Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 69 (2023) 464–471

Transportation Research Procedia

www.elsevier.com/locate/procedia

AIIT 3rd International Conference on Transport Infrastructure and Systems (TIS ROMA 2022), 15th-16th September 2022, Rome, Italy

# Preliminary evaluation of infrastructure and mobility services in mega-event: the Italian case study

Fabio Borghetti[a], Michela Longo[b*], Renato Mazzoncini[c], Claudio Somaschini[d]

*[a]Politecnico di Milano, Design Department, Mobility and Transport Laboratory, Via Candiani 72, Milano – 20158, Italy*
*[b]Politecnico di Milano, Department of Energy, Via La Masa 36, Milano – 20156, Italy*
*[c]CEO of A2A S.p.A., Corso di Porta Vittoria 4, Milano – 20122, Italy*
*[d]Politecnico di Milano, Department of Mechanical Engineering, Via La Masa 1, Milano - 20156, Italy*

**Abstract**

Mega-events play an important role in the urban agenda of contemporary metropolises. This importance lies in the fact that such events are seen as possible catalysts for the urban development of a metropolis and more generally of a territory, and an opportunity to establish them as global cities.
The planning and programming of a mega-event can be a country's showcase on the international landscape, and the mobility sector plays a significant role in defining its success or failure.
Transport infrastructure generally requires high resources for both construction and maintenance even after the event. Therefore, in order to ensure a good outcome, it needs to be planned strategically at multiple levels; this condition brings a benefit to both the host city and the community. The main purpose of this study is to analyze a mega event like the Olympic Games by highlighting the relationship between existing mobility solutions and sustainable solutions considering also the surrounding area. This is to enable the creation of new intelligent transportation options.
The Olympic Games, in fact, can represent a valuable opportunity to modernize the existing infrastructure of a country by improving the level of service and quality. The study considers, on the one hand, the expected demand for transport during the event and, on the other, the specific features of the different solutions that can be adopted to meet mobility needs.



*Keywords:* Transportation service; Mega-event, 2026 Olympic Games; green mobility; urban planning; sustainable transportation; infrastructure

## 1. Introduction

Mega-events play an important role in the urban agenda of contemporary metropolises and can be seen as a catalyst for a city's urban development. Moreover, the organization of a mega-event can be a country's showcase in the international arena; transportation and more generally mobility can be the determining factor in the success or failure


10.1016/j.trpro.2023.02.196

of the mega-event. Infrastructure and transportation systems require high investments for both the implementation and maintenance phase after the event. As a result, without strategic planning and programming (before, during, and after the event), the mobility and transportation sector could be a negative rather than a benefit to the host city and the resident population. Several studies in technical scientific literature have analyzed the positive and negative impacts associated with mega events.

In the work of Chen et al. 2021, the elements of transportation service that various passenger groups pay attention to while handling mega events are identified and analyzed. Specifically, questionnaires are implemented to understand transportation service quality needs among passengers.

The Olympic Games and the FIFA World Cup are mega-events that require a lot of people to plan and organize their mobility. However, these events can also bring negative impacts to the affected locations. The work by De La Cruz et al. 2019 analyzes the environmental impacts associated with major sporting events, showing how the concentration of air pollution can vary depending on the host city. Specifically, the work assesses air pollution before, during and after the Rio 2016 Olympic Games.

Mega-events such as World Expos are also capable of bringing economic, social, infrastructural, image and cultural impacts on host cities. Some studies have examined the economic effects of such events but have neglected the medium-term effects on the Quality of Life (QOL) of host city citizens. The work of Magno and Dossena, 2020 proposes a model that is based on social identity theory, thus considering host city residents as a group of people characterized by a shared identity. The model uses data collected through a survey of Milan city residents in Italy three years after the end of Expo Milano 2015.

In the work of Anoyrkati et al., 2021 the importance of sustainable mobility within the sports tourism sector is analyzed by considering the Athens Marathon as a case study. Through the opinion of experts in the transportation sector and by conducting interviews, Megatrends that can influence sustainable mobility were identified and classified. In this way it is possible to acquire information to plan and design mobility during the event.

The main goal of the Chirieleison et al. 2020 study is to explore and measure the existence of a positive mutual influence between the sustainability of an event and sustainable transportation. The case study concerns events organized in the city of Perugia in Italy in which there is an innovative light rail transit (LRT) system called Minimetro. The research is a valuable contribution in the field of event and transportation sustainability, highlighting possible positive effects on the host community.

Finally, the work of Menezes and Souza (2014) studies the strategies adopted in the planning (pre-event), production (during the event), and legacy (post-event) phases with reference to the World Cup held in Brazil in 2014. The goal of the study concerns the evaluation of the positive and/or negative results that the mega-event brings in the area of transportation and mobility in Brazil and specifically in the city of Recife.

The main purpose of this study is to analyze a mega event like the Olympic Games by highlighting the relationship between existing mobility solutions and sustainable solutions considering also the surrounding area. This is to enable the creation of new intelligent transportation options. The Olympic Games, in fact, can represent a valuable opportunity to modernize the existing infrastructure of a country by improving the level of service and quality. The study considers, on the one hand, the expected demand for transport during the event and, on the other, the specific features of the different solutions that can be adopted to meet mobility needs.

## 2. Passenger Demand Estimation

The Winter Olympic Games represent a great opportunity for host cities and their communities. Indeed, such events serve as catalysts for innovative processes, economic development, internationalization, and integration among communities. With the support of three involved regions (Lombardy, Veneto, Trentino Alto Adige), Milan-Cortina 2026 can become an opportunity to facilitate greater cooperation among Alpine regions, establishing them as the world's leading hub for winter sports. Special attention is given to the issue of sustainability, one of the key principles guiding the organization of the Games. Considering that the Dolomites area is part of the UNESCO World Heritage Site, this area must be preserved. Mobility plays a key role in these events, which are characterized by high travel demand. This can be used as an incentive to increase the accessibility of mountain areas, thus addressing the depopulation to which mountain territories are exposed. Veneto region is characterized by different tourist attractions where Cadore is the hub of mountain tourism in the Veneto, both in the winter and summer seasons. Several resorts are located in Cadore, but only Calalzo, San Vito and Cortina are of interest for the Olympic Games as shown in Fig.1.


Fig. 1. Location of the Cadore area and the 3 places involved the Olympic Games.

Figure 2a shows the distribution of arrivals for the year 2019 in the three main locations of interest. Two main aspects are visible, namely the peak of arrivals in the summer seasons considering that Cortina even without the Olympic Games turns out to be the main tourist attraction. Looking at arrivals to Cortina in the different months, it is possible to see that summer represents the main season for this resort. Cortina's peculiarity is a strong ski area that attracts people from all over the world. The number of foreign tourists has increased steadily over the past 15 years (see Fig. 2b). This suggests how Cortina already has a great ability to attract international tourists, which can also be increased by the Olympic events. Therefore, it is of great importance to design the transportation system for the Games accordingly. Foreign visitors should reach Cortina in two main ways: from the northern corridor (Dobbiaco) or from nearby airports.

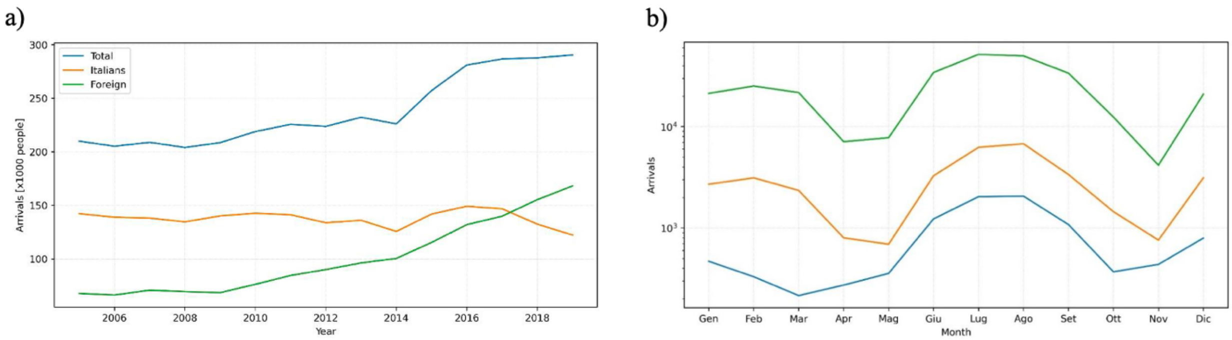


Fig. 2. Arrivals tourist (a) in Cadore; (b) in Cortina.

### *2.1. Transportation Demand*

Multiple events can take place on the same day and at different times of the day, from morning to evening. The Games will take place from February 4 to 22, with a total duration of 19 days. The expected spectators for each day are presented in Fig. 3 reaching an average of 25,000 people. Subsequent days show an uneven distribution but spectators, with the exception of two days, are always above 10,000, peaking at 35,000 spectators on day 14.

### *2.2. Arrival distribution model*

The transportation service is sized on incoming and outgoing spectator flows. Tourist flows are calculated from daily attendance and expected origin. The main assumption is that the farther away the area of origin, the longer their presence in Cortina. First, tourists were classified into two main classes, "Leisure" and "Olympic." The former aggregates those who are interested in both seeing the Olympic events and skiing; the latter, on the other hand, consists of tourists interested only in watching the events. It was assumed that 30 percent of total arrivals belong to the "Leisure" class, while the remaining 70 percent belong to the "Olympic" class. Based on these values, an average period of stay of 4 days was considered for the class of Italian "Olympic" spectators, and 5 days for foreign "Olympic" spectators. On the other hand, for those interested only in the Games, a reduced average stay period of 2 days for Italians and 3 days for foreign tourists was assumed. The stochasticity of arrivals (before the event) and departures (after the event) was modeled with a probability function.

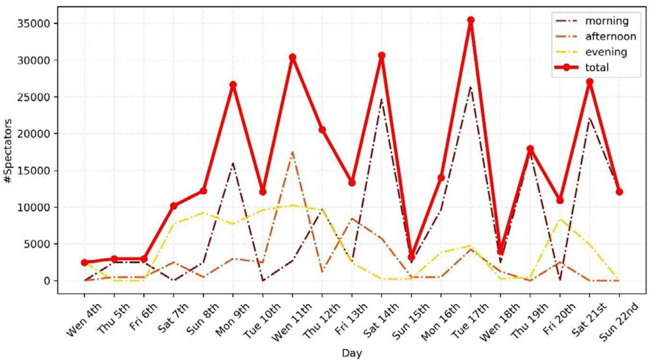


Fig. 3. Expected spectators at the Cortina 2026 Olympic games

The function distributes arrivals up to 2 days before each event, with a high probability (80%) that tourists interested in the Games will arrive in Cortina the day before the event. The first consequence is that transportation service starts (and ends) 5 days before (and after) the Games, for a total of 29 days. Departure flows were modeled with a Gaussian probability function centered on the average period of stay ("day 0"): tourists can leave up to 2 days before and after the scheduled departure day. Finally, as the last step in defining the arrivals model, an additional flow of 900 people per day was added. This value is calculated as a subset of total arrivals in February (60 percent of total arrivals in the first two weeks of the month and 40 percent in the remaining two). This flow is introduced for two main purposes:

- Conservative sizing of the transportation system: until now, the system has been sized on the number of spectators at events, neglecting any other source of passengers. In this circumstance, oversizing the transportation system, although it may make the service more expensive, is preferable to undersizing. The latter would result in a poor customer experience and poor system responsiveness to unexpected events.
- Uncertainty of demand: the service is sized on the expected number of spectators 5 years before the Games (at the time of writing this report). The oversizing is quite modest (ranging from 30% to 3% of spectators).

The final outputs of the arrivals model are arrival and departure flows. The expected peak arrivals is about 23,800 people. For perspective, this value almost corresponds to the average number of arrivals in Cortina during the entire month of February. The day with the highest number of people leaving Cortina has 20,900 departures. The evaluation of peak demand is of fundamental importance for service sizing. By summing the two curves, it is possible to obtain the total number of tourists on the move for each day, reaching a maximum of almost 41,800 passengers in a single day (almost 7 times the entire population of Cortina).

### *2.3. Intra-day distribution*

The next step is the sizing of the transportation service throughout the day. Considering that events are scheduled throughout the day, some considerations were made:

- Morning events: 10 a.m.-12 p.m. It is assumed that tourists arrive on average 1.5 hours early and leave 4 hours after the event ends.
- Afternoon events: 3 p.m.-6:00 p.m. Tourists may arrive 4 hours before the start and leave only 30 minutes after the end.

- Evening events: 9 p.m.-11 p.m. For this last class of events, only arrivals (on average 6 hours before the event) were considered, assuming that spectators would stay overnight in Cortina.

Intraday arrivals and departures were modeled with a Poisson distribution, bounded between 6 a.m. and 8 p.m. The share of arrivals for events in the three periods of the day is calculated from the expected number of spectators, which sees 51% of arrivals for morning events, 17% and 32% for afternoon and evening events, considering only tourists arriving or departing from Cortina on the same day they want to attend the event, or 24% of the total expected tourists. The remainder of arrivals and departures are distributed over the entire day according to two Gaussian distributions, centered between 2 p.m. and 4 p.m. for arrivals, and between 10 a.m. and 3 p.m. for departures. These times were assumed by considering a departure time from Milan at 9 a.m. (the entire trip takes more than 5 hours using only public transportation) and a departure time from Cortina at 10 a.m. The variance associated with each Gaussian function depends on the time of day: a smoother distribution is used for the afternoon and a sharper one for the morning. Figure 4 shows two examples of intra-day arrival and departure distributions. The left shows a day with many tourists arriving, while the right shows one in which most of them leave Cortina.

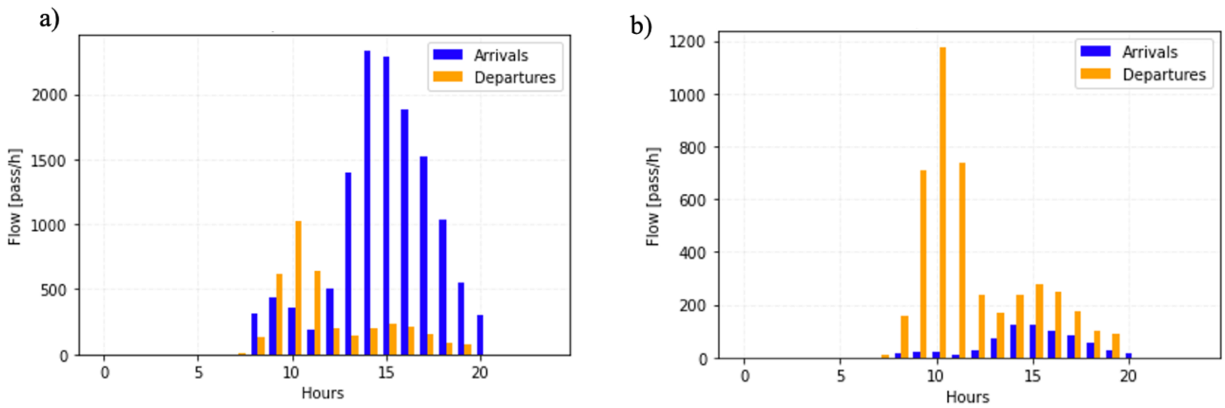


Fig. 4. Intra-day distribution of (a) arrivals and (b) departures.

## 3. Bus Rapid Transit (BRT) Service

### *3.1. Road Infrastructure - Accessibility*

Two roads represent the way of access to Cortina: SS 51 and SR 48. The first one is the SS 51 at Alemagna that crosses the mountain village from south to north while the SR 48 – the second one – from east to west. The latter is mainly a secondary road that connects Cortina with other ski resorts in Badia and Gardena valleys. The SS 51, instead, is the most important among the two: it starts between Pordenone and Treviso and ends in Dobbiaco, near the Austrian border. For this reason, is a very congested link – especially in winter and summer during holidays –, since represents the main access to Pianura Padana one side and to Sud-Tirol on the other. It extends in the southern direction as a highway (A27) which then connects to the A4 Milano – Venezia highway. The Games are expected to be reached through the use of public transportation. Considering that the total number of tenants is about 15,500; this number of tourists is distributed over the different days of arrival and subtracted from the potential BRT demand. No bus service is provided along SR 48 (Canazei-Cortina) due to the characteristics of the road, which make it difficult to operate an efficient and high-frequency bus service.

### *3.2. Bus fleet scheduling*

The buses currently in service are 12-meter suburban buses powered by a diesel engine. Their capacity is limited to 50-60 passengers on average, with a compartment for luggage and ski equipment. A bicycle trailer can also be attached. A new vehicle is proposed for the BRT service, the e-Citaro REX. It is an 18-meter electric bus with a Fuel Cell – FC range extender. It has a capacity of up to 145 passengers and is designed for urban service, so a 10% capacity reduction is considered to account for luggage. The power unit consists of an FC and a 441 kWh battery pack that provide power to the electric motors. The FC stack (about 30 kW) combines hydrogen pressurized to 350 bar (with oxygen from the air) to produce electricity. This power can be used directly by the electric motors or stored in the solid-state battery pack. The combination of the FC with the battery pack allows the FC to operate in its best condition (constant efficiency), while the battery system manages the variation in energy demand. The average consumption in urban areas is 8 kg/100 km, allowing a range of 250-300 km. The vehicle is primarily an electric bus with the addition of a fuel cell, which implies the need for a robust electric charging infrastructure in depots and possibly charging during service. This implementation, although common in e-bus fleets, is not sustainable in the context of the Games. The charging infrastructure would be severely underutilized in "normal" service, thus making the investment unsustainable. On the other hand, a fully hydrogen-powered vehicle may be an optimal solution to provide a sustainable, locally zero-emission service with short refueling times and higher availability (due to the longer average range of hydrogen buses compared to battery buses), compatible with a BRT service. In addition, the required hydrogen infrastructure can be scalable and mobile. The Calalzo-Cortina line is 34 km long and takes about 60 minutes to travel, with an additional 7 minutes of stopping time at each terminus. The other line, Dobbiaco-Cortina, is 31 km long and runs in 40 minutes, plus a 7-minute stop time at the terminal. The first line passes through several towns with several stops (normal service must be guaranteed), while the second is almost in the open field. The distribution of passengers between the two lines is assumed to be about equal, with a slight bias on the Calalzo list (56%). The size of the fleet has been performed with an additional +12% of vehicles for reserves. As a result, the fleet is composed of 54 vehicles. The fleet scheduling has been carried out in a 3-step process:

1) *Day Classification-Transportation demand* can change greatly on different days of the Games, and therefore service must be planned accordingly by classifying days into three categories with a dedicated level of services;
2) By *identifying peak hours and optimizing the fleet* within individual days, the variability of demand allows for a classic distinction between "peak" and "soft" hours. This distinction results in specific fleet and service level scheduling.
3) *Timetable definition*: this is a final overview of the different levels of service.

The goal of the *first step* is to tailor the level of service on the expected demand for each day. The starting point is the maximum flow between arrivals and departures for each day (Fig. 5a). The days were then classified into three classes based on maximum flow: highly congested ("High") if it is more than 75% of the overall peak of the curve; medium congested ("Medium") if the flow is between 30% and 75%; and low congested ("Low"). This classification allows three different schedules to be defined, depending on the expected flow of spectators. The *second step* focuses on the intraday distribution of arrivals and departures. Peak hours are those between 10 a.m. and 4 p.m., when the flow of tourists increases dramatically. The number of buses operating during peak hours is sized to meet the maximum flow (different for the 3 levels of service). In contrast, the service during "soft hours" is defined to guarantee 75% of the demand. Figure 5b shows an example of the number of buses (continuous red line) that are allocated on the Cortina-Calalzo line for a day of heavy congestion. The dotted lines, on the other hand, represent the number of buses that should theoretically be allocated to cover the demand for each day classified as highly congested (High). Finally, it is possible to note that the dotted lines have an hourly variation that is not compatible with the scheduling of a transportation service (the timetable cannot change every hour), while the red curve always covers demand during peak hours, while trying to optimize the number of rides for soft hours.

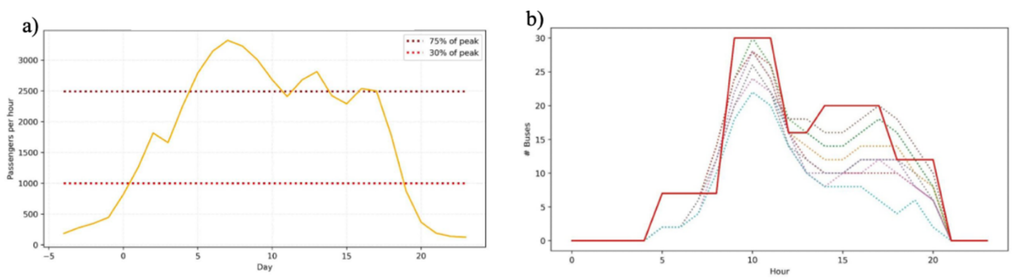


Fig. 5. (a) Maximum flow between arrivals and departures and (b) Number of vehicles operating on the Cortina - Calalzo line in highly congested day (High).

### 3.3. Bus fleet scheduling

Buses were assigned along the two lines according to the demand depicted in Fig. 6, so 34 buses were assigned to the Calalzo - Cortina line, and the remaining 20 to the Dobbiaco - Cortina line. These values also include reserves: three for each relationship. In case of emergency, the current diesel buses could be used. The depots should be sized on the number of vehicles that can be parked, thus: 17 buses in Calalzo, 10 in Dobbiaco, and 27 in Cortina (being the terminus of both lines). A depot is already available in Calalzo, with an area of 2,100 square meters, and should be expanded. In Cortina and Toblach, however, there are only bus terminals, so some locations need to be identified as potential temporary depots. The depot in Calalzo has been supplemented with some parking spaces for the 2021 World Alpine Ski Championships. Back-up vehicles (during service) would be parked in Cimabanche and Borca di Cadore, two small locations halfway between Cortina and Dobbiaco/Calalzo: in case of problems in the service (e.g., due to unexpected high demand or vehicle failure), the time needed for an intervention would be minimized.

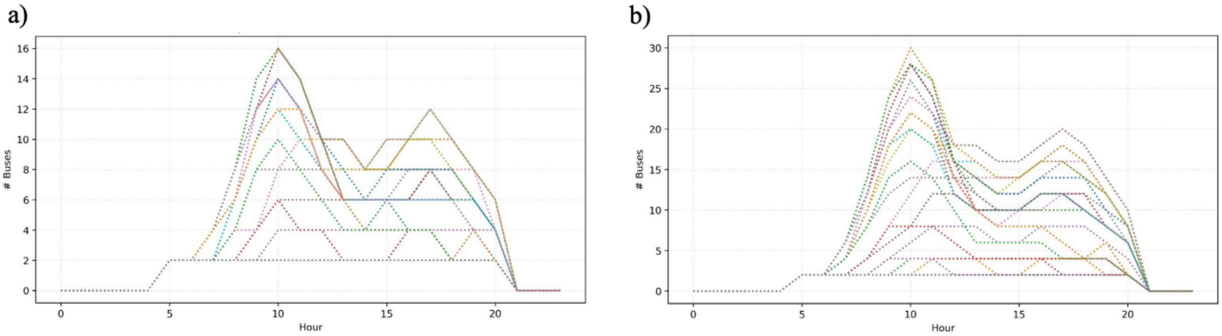


Fig. 6. Vehicle required on (a) Calalzo - Cortina line and (b) Cortina - Dobbiaco line.

## 4. Possible scenarios for integrated mobility

A sensitivity analysis was performed to assess how service requirements would change by changing some boundary conditions (*Scenario A* – BRT Transport). The five scenarios aim to evaluate the performance of the transportation service to fluctuations in two main factors: spectator distribution and available parking spaces.

*Scenario B* involves upgrading the existing parking lots in Cortina, doubling their capacity, but without creating additional interchange parking in Dobbiaco, Calalzo, and Belluno. The availability of only 3,200 parking spaces compared to the 9,300 needed (-65%) would force some tourists to use LPT or other means, creating a new modal distribution. This resulted in a -95% contraction in the number of spectators reaching Cortina by car, with an increase in other means: +65% in LPT use, +68% for GT, and +58% in express services. The main problem that could arise with this scenario is the potential interaction between the BRT system and the flow of cars arriving in Cortina: this situation could create congestion and interruptions in the service, which is characterized by a very high frequency (2-3 minutes) during peak hours. The average additional car flow was estimated at 90 vphpd (vehicles per hour per direction) and 50 vphpd via Calalzo and Dobbiaco, respectively, with peak values of 760 and 590 vphpd. These values might be acceptable, assuming that the average capacity of SS 51 is about 1,600 vphpd. Alternatively, one could open access to these cars only in the early morning or late afternoon hours, avoiding overlap with peak BRT frequencies; or let cars reach Cortina only by using SR 48, without any interaction with bus service. *Scenario C* envisions the realization of a total of 10,000 new parking spaces distributed among all three major mountain clusters. Given that Cortina is one of the most difficult clusters to reach by LPT but at the same time the most popular of all, it was assumed that 6,500 parking spaces would be realized for Cortina (distributed between the Calalzo and Dobbiaco interchange areas), well below the maximum projected need. This limitation would have an impact in the modal split, as seen above for Scenario B. In this case, the -30% reduction in available space for cars was estimated to be -28% in the modal share of cars, increasing the use of rail by +19%, GT by +23%, and express services by +17%. *Scenario D* is developed to evaluate the design requirements for underestimated demand flows. Since peak demand is nearly tied to departures, the system is stressed by reducing the variance of the Gaussian distributions for intraday arrivals: -25%

for the morning peak hour and -20% for the afternoon peak hour. In addition, the number of parking spaces was limited to 6,500, as in Scenario C. Finally, *Scenario E* is designed considering the assumptions for scenario C, also taking into account the electrification of the Belluno-Calalzo railway line. Simulations were carried out in order to estimate demand flows, plan and size the service for different scenarios. Figure 7 reports different scenarios for different costs respectively Capex and Opex.

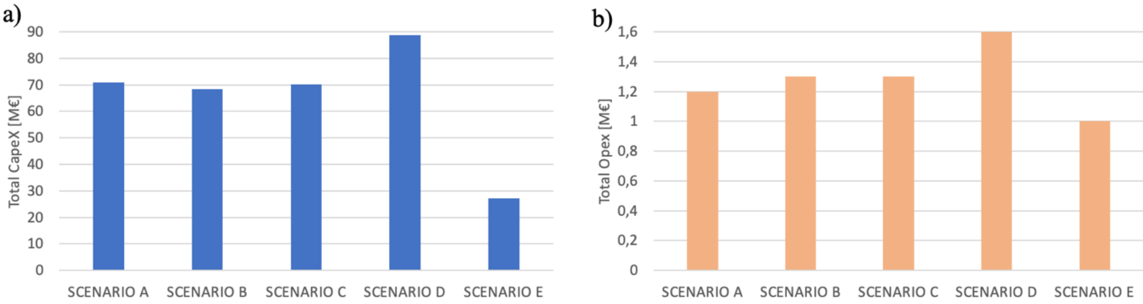


Fig. 7. Total costs for different scenarios for (a) Capex and (b) Opex

## 5. Conclusions

This project focused on the mobility problem that will arise during the Milan-Cortina Winter Olympic Games. For this reason, passenger demand during the event period was analyzed. The aim was to hypothesize the most effective transportation solution possible by decarbonizing the bus fleets operating on the main access routes to Cortina. The interesting aspect is to evaluate considering already existing transportation in the area new possible scenarios integrated with new green and sustainable transportation.

Innovation and sustainability were the keywords of the study while trying to increase the level of service and improve the connectivity of the Ampezzo Valley. All the analysis that is done is with the goal of making a scalable transportation that is adaptable to the passenger demand in the area. The choice of BRT vehicles proved beneficial in terms of sustainability and quality of service. Fuel cell vehicles can comfortably operate for longer range than plug-in electric vehicles. Fuel cell buses have the potential to replace diesel buses, with long driving range, route flexibility, and reduced refueling times. All assumptions started by considering demand forecasting. For an event of this magnitude, there are other aspects that can be considered. However, this work shows the possibility of also creating integrations with other types of existing mobility in the area (e.g., train, parking, hydrogen production) involving substantial investment costs that cannot be borne by the event organizers alone, especially for purchasing fleets. Therefore, different stakeholders will need to be found in order to improve the service. Obviously, the ultimate goal is to think of a permanent proposal that can provide better service with the help of innovative technology.

## References

Anoyrkati E., Kenanidis T., Alexandris K. (2021) Megatrends that Affect Sustainable Mobility Planning and Their Implications on Sports Tourism: The Case of the Authentic Marathon, Athens. In: Nathanail E.G., Adamos G., Karakikes I. (eds) Advances in Mobility-as-a-Service Systems. CSUM 2020. Advances in Intelligent Systems and Computing, vol 1278. Springer, Cham. https://doi.org/10.1007/978-3-030-61075-3_54

Chen, M. , Hsu, C. , Huang, C. (2021). Applying the kano model to investigate the quality of transportation services at mega events. Journal of Retailing and Consumer Services, 60 doi:10.1016/j.jretconser.2021.102442

Chirieleison, C., Montrone, A., & Scrucca, L. (2020). Event sustainability and sustainable transportation: A positive reciprocal influence. Journal of Sustainable Tourism, 28(2), 240-262. doi:10.1080/09669582.2019.1607361

De La Cruz, A. R. H., Dionisio Calderon, E. R., França, B. B., Réquia, W. J., & Gioda, A. (2019). Evaluation of the impact of the Rio 2016 olympic games on air quality in the city of Rio de Janeiro, Brazil. Atmospheric Environment, 203, 206-215. doi:10.1016/j.atmosenv.2019.02.007

Magno, F., & Dossena, G. (2020). Pride of being part of a host community? medium-term effects of mega-events on citizen quality of life: The case of the world expo 2015 in Milan. Journal of Destination Marketing and Management, 15 doi:10.1016/j.jdmm.2020.100410

Menezes, T. R. D., & Souza, J. F. D. (2014). Transportation and urban mobility in mega-events: The case of Recife. Procedia - Social and Behavioral Sciences, 162, 218-227