The role of the cable car in sustainable mobility: management choices and an assessment of environmental sustainability. The Trento-Monte Bondone project

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Abstract

Purpose of the paper: *The aim is twofold: a) to analyse the contexts best suited to, and to identify the best practices for, designing sustainable cable car mobility; b) to evaluate and compare the environmental impact of the management of cable car systems by defining two possible scenarios.*

Methodology*: In the first phase, two examples of excellent cable car systems and intermodality in the alpine area (Innsbruck and Alpe di Siusi) were examined in order to identify good practices as applicable to the evaluation of the (T-MB) project. Seven key dimensions were identified to evaluate the origins and implementation of the two completed cableway projects. In the second phase, a Life Cycle Assessment (LCA) was carried out to evaluate the environmental sustainability of the project.*

Findings*: From a managerial point of view, the T-MB project was initiated by public actors and adopts the instruments of participatory strategic planning widely used by the municipality of Trento over the last twenty years. The evaluation of environmental sustainability highlights the cable car as a valuable alternative transport mode because it reduces* CO_2 *emissions and pollution and it can be constructed with minimal impact on the territory.*

Research limits: *The T-MB project is still in the evaluation phase. It was not possible to access all the data necessary for either a detailed evaluation of the managerial implications or for the LCA analysis.*

Practical implications: *Identification of key dimensions and best practices for the implementation of sustainable cable car mobility projects.*

Originality of the paper: *The use of LCA analysis for the calculation of the environmental impact of cable care structures is innovative and it is one of the first studies in the field.*

Key words: cable car; sustainable mobility; participatory development projects, life cycle assessment; environmental sustainability; best practices

1. Introduction

The transport sector plays a strategic role in economic development, both in urban and rural areas (Genovese, 2018). Transport is, however, one of the most environmentally damaging sectors, largely because of the atmospheric pollution caused by the use of carbon intensive energy sources. According to the International Energy Agency (2019), transport systems are responsible for 24% of the global CO_2 emissions. The issue of air pollution is particularly acute in the areas near huge urban conurbations. Europe's energy system is dependent on fossil fuels, and the EU imports about 95% of its needs (Eurostat, 2018). Another issue is the negative impact of land consumption for transport systems on biodiversity (EEA, 2019), their expansion accounts for about 8% of annual new land use - it is estimated that, in Europe, 10 hectares a day are paved over. ISPRA (2014) reveals that between 2006 and 2014 42% of the newly paved land (an annual average of c. 200 km2) was destined for transport infrastructure.

The strategic role of the transport sector, on the one hand, and the problems which accompany its development, on the other, have initiated the research for solutions that allow a transition to sustainable development models at the centre of an international discussion between policy makers, businesses, organisations and the scientific community (Capolongo, 2017; Pastore and Ugolini, 2020). The specialists' attention being devoted to these questions is accompanied by a general awakening to, and growing consumer awareness of, environmental problems (Barr and Prillwitz, 2012; Tencati and Pogutz, 2015). Notable progress is being made in the search for effective solutions and the development of mobility plans that focus on improved environmental performance, largely thanks to national and international financial support and stimulus (May, 2015; World Bank, 2017). Alongside the choice made by some administrations to develop soft transport, various innovative means - and uses - of transport are being tried out. The "sharing economy" is a popular new trend (Santos, 2018), and electric transportation modes - which have a low environmental impact, especially when the electricity comes from a renewable source - are being rapidly developed and rolled out (Maiolini *et al.*, 2018; Vargas-Sánchez *et al.* 2019).

This paper contributes to the discussion on the mobility solutions which can best improve a territory's transport network, reducing emissions and improving the residents' quality of life. Our results are based on a study conducted in Trento, a small provincial capital (pop. c. 100,000), located in the Italian Alps. The research is based on a proposal made by the autonomous Province of Trento to construct a cable car between the city centre and Monte Bondone (known as "Trento's Alp" because it abuts the city and has long been a vacation area for residents).

The research objectives are: *a)* to analyse key dimensions and best practices in the designing of sustainable mobility systems; *b)* to measure and compare the environmental impacts of a future T-MB cableway with those of *(i)* 100% private vehicle use, and *(ii)* combined private vehicle/ traditional public transport use. In pursuit of the first objective, the good practices that emerge from a literature review and from the detailed analysis of two examples of excellence in the Alpine area (Innsbruck in Austria and the Alpe di Siusi area in South Tyrol) were considered. The literature review highlights best practices of sustainable mobility that have been adopted in Alpine areas to contribute both to the quality of life of residents and to the sustainable tourism local development. The second objective was achieved through the *Life Cycle Assessment* (LCA) applied to the T-MB cableway.

The paper is divided into four sections. The second includes a concise review of the main contributions to the literature on sustainable mobility, noting some relevant examples of the introduction of cable cars to urban transport systems in a variety of countries. In the third section, the research methods are discussed: the analysis of examples of excellence in Alpine areas and the LCA. Our main findings are set out in the fourth section. In the conclusion, the most significant findings are discussed, and the contribution, originality - and limitations - of the study are explained.

2. Literature Review

2.1 Sustainable mobility: promoting territorial development and increasing accessibility

Since the 1990s, the urban transport sector has grown rapidly, due to both an increase in trips made and to growing urban populations. In the future, these journeys are expected to increase: by 2030 it is estimated that urban passenger traffic will have grown by 50% (World Bank, 2017)[1]. Urban population growth, too, makes the need to find solutions for mobility and accessibility in urban areas particularly pressing, especially as the world population growth is projected to continue for the foreseeable future (Sodiq *et al.*, 2019). Moreover, the areas around the biggest population centres, and areas of low population density, also need to have quick, efficient transport links with the major cities. Accessibility - "the opportunity of an individual in a particular place to participate in an activity or set of activities" (Hansen, 1959, p. 73.) - has become fundamental to transport planning.

Nowadays, a concept of mobility which is no longer linked simply to vehicular traffic, but is part of a multimodal perspective, is gaining valence (Banister, 2008). Transport planning goals are no longer focused entirely on efficient traffic flows, but are concerned with people and the social dimension (of accessibility and inclusivity), prioritising pedestrian traffic, cycling and public transport use and proposing alternatives to the car, increasingly promoting choices with the smallest possible environmental impacts. City planners and policy makers are therefore now looking for integrating transport, tourism and territorial development, aiming for energy efficiency, zonal redevelopment, pollution reduction and more social inclusion (UNWTO, 2001).

[1] Covid-19 brought the evolution of the sector grinding to a halt, leading - in an extraordinarily short time - to a global crisis. According to ISTAT (2020), in just five weeks passenger dropped by over 85%, severely impacting the airline industry, which saw a drop of 66% from March 2019 (almost 2 flights in 3 have been cancelled). The public health emergency led to the rapid acceleration of digitalization in most economic sectors. According to UNECE and ILO (2020) it will never be possible to return to (pre-pandemic) "business as usual", and this impossibility could stimulate endeavors to achieve the Agenda 2030 SDGs and to incentivize the structural transformation of transport systems, favouring public transport and electrification, while generating jobs.

In the last forty years, more and more sustainable transport measures have been adopted, particularly in the urban environments where populations are in constant growth (Sodiq *et al.*, 2019). The biggest challenge for urban transport planners is to find a balance between people's growing personal mobility requirements and the transport of goods (both functions of economic growth) and the need to protect the environment and provide a satisfactory quality of life, including reasonable access to services, for all citizens (Lindenau and Bohler-Baedeker, 2014). Copenhagen has made huge progress in this direction and is generally seen as a *green economy* policy leader. The city has been able to achieve consistent progress towards carbon neutrality. Not only, in fact, have a number of changes been made to the transport infrastructure in order to improve connections between the main residential and commercial areas, but the "Station Proximity Principle" has also been successfully realised. This principle requires large offices to be sited no further than 600 metres from a subway station (LSE Cities, 2014). Among the greatest strengths of Copenhagen's transport system is the widescale promotion of cycling and other forms of soft mobility, which reduce urban congestion, emissions and land consumption. Copenhagen has taken more comprehensive action than almost anywhere else, in terms of encouraging perceptions of public spaces as available for community use, improving people's health and increasing the city's livability (Sick Nielsen *et al.*, 2013). There is positive feedback, too, for the city's sustainable tourism approach, which has been shown to provide a form of environmental education for tourists who may, when back at home, reproduce the eco-friendly behaviours they have experimented with while on holiday (Gillis *et al.*, 2016).

Copenhagen's experience is not the only example of virtuous choices in relation to sustainable mobility planning. Numerous other cities around the world have shown that it is possible to implement sustainable transport policies even in very complex urban environments. In these contexts, the construction of cable car systems is revealed as a real opportunity within sustainable mobility planning, as the following sections will demonstrate.

2.2 Sustainable mobility and cable car systems: the managerial implications considered with reference to some international examples

In recent decades, cable car systems have made remarkable technological advances, as evidenced in their widespread use in winter sports infrastructure. Due to the many ways in which their environmental credentials, safety, comfort and capacity have all increased in these years, cableways are also gaining popularity within urban contexts (Težak and Sever, 2016). Their main environmental benefits are (Papa, 2010): no CO_2 or exhaust emissions; the infrastructure, since it is removable, has minimal environmental impact; reduced noise pollution. Cable cars have proven to be eco-friendly, profitable tourist attractions, by their very nature ideal for hard to access locations, and representing an original travel experience (Brida *et al.*, 2014).

Cableways are also used for public transport, not only to decrease city traffic but also to solve problems linked to geographical/topographical obstacles. They can cope with all kinds of terrain and represent an ideal solution for cities built on and at the foot of hills or mountains, reaching areas which no conventional public transport system could feasibly access (Pojani and Stead, 2015). The integration of a cableway (often using the gondola system) into the existing transport network also has economic benefits (Carlet, 2016). In recent years, many cities in the developing world have implemented mobility schemes intended to enable low-income citizens to access services (Bocarejo and Oviedo, 2012).

The trend was undoubtedly set by the "Metrocable" in Medellín. The city decided to focus on upgrading its public transport system, a bus fleet with a very limited route network. By the first decade of this century, spatial inequality had become a serious problem because it was very difficult for the inhabitants of the periphery to reach the city centre, where health and education services, and most jobs, were located (Bocarejo *et al.*, 2014). In 2004 the Metrocable was built. It is an innovative cable car system, which now has 3 lines and is integrated within a broader and more ambitious city plan: today, all the peripheral zones, including those on the mountainsides where the city's poorest inhabitants live, enjoy much improved accessibility. The principal goal of this intervention - along with a set of related policies, such as building controls, limits on private car use, incentives to use public transport - was to enable the cableway to serve as a feeder for the subway system, which had previously been hard to reach (Bocarejo *et al.*, 2014).

Other cities in Latin America have been following suit, driven by the same desire to improve their public transport services: like Medellín, Caracas, Rio de Janeiro and La Paz are situated in valleys, surrounded by settlements on steep hills, whose residents cannot easily access the city centres (Olszyna *et al.*, 2015). Caracas, the capital of Venezuela now has the world's most advanced cable car system, which has made it easier for the millions of people who live in the furthest reaches of the periphery to reach their destinations (Lopez, 2010; Spinosa, 2017). Policy and strategic choices to focus on intermodality and sustainability when planning transport systems are often the products of innovative, participatory decision-making processes. In the case of Caracas, this process took 3 years and was supported by an "Urban Think Tank" which included residents in the decision-making process. The Metro Cable has become not just a public transport system, but also a key part of the area's social fabric (Golinger, 2010). La Paz (Bolivia) has built a cableway which links the El Alto area with the rest of the city. With its highest point at 3,600 msl, this is the highest urban cable car system in the world (Spinosa, 2017).

A number of European cities have included cable cars within their transport systems. The "Emirates Air Line" gondola system in London, for instance, was inaugurated for the 2012 Olympics and is still both a public transport link and a tourist attraction (Alshalalfah *et al.*, 2014; Olszyna *et al.*, 2015). In Germany, a cableway linking two areas of former East Berlin was opened in 2017 as part of the city's "Gärten der Welt" Exhibition, and now functions as an element of the local transport system. In Spain, two striking examples are Barcelona's cable car system and Madrid's "Teleferico" (Papa, 2010).

While, to date, Italy has not built many urban cableways, the "Minimetrò" in Perugia is an excellent example of a small funicular system, which is now considered the backbone of the city's transport service. The cable propelled automated people mover has proved to be an extremely environmentally friendly addition to the existing transport network: its capacity equals that of a bus or tram, its footprint is minimal and it is the most efficient way of transporting people up and down the hillside (Leitner Ropeways, 2019). In 2009, Bolzano (the provincial capital of South Tyrol) opened a cableway which links the city centre with the plateau of Renon, an area which offers magnificent views of the city and surrounding mountains. Approximately one million visitors a year use the cable car, thus leading to a considerable reduction in road traffic (Leitner Ropeways, 2019).

Although of course each city has its own particular profile, it is very evident that all their decisions to build cable car systems have been prompted by the need to provide people with a more efficient and environmentally friendly way to move around the city. Analysing the literature, it becomes evident that certain features emerge as key to the actual realisation, and subsequent management, of such transport systems. The most notable of these features are: securing the necessary finance, general agreement on the importance of decreasing journey times (including from areas separated from the centre by natural or manmade obstacles), and the feasibility of integrating the cable car within the existing transport system (Papa, 2010).

The problems connected with mobility can be exacerbated when tourist destinations whose attraction lies in their unique natural resources become increasingly popular. Mountain territories epitomize this dilemma, since their transport networks connect the most remote areas with the main valleys and urban centres (Scuttari *et al.*, 2013; Tischler and Mailer, 2014), and this may have negative effects on the former (Orsi, 2015), which are increasingly turning to nature-based tourism, now an extremely popular leisure activity which presents a number of challenges in regard to establishing an equilibrium between a territory's valorisation and its conservation (Luo and Deng, 2008; Weber *et al.*, 2019).

3. Research method

In order to achieve the study's two objectives, the research was divided into two phases. The *first step* involved analysing two (intermodal) cable car systems in the Alps. These systems are considered examples of excellence and enable us to identify the best practices that then inform our evaluation of Trento's sustainable mobility development plan. The two exemplars are Innsbruck (in Austria) and the Alpe di Siusi area (in South Tyrol, Italy):

- Through a public private partnership, Innsbruck has rebranded itself; part of the scheme involved the construction of an all-season cableway which links the city to the Nordkette mountain behind it (see section 4.1).
- Alpe di Siusi has tackled the problem of traffic congestion by building a cableway which allows the plateau to be accessed in a more sustainable manner (see section 4.2).

The two cases were analysed taking seven dimensions into account (identified in the literature review) which are considered key to the realisation of the projects:

1. *How the project originated:* the presence of one or more types of actors (public or private) in the initial phase of the plan.
2. *Involvement of the local community in planning the project:* the range and type of stakeholders involved.
3. *The main aim of the project:* the final goal of each project and the objectives achieved.
4. *Existence of a local strategic development plan:* construction of the cableway as part of the local development plan/revalorisation of the area.
5. *Specific characteristics of the project:* identification of the main features of the cable car systems concerned.
6. *Efficacy of the project/achievement of goals:* assessment of whether declared objectives were met.
7. *Environmental performance:* analysis of the environmental sustainability of the project, and of any measurement techniques and/or indicators adopted.

Consideration of the two cases allowed us to analyse and evaluate the opportunities presented to policy makers by the initial phase of the project of upgrading and extending the T-MB cable car link (see section 4.3).

The *second stage* consisted of a *Life Cycle Assessment* (LCA) to assess the environmental sustainability of a new cable car system between the city of Trento and Monte Bondone. The LCA took as its starting point the most recent plan, *Trentino Sviluppo*'s 2011 "Masterplan" (http://trentinosviluppo.etour.tn.it) which envisions a cableway that replaces the existing Trento-Sardagna connection and then continues up to Vason, via Vaneze (a total of 4 stations), allowing passengers to reach the highest station (about 1560m sl) in 20 minutes.

An LCA is a method, standardized by an ISO (International Organization for Standardization), which evaluates the impacts associated with a product, process or activity, throughout its life cycle (ISO, 2006a, 2006b). An LCA study involves four stages: (i) goal and scope definition; (ii) a life cycle inventory (LCI), aimed at gathering input and output data throughout the life span of the good or service; (iii) a life cycle impact assessment (LCIA) for the quantitative evaluation of the type and extent of environmental impacts, based on data collected in the LCI and, finally, (iv) an interpretation, including recommendations to the commissioner of the study.

The LCA method was chosen because of its comparative nature and multi-indicator approach, and because it has established itself as a useful tool for assessing the environmental aspects of new strategies being devised to inform urban planners in their decision making (Petit-Boix *et al.*, 2017; Guerin-Schneider *et al.*, 2018; Ipsen *et al.*, 2019) and sustainable mobility initiatives (Al-Thawadi *et al.*, 2019; Severis *et al.*, 2019; Del Pero *et al.*, 2015), although the literature to date includes only one example of its use to calculate the environmental impact of a cable car system (Biberos-Bendezù and Vazquez-Rowe, 2020).

In line with the ISO 14040 (2006a; 2006b) regulation, the parameters of the system were determined in order to establish the processes and materials to be included in the LCA. In the present study, the following are included: the infrastructure; the structure and its operation, excluding their end of life (i.e., dismantling and removal of the structures, disposal of the materials and the restoration of all affected areas). The functional unit for all the data is one year of cableway operation, estimating 600,000 trips (300,000 passengers). The working life of the system is estimated to be 35 years.

Data on the system were taken from the *Trentino Sviluppo* Trento-Bondone plan mentioned above. The data on materials and energy consumption were supplied by Leitner Ropeways, or found in the literature, or in the Ecoinvent 3.3 database, included in the SimaPro 8.3 software used for calculating the different forms of environmental impact involved.

The system's impact was subdivided according to the three main stages of its life cycle (transport of materials included):

1. *The infrastructure:* i.e. the four stations and the cable itself. The total quantity of materials necessary for the construction of the stations and the transport of the former, plus the materials used in the cableway's support pillars, cables and rollers, and the lorry and helicopter transport of the same, must be factored in.
2. *The structure:* i.e. the cabins, taking into account the construction materials and their lorry transport (by the supplier/producer) to the assembly site.
3. *Operation:* the energy consumption of the three electric motors that power the system is taken into account.

The consideration of electricity consumption takes into account the energy mix (100% renewable, mainly hydroelectric) of Trentino's main supplier. The principal findings from the LCA are illustrated in section 4.4.

4. Results

4.1 Cable car systems and intermodality in mountain areas: the case of Innsbruck

Innsbruck is one of the biggest "mountain cities", with more than 100,000 inhabitants and a total urban region population of > 300,000. For years, the city's image as a tourist site was closely linked to the Winter Olympics, and it became known as the "capital of the Alps". Since the 1970s, the city has grown extremely rapidly, becoming more and more cosmopolitan and popular with tourists (Haller *et al.*, 2020). Innsbruck's cableway - designed by the architect Franz Baumann and opened to the public in 1928 - has always been an important element of the city's image. In 1950, its capacity was increased and at the beginning of the twentieth century a complete upgrade of the system began. The centre of the city has now a cable car running up to the Nordkette mountain range, which is part of one of Austria's biggest natural parks, the Karwendel Alpine park (Haller *et al.*, 2020). The cableway upgrade is part of a wider re-branding project, which took a "Brand Driven Identity Development" approach (Botschen and Promberger, 2017). The introduction of the cable car is thus just one element of a project aimed at revitalizing the tourism sector, combined with the rebranding strategy of Innsbruck's identity as an Alpine city destination.

The project began in 2009 when a group of stakeholders from the hospitality sector proposed to rebrand the city, suggesting that success would depend on a participatory process. Key players were (Botschen and Promberger, 2017):

- the core group: the mayor, members of the Tourism Association, city marketing and three facilitators;
- the "microcosm": 120 participants from various areas (education, politics, sport, mobility, gastronomy, crafts, commerce);
- the support team: researchers and consultants who moderated and guided the process at all times.

The work was carried out in three phases, as shown in Table 1.

Tab. 1: Main phases of Innsbruck's rebranding

Phase 1 Establishing the city's brand identity	- Identifying the resonance of the city's historical identity. - Microcosm participation and in-depth interviews. - Identification of socio-cultural characteristics through an iterative process. - 7 pillars upon which to base the future brand identity.
Phase 2 Translating the brand identity into touchpoint experiences	- Wide-ranging workshops for the creation of brand teams. - Defining the scope of action (public services, retailers, gastronomy, the mountain areas, transport, cultural events). - Translating the brand identity into points of contact with the visitor (visitor experiences).
Phase 3 Turning the touchpoint experiences into new ways of valorising the destination.	- Adapting structures, services and processes. - Forming the brand teams. - One brand team was in charge of the activities on Nordkette (extreme sports, family entertainment, scenic walks/hikes, sign-posting).

Source: authors' elaboration, adapted from Botschen and Promberger (2017).

The initiative focused on the establishing of a new brand for the city, summed up in the slogan "Alpine city life", based on seven pillars: the appeal of the Alpine environment; sports skills; a vibrant urban space; an avant-garde Alpine aesthetic; a young, intelligent, cosmopolitan population; a healthy lifestyle; and environmental excellence.

The work of the second and third phase - carried out by the ad hoc "brand teams" - involved translating the city's new slogans into visitor experiences and adapting existing structures and services to meet the new requirements. It was quickly recognised that being able to spend time in natural mountain areas was a key attraction for visitors: this they were able to do by taking the cable car to the Nordkette Park. One of the brand teams was tasked with setting up and managing activities in the Park (such as family entertainment, scenic hikes/walks, sports activities and events). The Karwendel Park is only twenty minutes from the city centre by cable car, following the route of the old cableway which runs along the Nordkette range and into this enormous national park; a station along the way gives access to the town of Hungerburg and the Alpenzoo.

The park received 600,000 visitors in 2015, 250,000 of whom were from Tyrol. Just 10% of the visitors had come to ski, confirming that the success of the project was by no means solely due to winter skiing: the vast majority of visitors chose instead to participate in one of the many activities available on the mountain (O'Faircheallaigh, 2010). The image of the "urban Alpine" city was encapsulated by the cableway, and it, in turn, was not only an attraction in itself, but also imminently functional in enabling the valorisation of the upland areas of the Karwendel Park. The system is a key element of the city's public transport service: it runs regularly throughout the year and allows people to travel rapidly between the city and the mountain, using a regular, safe, environmentally friendly service.

Innsbruck's environmental performance is further improved by the fact that residents are increasingly choosing to cycle as they go about their daily business, and private car use is decreasing. City policy is to facilitate these changes (Pospischil and Mailer, 2014).

No formal environmental assessment of Innsbruck's mobility has been completed to date, and so the environmental impact of the cableway's use cannot be evaluated. This is a lack which policy makers could fruitfully address: they could thus assess the latter's environmental sustainability - cableways are, anyway, perfectly coherent with the brand of an urban Alpine destination - and thereby undoubtedly strengthen the city's green mobility image.

4.2 Cable car systems and intermodality in mountain areas: The Alpe di Siusi

The Alpe di Siusi, situated near the Val Gardena and the Valle Isarco (South Tyrol), is one of the most extensive (50 km2) plateaux in Europe, and home to one of the most important ski areas in the Dolomites. It began to be developed for tourism in the early 1900s and is now a well-known (winter and summer) tourist destination (in 2019, according to ASTAT, about 1,823,000 people visited the area).

The plan to build a cable car connecting Siusi with the Alpe di Siusi grew out of the realisation that the congestion on the only road up to the plateau caused by private cars (especially during high season) was causing serious environmental damage. The initial input for the construction of the cable car was made by local ski-lift and cable car operators, but the project was carried forward as part of the bigger ALP.IN.SKI (Alpine Innovation Ski) project led by Arge Alp. Six partners belonging to Arge Alp collaborated on ALP.IN.SKI with the objective of promoting virtuous mobility practices in the ski stations. The overall goal was to promote an alternative mode of transport, in order to make access to the plateau more sustainable, mitigating the negative environmental impact of private car journeys. The construction of the cableway was completed in 2003, after a ten-year gestation. The main phases of its conception and construction are summarized in Table 2.

The decision-making process was long drawn out and, despite initial enthusiasm, it took almost ten years of debate and adaptation before the cableway was finally finished - and the support of the provincial government was undoubtedly essential. Most of the resistance came from local residents, unhappy about having - for the first time - to pay for access to the plateau, and from the hospitality sector, concerned that the change would put tourists off coming to the area. To persuade people to accept the plan, the provincial government subsidised a discounted pricing system for the local community and undertook to ensure effective intermodality between the cable car and the local bus service (Scuttari et al, 2016).

Tab. 2: Main phases of the Siusi-Alpe di Siusi cableway project

Phase 1 An unsustainable situation	- Traffic congestion on the access road (up to 20,000 visitors a day) (Scuttari *et al.*, 2016). - Local operators recognise the problem. - The idea of a cable car connection is born.
Phase 2 A solution (i.e. the cableway) is promoted	- Ten years of debate and adaptations. - Resistance from local residents to the proposed cost of access to the plateau - resolved by proposing discounted ticket prices for residents. - Carrot and stick approach adopted. - Integration with the local bus service
Phase 3 The current situation and future prospects	- 1.4 million passengers between 2013 and 2014 (Arge Alp, 2015). - Stabilization of vehicular access. - Economic returns. - A reduction in traffic (and consequently also in air and noise pollution).

Source: authors' elaboration.

Another factor which changed people's minds was the inclusion of carrot and stick measures such as allowing only residents and overnight visitors to access the plateau between 9 am and 5 pm (Scuttari *et al.*, 2016). The two-line system (with 16 passenger capacity cars) connects the village of Siusi to the plateau 850m above and can carry 4,000 people/hour. The public transport system now includes a shuttle bus service (with a seasonally adjusted timetable) to serve the municipality area. Currently, the cable car, planned and constructed also with provincial government funds, is managed by a private company, "Funivia Siusi-Alpe di Siusi S.p.A.", which has become an important player in the area's tourism development.

The declared aims of the project include a range of issues, including (Arge Alp, 2015): reduced road traffic (and thus air pollution), reduced parking footprint in the Alpe di Siusi area, reduced noise pollution and reduced individual journeys from the centres of habitation to the departure station of the new cable car.

The results achieved are in line with the overall objective: traffic stabilized between 2005 and 2015; the parking areas on the plateau have been significantly downsized; the operators' fears have been confounded by a 25% increase in overnight stays, with almost 1.5 million cableway trips registered annually and increased profits for the small and medium sized operators of ski-lifts, hotels and other receptive structures, and restaurants.

As for the environmental benefits: a decrease of 25,000 km of car/bus journeys has been calculated, which translates into a reduction in CO_2 emissions of 2.13 tonnes per year (Arge Alp, 2015).

Analysing the two cases, we find that in both Innsbruck and the Alpe di Siusi the projects are part of two distinct sets of diverse initiatives. The Nordkette cable car is part of an intervention designed to revitalize tourism and rebrand Innsbruck. The overall project that includes the Siusi cable car upgrade (ALP.IN.SKI) seeks to solve environmental problems, with a focus on environmentally sustainable transport and other areas of sustainable planning. In both destinations the building projects were grounded in a participatory process, which was more inclusive in Innsbruck, probably because the rebranding plan had such a wide scope. Table 3 provides a summary of the main findings from the two case studies, and the key variables for the achievement of the objectives of the projects concerned.

Tab. 3: Main findings on the experiences of Innsbruck and the Alpe di Siusi

Key factors	Innsbruck	Alpe di Siusi
Who were the decision makers? And were they public or private actors?	The mayor, the local Tourist Association, stakeholders in the hospitality sector.	Arge Alp, Province of Bolzano, local operators (ski-lift, cable car, hotel, restaurant).
Community involvement/ participation in planning the project	Core group, microcosm, support team	Community involvement, discounted tickets for residents.
Primary objective	Tourism development, building the city's image/ identity	Traffic reduction, alternative mobility.
The project as part of an overall strategic development plan	Brand Driven Identity Development	ALP.IN.SKI
How the plan was realised	Upgrading of an existing cable car system.	A two-cable system, integrated within the local public transport network.
Efficacy of the project/ objectives met	Tourism development, improved public transport, deseasonalization, compatible with an Alpine identity.	Enhanced tourist attractivity, economic benefits, environmental sustainability, energy saving, pollution reduction, traffic/parking reduction,
Environmental performance measurement	None	Collection of data on traffic and CO_2 emissions, calculation of energy savings

Source: authors' elaboration

4.3 The case of Trento: analysis and evaluation of the key factors for the launch of the sustainable mobility plan

The two transport systems within the municipality of Trento are very different, both in terms of their geography and their function: in the valley the rural-urban system is tightly interconnected and well developed, whereas Monte Bondone is a natural park, rising steeply above the city. Historically and in terms of identity, the two zones are inextricably linked, but nowadays their actual transport links are weak. The current mobility system guarantees a network of urban and rural routes (Danielis *et al.*, 2014), but there is still a shortage of connections between Trento and the villages on Monte Bondone where public transport provision has not improved since 2015. Currently, Trento and Sardagna (a village on Monte Bondone) are connected by a cable car with a very small capacity and the (bus) routes to the other villages on the mountain are slow and winding.

Although they are promoted together to tourists, the data that we have gathered reveals that, on the ground, the two destinations are still disconnected. On the one hand, cultural and event-led tourism is allowing Trento to provide an ever richer and more focused tourist offer, on the other, Monte Bondone - despite a series of attempts, and plans to upgrade the ski offer - has not been able to keep up.

The possibility of a cable car connection between the city and its mountain was first raised in the early 1900s, and a number of different feasibility studies have been carried out in the intervening years. The project that this study examines is the most recent and envisions the construction of a Trento-Bondone cableway by 2030, under the auspices of a public partnership between Trentino Sviluppo, the autonomous Province of Trento and the municipality of Trento. The authors' project considers that it needs to form part of a broader tourism development plan for the two destinations which, through the building of the cableway, can redesign the relationship between Trento and its mountain, which are currently so poorly integrated, both in terms of tourism and mobility (for all concerned).

The cableway, according to the project proposal, would facilitate the offer of services - for tourists, locals and students alike - on the mountain, while simultaneously providing a mode of alternative mobility. The plan includes a number of elements which suggest good reason to expect that the initiative would prove successful:

- the strong growth of tourism in the city of Trento (presences have tripled in the last 18 years) and the consequent increase in consumer demand for a cableway;
- the fact that cableway construction methods have evolved considerably over the years, and the new technologies offer improved safety, increased capacity and are, above all, very environmentally sustainable;
- the immediate enhancement of the tourist experience (just traveling in a cable car is in itself a sought-after tourist experience);
- tourists' growing environmental awareness and knowledge of environmental issues (i.e. the demand segment is increasingly sensitive).

The plan proposes a cable car system that replaces the current Trento-Sardagna section, with four stations. The structure would involve a 5.8 km cableway, with an increase in elevation of 1,460 metres. A detachable gondola mono-cable system is envisioned, with 10 person cars, Wifi, an induced air system, digital information devices, a capacity of 1,500 persons/hr.

The benefits - most of which are primarily long term - are expected to be:

- extended seasons, particularly summer and mid-season, when the receptive structures are usually less busy;
- an increase in services: the newly constructed cableway would encourage new initiatives drawing on the widest possible range of

expertise (city planners, rural experts, local businesses);
- increased hotel occupancy, since the current tourist offer offers substantial room for improvement;
- synergies between mountain and urban tourism;
- positive outcomes for the territory due to the upgrading and valorization of existing structures, the improvement of services on the mountain, a decrease in road traffic, and increased employment opportunities.

Our analysis of the cableway's potential environmental performance is very promising, since the cable car system has a simple life cycle, is quickly constructed, and - because it can be dismantled and removed - has a low impact on the territory (in the long term). Table 4 sets out the most salient facts about the plan, applying the same key factors used in the Innsbruck and Alpe di Siusi case studies.

Another environmental benefit would be a reduction in traffic flow: according to an estimate[2] from "Trentino Sviluppo", this could amount to an annual saving of 7.2 million kilometres (corresponding to 1.7 million kg of CO_2).

Tab. 4: Main findings on the Trento-Bondone cableway project

Key factors	Trento - Monte Bondone Project
Who were the decision makers? And were they public or private actors?	PAT and the municipality of Trento
Community involvement/ participation in planning the project	The local population was consulted, through the gathering of 5,000 signatures (in 2019) supporting the project.
Primary objective	To provide a mode of alternative mobility, synergetic tourism development, experientiality.
Project is part of a broader strategic development plan	Premised on joint tourism development
How the plan would be manifested / be realised	A new cableway
Efficacy of the project/objectives	Deseasonalisation, tourism development, upgrading of services and structures on the mountain, increased employment and hotel occupancy, reduced traffic, environmental sustainability.
Environmental performance evaluation	Energy saving, reduced CO_2 emissions.

Source: authors' elaboration

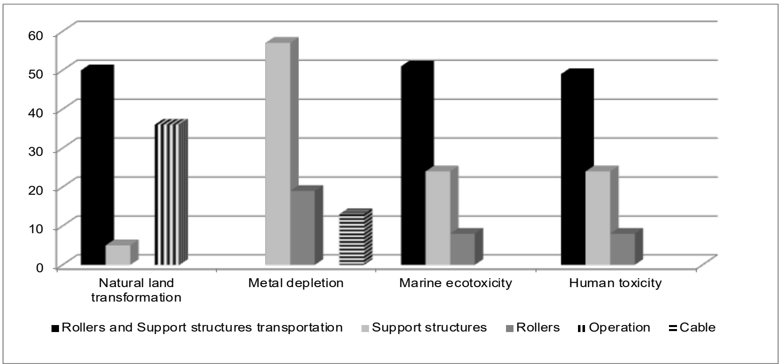
4.4 Trento Cableway: LCA and evaluation of environmental impacts

The LCA evidences the fact that the cable car system impacts particularly on 4 of the 16 impact categories considered (see Figure 1):
- *natural land transformation (NLT):* this covers all the eventual anthropogenic changes to the local ecosystem would undergo, such as the infrastructure for the road transportation of materials (50%) and the hydroelectric dams and reservoirs (36%). This category reports the damage caused to an ecosystem, factoring in the time needed to restore

[2] Based on an estimate of 600,000 trips a year, equal to 822 vehicles travelling 16 km with an estimated 237g of CO2 emitted per vehicle.

the land to its original state.
- *metal depletion (MD):* includes the extraction of the metal ores and the costs of prospecting and mining. The cableway infrastructure itself is clearly the most metal intensive: the support structures (57%) and the rollers (19%), and the cable's components all use a large quantity of steel.
- *marine ecotoxicity (ME):* the effects of toxic substances released into the water, air and soils of marine ecosystems. The largest effects are those of the transport of the support structures and rollers (57%) and of the manufacture of the support structures (24%).
- *human toxicity (HT):* the potential damage to human health from chemicals released into the environment by a particular process. Here, the biggest impact would be that of the transport of the rollers and support structures (49%), and of the manufacture of the latter (24%).

Fig. 1: Contributions of the required processes and materials to 4 impact categories (in %).



Source: authors' elaboration

The transport of the heavy materials used for the cableway (rollers and support structures) impacts on all 16 of the categories considered and is, in some categories, noticeably more damaging than the other processes/materials. In the Ozone Depletion category, for example, it accounts for 73% of the total impact, in the Fossil Depletion category, 60%, and in the Climate Change category, 48%; the system operation significantly impacts only on the Water Depletion category (99%). The use of electric motors results in the most important environmental benefit: when no fossil fuels are burnt, GHG emissions diminish considerably, as confirmed by the fact that, when operating, the cableway does not make a significant contribution to the Climate Change category. Two problems, however, emerge. The first concerns the use of hydroelectric energy which, although considered to have a low environmental impact, involves the depletion of water resources and changes natural habitats, home to a number of indigenous plant and animal species (evidenced in the Water Depletion and NLT categories). The second problem is caused by the transport of materials, which involves both heavy goods vehicle movement and - for the last stages of the cableway construction - helicopter flights.

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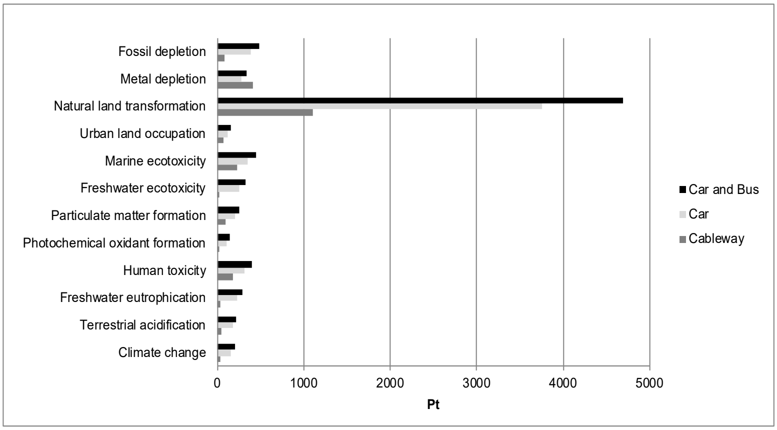
In order to provide further evidence of the environmental benefits of the cableway, a final LCA was carried out. The environmental impacts of the cableway were compared with those of two scenarios which, although hypothetical, more closely approximate the current traffic flows:

- *Scenario 1:* 300,000 passengers travel in private vehicles on the road Trento-Vason. This scenario was evaluated taking into account the characteristics of the Province of Trento's (private) vehicle fleet in terms of fuel (60% diesel, 40% petrol) and engine size (70% medium, 30% big) and the kilometres travelled by each vehicle type were calculated on the basis of an average of two occupants per vehicle.
- *Scenario 2:* 300,000 passengers of whom 80% travel in private vehicles (see scenario 1) and 20% use the public transport currently available (buses with diesel engines) operating with an average 70% of capacity (equivalent to 42 passengers in a vehicle with a maximum capacity of 60).

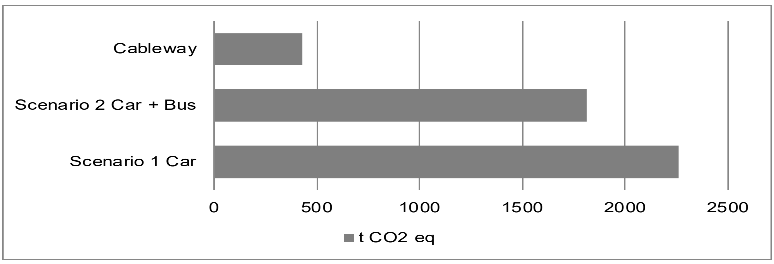
Figure 2 illustrates the contribution of the three transport systems to the 16 different impact categories.

Fig. 2: Contributions of the three transport systems to the analysed impact categories



Source: our elaboration

Fig. 3 Annual CO_2 emissions for the three scenarios, calculating for 300,000 passengers/year



Source: authors' elaboration

In terms of NLT, the difference between the contributions of the different scenarios is striking. The contribution of the cableway represents a sharp reduction of that in scenarios 1 and 2: the negative effects of scenario 1, in particular, would be almost four times greater than if the same number of people were using the cableway. It is evident that when the three scenarios are compared, the environmental performance and sustainability of the cableway is consistently higher than the other two, both of which, of course, are much more similar to the situation on the ground today. The addition of a cableway to the mix would clearly offer a beneficial alternative for passengers.

With regard to Climate Change, moreover, the impact of the cableway is significantly smaller: as Figure 3 demonstrates, the cableway, if it were carrying 300,000 passengers a year, would emit c. 75% less CO_2 than that calculated for scenario 2 and 80% less than scenario 1.

5. Discussion and conclusions

The present study contributes to the current urgent debate on the strategic role that the transport sector can play in reducing *a)* the consumption of primary materials, *b)* the atmospheric pollution caused by carbon intensive energy sources and *c)* land consumption. Choices about mobility are a complex challenge for public managers, because although transport is one of the biggest drivers of environmental change, it is also often a crucial factor in an area's socio-economic development.

The present study took the (2011 Trentino Sviluppo) plan for a cableway between Trento city centre and Monte Bondone as its starting point. The city lies right at the foot of the mountain and the latter has long been a popular destination, for locals and tourists alike. Our analysis had two objectives: the first was to identify the local circumstances and best practices that, might persuade policy makers to redesign mobility with a focus on sustainable solutions. The second objective was to measure and compare the environmental impacts of the proposed cableway with those of a) private vehicle use and b) a mix of private and public road transport.

To achieve the first objective, two examples of excellence in the Alps were examined. This enabled us to identify a) the characteristics of the decision-making processes that lead to the choice of an alternative mobility system, b) the involvement of local community and c) the position of the new mobility projects with respect to the respective area's planning instruments.

Our findings show that the decision-making process that led to the choices in both case studies involved a public-private partnership between the municipality or the province, local stakeholders and the hospitality sector. With regard to community involvement, Innsbruck adopted a limited form of participation (by a "core group"), while in the Alpe di Siusi, the participatory process was broad. The construction of the Alpe di Siusi cableway was part of an extra-regional plan, in the hands of Arge Alp and part of the ALP.IN SKI project. In Innsbruck, the decision to develop the cableway was part of a Brand Driven Identity Development tourism strategy. The T-MB cableway plan was initiated by public decision makers at the municipal and provincial level and elaborated in line with the municipality of Trento's well established (over twenty years) participatory planning strategy. The objective of all three projects is to reduce traffic and minimise the environmental impacts of mobility; it is hoped that the Trento proposal would, as in Innsbruck, enhance the city's infrastructure while also becoming a tourist attraction per se, thus contributing to the revitalization of tourism on Monte Bondone.

The success enjoyed by the Innsbruck and Alpe di Siusi cableways provide useful pointers for policy makers in this field, both in Trento and elsewhere. In particular, it is evident that the realisation of the T-MB cableway could help to strengthen Trento's identity as an Alpine city, by emphasising its proximity to, and identification with, the mountains, and working with a formula which has already proved successful in Innsbruck.

Our analysis of the examples of excellence confirmed the crucial role of public stakeholders in initiating mobility plans and coordinating the local actors involved. The positive reception given to the T-MB cableway when a petition in support of the plan was circulated suggests that the local community and its businesses will want to become actively involved in the various phases of the project. This involvement proved vital both in Siusi (the participation of local operators was crucial) and in Innsbruck, where stakeholders from various fields participated in the project.

As the literature review indicates (Papa, 2010; Scuttari *et al.*, 2016), and as evidenced by the examples of excellence, the T-MB project would benefit from an approach combining the integration of the cableway into the local transport system, traffic reduction measures and a discount ticket pricing for residents.

Turning to the second objective, the evaluation of environmental impacts focuses on the T-MB cableway project and was carried out through an LCA. It was considered the plan to replace the existing cableway and build a new one, with four stations and an end-to-end journey time of twenty minutes. To demonstrate the environmental benefits of using the cableway as a means of transport, the LCA of the new plan was compared with LCAs of two other scenarios, both of which are relatively close to the current mobility pattern.

The *first scenario* envisions the environmental impact of private vehicle use, hypothesising 300,000 passengers on the road between Trento and Vason and taking into account the profile of the province's (private) vehicle fleet in terms of fuel (60% diesel, 40% petrol), and engine size (70% medium, 30% big). The kilometres driven were calculated on the basis of the proportions of vehicle types and an average vehicle occupancy of 2 was factored in. The *second scenario* envisioned a mixture of private and public transport; of the 300,000 passengers, 80% would travel in private vehicles (fuel/engine size as in scenario 1) and 20% in public (diesel powered) vehicles. Average bus occupancy was put at 70% (42 passengers in a vehicle with a maximum capacity of 60).

The results demonstrate that, although the impact on NTL of the cableway would be significant, when compared to that of either private vehicles only or the mixed transport scenario, we have a new perspective:

the negative environmental impact of scenario 1 (private vehicles only) would be almost four times bigger than the scenario in which the same number of people used the cableway.

The mixed road transport hypothesis does not, considering all the environmental factors, perform very much worse than the cableway option; nevertheless, the latter undoubtedly does still perform better. When compared with the other two scenarios, therefore, the cableway consistently demonstrates superior environmental performance, and can thus be proposed as a more sustainable transport alternative. With regard to the *Climate Change* category, when the CO_2 emissions of the three scenarios are calculated (tonnes/year), the cableway is shown to emit 75% less than scenario 2 (the mixed system) and 80% less than scenario 1 (private vehicles only).

The findings of this study substantiate the claim that the cableway represents a viable alternative mobility system, powered by a renewable energy source and thus contributing to a reduction in greenhouse gasses emissions. Furthermore, its construction, if carried out with appropriate care in terms of the provision of materials and their transport, would have a minimal impact on the area considering its minor land consumption (and potentially temporary).

A high frequency service would also dramatically improve the connection with the villages on the mountainside which currently have only one road link. It would also prove to be a tourist attraction in its own right. In the long term, the construction of the cableway could be a starting point for the sustainable tourism development of Monte Bondone: benefitting from the city's tourist flows, the cableway could open a door for the place-appropriate, eco-friendly enjoyment of the mountains.

The fact that the T-MB project is still in the evaluation phase means that it has not been possible to access all the data necessary for either a detailed evaluation of the project's managerial implications or for the LCA analysis. This gap is the main limitation of the present study but is also the starting point for our next research project. An investigation of the proposed cableway's social and economic impact would strengthen the current analysis and provide a more comprehensive evaluation of the project, placing it squarely upon the three pillars of the sustainable approach.

In line with previous studies (Scuttari *et al.* 2013 and 2016), our research investigates sustainable mobility as an element of integrated territorial planning. Our methodology, however, is original: other than in the contribution of Biberos-Bendezú and Vázquez-Rowe (2020), there are no examples in the literature of an LCA being used to calculate the environmental impact of a cable car system.

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