERN** | 0 | Walking Time from Parking to CERN's Entrance | Probability of finding free parking space Outside CERN | Shuttle Bus Frequency | 0 |
| | $\beta_5$ | $\beta_6$ | $\beta_7$ | $\beta_8$ | |
| **PARKING INSIDE CERN** | Number of daily trips individual conduct inside CERN campus | 1 if individual does scientific and engineering work; 0 otherwise | 1 if individual does scientific work (experimental and theoretical physics); 0 otherwise | Age | |
| **PARKING OUTSIDE CERN** | 0 | 0 | 0 | 0 | |

The estimation result of the parking choice model is presented in Table 8. The positive sign of the alternative specific constant for the Parking inside CERN shows that there is inertia towards outside parking. The main attributes, such as walking time from parking location to CERNs' entrance or Office, the probability of finding available parking space and the frequency of the shuttle bus are significant and with expected coefficient signs, as expected. In particular, as travel time between the parking location and CERNs entrance increases, the probability of choosing outside parking locations decreases. Similarly, as the walking time between the parking location and the office increases, the probability of choosing inside parking decreases.

Moreover, as the number of daily tips inside CERN increases the more likely are individuals to choose Inside CERN parking. Individuals that conduct scientific and engineering work, as well as scientific work (experimental and theoretical physics) are more likely to park their car inside CERN. Finally, as the age of the respondents increases the probability of choosing outside parking decreases.

***Table 8:*** *Parking Choice Model Estimation Results*

| **Name** | **Value** | **Robust t-test** |
|---|---|---|
| ASC1 | -1.58 | -1.7 |
| $\beta_1$ | -0.23 | -10.68 |
| $\beta_2$ | 4.58 | 10.14 |
| $\beta_3$ | -0.16 | -8.91 |
| $\beta_4$ | 0.91 | 1.71 |
| $\beta_5$ | 0.07 | 0.84 |
| $\beta_6$ | 1.11 | 1.97 |
| $\beta_7$ | 0.75 | 1.31 |
| $\beta_8$ | 0.06 | 2.80 |
| $\Sigma$ | 3.52 | 10.54 |
| **Summary Statistics** | | |
| Number of Observations | 1494 | |
| Number of Individuals | 374 | |
| Initial log-likelihood | -1035.56 | |
| Final log-likelihood | -608.79 | |
| Rho-square | 0.41 | |
| Adjusted Rho-square | 0.40 | |

Figure 6 presents the effect of different shuttle bus frequencies from outside parking to CERN's entrance, on the demand for both parking facilities, assuming that everything else remains the same. As the travel frequency of the shuttle buses increases, the probability of choosing outside parking increases as well. Assuming that the shuttle bus to CERN's entrance has a headway of 2 minutes, then the probability of someone choosing outside parking is approximately 43%.

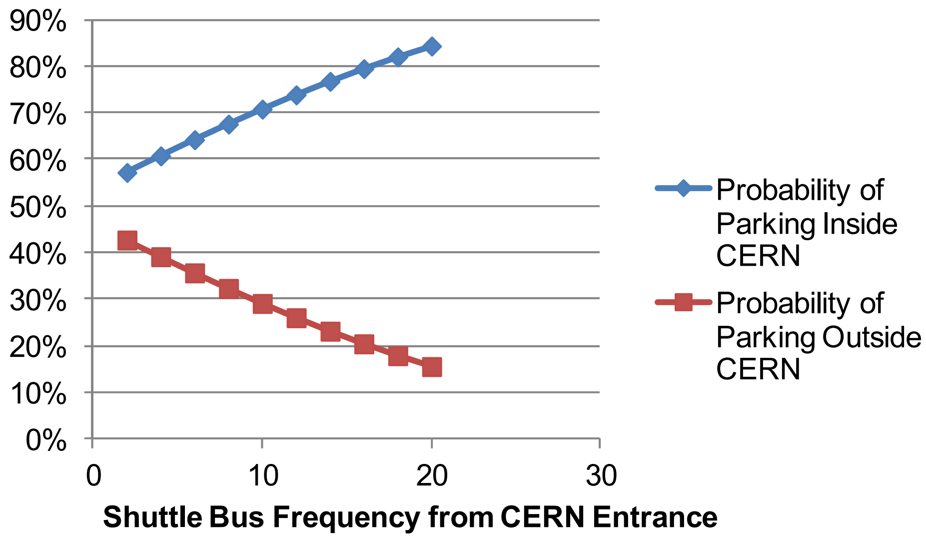


***Figure 6:*** *Shuttle bus frequency and probability of parking inside or outside Cern.*

## *7. Evaluation Traffic Impacts of Mobility Policies*

### *7.1 Mobility Policies*

Studies in RA communities have been prepared worldwide in an effort to investigate impacts and acceptance of mobility policies. Among the most successful solutions targeting into shifting demand from cars to sustainable transport modes, are the availability of a discounted transit pass, increasing reliability and frequency of transit service and of the availability of a long-term on-campus parking permit (Zhou 2012, Schneider and Hu (2015), or combined policies of discounted transit pass and parking pricing (Rotaris and Danielis 2014).

In the case of CERN, Table 9 summarizes scenarios for mobility policies to be evaluated using simulation. The first two scenarios (A1 and A2) refer to funding policies of tram and train tickets, whereas scenarios B1 and B2 target to the increase of the shuttle bus service from/to tram and train. The last two scenarios (C1 and C2) attempt to quantify the combined effect of shuttle bus service frequency from/to tram and train, but also from/to parking areas outside CERN campus.

***Table 9:*** *Mobility policies for CERN.*

| Base Scenarios | Mode Choice | | | Inflow by car |
|---|---|---|---|---|
| | Tram | Train | Car | |
| A1: Tram ticket subsidization | 50% | 29% | 21% | |
| A2: Train ticket subsidization | 43% | 36% | 21% | |
| B1: Tram shuttle bus frequency 5min | 60% | 22% | 18% | |
| B2: Train shuttle bus frequency 5min | 39% | 41% | 20% | |
| Combined Scenarios | | | | |
| C1: Tram/ parking areas shuttle bus frequency 5min | 60% | 22% | 18% | 62% |
| C2: Train/ parking areas shuttle bus frequency 5min | 39% | 41% | 20% | 62% |

Based on the nature of the OD trips, these above policies will influence entering flows during morning peak at Gates A and B that serve the demand from Switzerland. Scenarios B1 and C1 have the largest effect on car share and, thus, are expected to be the most influential for the CERN's inner road network.

### *7.1 Simulation model preparation*

The Meyrin road network is coded in AIMSUN (Figure 7). The inputs of the networks in terms of geometry (link lengths, number of lanes, curvatures, type of intersections etc), control (signs), traffic related data (existing demands, turning volumes, OD data etc) and other data, such as bicycle and pedestrian conflicting flows are selected and coded.

A critical step in the analysis is the selection of the proper Measures of Effectiveness (MOEs) that will be used to evaluate network's performance and compare different demand scenarios. MOEs are the system performance statistics that categorize the degree to which a particular alternative meets the project objectives. The MOEs that are utilized in order to present the operational characteristics of the campus road network are seen on Table 11.

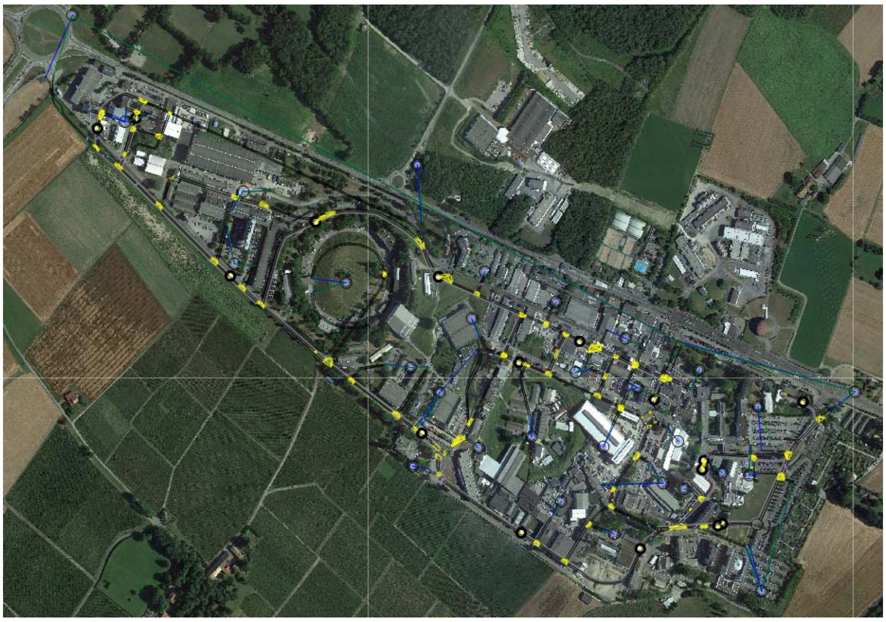

***Figure 7:*** *CERN road network in AIMSUN.*

***Table 10:** Measures of Effectiveness.*

| Measures | Unsignalized Intersection | Roundabout |
|---|---|---|
| Traffic Related | | |
| *delay per vehicle (s/veh)* | ✓ | ✓ |
| *travel speed (km/h)* | ✓ | ✓ |
| Fuel and Emissions Related | | |
| *Fuel Consumption (l/100km)* | ✓ | ✓ |
| *PM (g/VkmT)* | ✓ | ✓ |
| *$CO_2$ (g/ VkmT)* | ✓ | ✓ |
| *NOx (g/ VkmT)* | ✓ | ✓ |
| *VOC (g/ VkmT)* | ✓ | ✓ |

For calibration purposes, traffic volumes and mix were collected on Meyrin's selected locations for 2010. Traffic data were collected on typical weekdays by field personnel, at 15 min intervals for a time period between 7:00 and 19:00. During data collection, both the number and the type of vehicles were recorded in each selected location for the different directions of traffic. The vehicle types were also recorded and include car, truck, bus and motorcycle. Figure 8 shows the incoming, outgoing and in-campus vehicle evolution for the Meyrin campus during a typical day.

A preliminary analysis of traffic data from the morning peak shows that the critical locations are the Gates A, B serving demand from Switzerland and Gate E, which serves demand from France (Figure 1). Gate B is controlled by signalization, whereas Gates A and E have a control barrier. Evidently, as the imposed mobility policies target demand from Switzerland, the affected critical areas are the Gates A and B (signalized intersection).

### *7.2 Existing traffic conditions and Mobility Policies Evaluation*

Results for the existing conditions, as well as the different mobility scenarios are summarized in Table 11. Table 12 provides the relative difference of each scenario with the existing traffic conditions.

***Table 11:** Traffic Simulation Results for the Network of CERN.*

| Scenarios | Average Delay (sec/veh) | Travel Speed (km/h) | Fuel Consumption (l/100km) | CO2 (g/VkmT) | Nox (g/VkmT) | PM (g/VkmT) | VOC (g/VkmT) |
|---|---|---|---|---|---|---|---|
| *Base* | 22.36 | 30.09 | 12.92 | 11.88 | 0.41 | 0.08 | 0.38 |
| *A1-A2* | 21.65 | 30.46 | 12.74 | 11.71 | 0.40 | 0.08 | 0.38 |
| *B1* | 21.18 | 30.57 | 12.43 | 11.44 | 0.39 | 0.07 | 0.37 |
| *B2* | 21.24 | 30.55 | 12.43 | 11.42 | 0.40 | 0.08 | 0.37 |
| *C1* | 19.44 | 32.03 | 12.18 | 11.27 | 0.38 | 0.07 | 0.36 |
| *C2* | 19.58 | 31.92 | 12.17 | 11.21 | 0.39 | 0.08 | 0.35 |

***Table 12:** Relative difference from the existing traffic conditions (Base Scenario).*

| Scenarios | Average Delay (sec/veh) | Travel Speed (km/h) | Fuel Consumption (l/100km) | CO2 (g/VkmT) | Nox (g/VkmT) | PM (g/VkmT) | VOC (g/VkmT) |
|---|---|---|---|---|---|---|---|
| *A1-A2* | -3.17% | 1.23% | -1.41% | -1.43% | -3.33% | -4.94% | -0.22% |
| *B1* | -5.28% | 1.60% | -3.77% | -3.68% | -6.82% | -8.40% | -2.37% |
| *B2* | -5.01% | 1.53% | -3.80% | -3.84% | -4.33% | -4.85% | -3.19% |
| *C1* | -13.06% | 6.45% | -5.73% | -5.13% | -8.59% | -10.39% | -5.26% |
| *C2* | -12.40% | 6.08% | -5.84% | -5.64% | -5.76% | -5.66% | -7.88% |

Results show a small but significant improvement in the traffic characteristics of CERN's road network in all mobility policies considered. The most efficient scenario from those evaluated is C1, followed by C2, which includes the joint effect of tram subsidization and parking shuttle service and improves average delay and speed by approximately 13% and 6.5% respectively. The improvement in traffic characteristics lead to an improvement in the environmental conditions inside CERN. As seen in Table 12, emissions and fuel consumption significantly decrease in when compared to the existing conditions for all mobility policies tested. On the contrary, adopting base scenarios only (A1, A2, B1, B2), leads to modest improvements in the campus traffic conditions. As such, only combined policies can considerably contribute in enhancing CERN traffic conditions.

## *8. Conclusions*

The present paper deals with the problem of mobility degradation of CERN's Meyrin Campus for the extensive use of private modes for transportation. For this, an extensive survey on CERN staff and users accompanied by traffic data collection on selected location of CERN campus have been undertaken with the aim to reveal the prevailing mobility patterns and detect problematic sections with regard to the mode use and traffic characteristics. The mode and parking choice behavior is further statistically modeled with the aim to produce sustainable mobility policies.

This paper analyzed current travel characteristic and patterns for the CERN campus and investigated the impact of alternative mobility policies to in-campus traffic conditions. Tools such as surveys, mode choice models and simulation were used for that purpose. Mode and parking choice model findings revealed that a combination of fare and shuttle bus frequency for both Tram and Train alternative modes could significantly increase their mode share. Finally, from the parking choice model, it was found that if a frequent shuttle bus service, between outside parking area and CERN entrance was to be established, parking outside of the CERN facility would increase significantly. The above findings were further formulated as mobility policies, whose effect on Meyrin Campus inner traffic was investigated using simulation. Findings indicated that future implementation of mobility policies are expected to significantly improve in both traffic and environmental conditions, if combined measures are to be undertaken. In particular the joint consideration of transit subsidization and shuttle bus service improvement seems to be the most efficient policy.

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