The lower emissions Brenner Corridor

The BrennerLEC project team

European city authorities are implementing low emission zones (LEZs) in the fight to tackle high concentrations of air pollutants produced by urban traffic.[1] These zones protect specific areas by prohibiting or severely discouraging the access of the most pollutant vehicles. However, in smaller urban areas, particularly in mountainous regions like in the Alps, alternative or additional solutions have to be designed.

Such is the case of the town of Bolzano, in the South Tyrol region in Italy. Traffic from the A22 motorway—which crosses the town—is estimated to be responsible for about 20 per cent of the overall NO_x emissions generated in the urban area (Antonacci *et al.*, 2010). As a result and upon input of the environmental protection agencies of the autonomous provinces of Bolzano and Trento, a local public-private consortium decided in 2016 to implement the BrennerLEC project (co-funded by the European Commission under the LIFE programme).

The 'low emission corridor'

The concept of the 'low emission corridor' (LEC) was developed in the scope of the project. LEC is associated with a set of motorway traffic control measures that have the clear goal of reducing emissions of air pollutants generated by transit traffic without introducing particular restrictions for the circulation of vehicles. Such measures, which are extensively described in Cavaliere *et al.* (2017), are mainly based on the use of variable speed limits (VSLs), which particularly target diesel passenger cars. According to preliminary studies, shortly summarised in Figure 1, diesel vehicles account for about 76 per cent of the entire fleet, and passenger cars for about 46 per cent of the total emissions produced by the A22 motorway traffic.

After five years of intense empirical testing, in part already reported in Giovannini, L. *et al.* (2018) and Cavaliere, R. *et al.* (2019), it is possible to provide a comprehensive assessment of the impact of the proposed measures and understand how they can evolve in the near future in light of the expected evolution of the circulating fleet and also in terms of cooperative and automated functionalities.

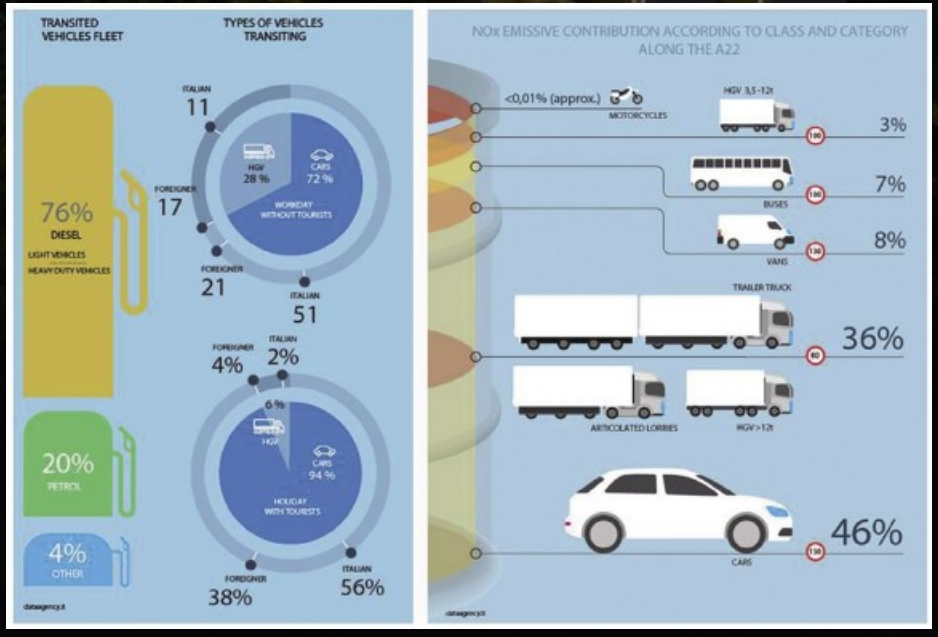

Figure 1: Initial assessment of the circulating fleet on the A22 highway and its impact on NOx emissions.

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Implementing the intelligent traffic system (ITS)

One of the main assumptions of BrennerLEC is that the activation of the measures must be proportional to the effective impact that they may generate. This means that VSLs should be activated when real-time and predicted traffic, meteorological, and air quality conditions are favourable to obtain valuable benefits. Thus, a complex ITS was implemented to let the traffic management centre (TMC) of the A22 dynamically activate the target measures (Figure 2).

The forecasting logics take advantage of the data integration provided by the Open Data Hub[2], an open platform developed by NOI Techpark, in which all relevant sensor measurements are collected and harmonised. The so-called 'traffic state machine' has the function of determining the traffic conditions on a real-time basis and suggesting different VSLs according to the congestion levels reached. A separate elaboration chain is used to evaluate if VSLs are needed to tackle high NO_2 concentrations, based on the following steps: *(i)* estimation of the traffic-generated emissions, calibrated according to the last available information of the circulating fleet, which is updated on a yearly basis; *(ii)* forecast of the meteorological conditions and in particular of the atmospheric stability; and *(iii)* estimation of the NO_x / NO_2 concentrations, also supported by data-driven assumptions of the background

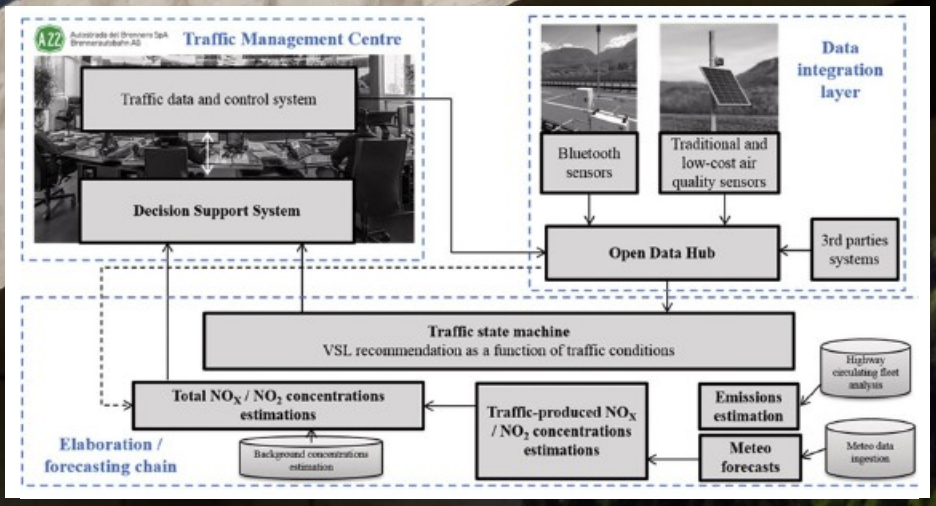


Figure 2: The final system architecture implemented in the BrennerLEC project.

concentrations. The system implemented also supports the dynamic integrated management of traffic flows between the motorway and the main urban centres of the region, e.g. for re-routing transit vehicles.

In Italy, the activation of VSLs due to solely environmental reasons is not presently allowed. This has significantly limited the compliance rate of drivers, particularly in relation to certain test typologies.

To address this challenge, an innovative solution was conceived and implemented. A mobile app automatically adds to or subtracts points from drivers depending on their adherence to reduced speed limits on the motorway. Users with the highest number of points can win prizes.

Field operational tests

Field operational tests have mainly been divided between VSLs triggered by poor air quality conditions (mainly characterised by the use of the recommended speed sign) and VSLs triggered by congestion phenomena. The first typology of tests has been extensively evaluated, with more than 4,000 hours of VSLs activated up to March 2020.

Despite the current regulation, the mandatory speed limit road sign was used during the first testing phase. This enabled the project team to consolidate various robust emission reduction scenarios that are associated with the average drivers' behaviour observed (Table 1). The results obtained clearly demonstrate the effectiveness of this measure also for the reduction of greenhouse gas emissions.

The possible added value of a section control system was evaluated to enrich the analysis. In this case, even if the average driver behaviour is completely simulated, the assumptions are based on available and reasonable state-of-the-art figures. As far as the impact on roadside pollutant concentrations is concerned, air quality measurements carried out by the environmental protection agencies, particularly in the first test phase, have demonstrated a reduction of 14 per cent of NO_2 emissions with an average speed reduction of 14km/h (from 123km/h without VSLs activated to 109km/h).

1 Please check the website https://urbanaccessregulations.eu/low-emission-zones-main for more information about the current LEZs developments in Europe

2 For more information about the Open Data Hub, please refer to the website https://opendatahub.bz.it

Scenario	NO_x emissions scenario / BAU emissions scenario [%]	CO_2 emissions scenario / BAU emissions scenario [%]
Scenario BAU	100.0%	100.0%
Scenario phase 3 – suggested speed limit (real)	95.8% (-4.2%)	98.1% (-1.9%)
Scenario phase 1 – binding speed limit without section control (real)	88.0% (-12.0%)	93.9% (-6.1%)
Scenario binding speed limit with section control (simulated)	74.6% (-25.4%)	87.1% (-12.9%)

Table 1: Emissions' reduction associated with different reference scenarios. The reductions are compared to the reference Business-As-Usual scenario (no VSL).

The second typology of the test was carried out less frequently since congestion phenomena are typically limited to spring and summer weekends and the Christmas period. Despite this, up to February 2020, it was possible to carry out more than 700 hours of tests and get solid results on the benefits of this measure. The most significant indications were collected during summer 2020, when, due to the COVID-19 limitations, it was not possible for the A22 TMC to carry out tests. In particular, a comparison was carried out between the overall levels of service observed with and without VSLs activated (years 2019 and 2020, respectively) during days that showed similar traffic volumes. In most observed cases, days with VSLs activated showed remarkable reductions in travel times.

Replication perspectives

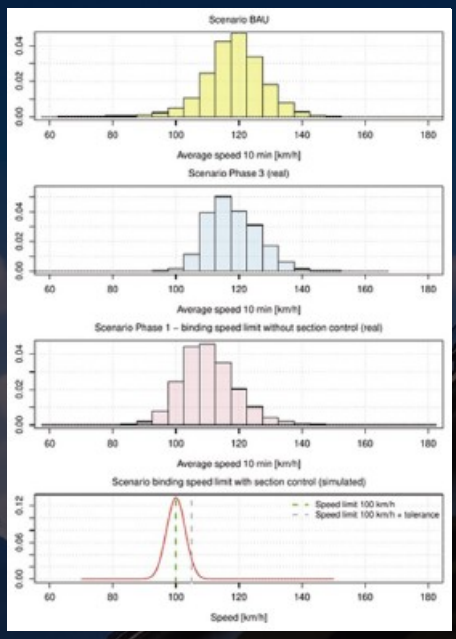
The long-term perspective is to build a so-called 'lower emissions Brenner Digital Corridor', in which the BrennerLEC measures are applied and extended by leveraging the C-ITS (cooperative intelligent transport system) hybrid infrastructure deployed, particularly in the scope of the C-Roads Italy and 5G-Carmen projects (Figure 3). More specifically, through one of the Day-1 applications (i.e. in-vehicle signage/speed limits), future connected and automated vehicles (CAVs) will be able to automatically receive the information of an active VSL and adapt their speed accordingly. Such cooperative scenarios are under research and development, and the first pilot tests have already been conducted on limited stretches of the A22.

Furthermore, annual studies (Figure 4) clearly show that the renewal of the vehicles driving on the A22 motorway is happening fast in terms of EURO class, but without significant variations in terms of the share of combustion engine type. For instance, the majority of transit vehicles are diesel light vehicles, with a share that increased from 75 per cent in 2017 to 82 per cent in 2019. A remarkable increase of 'clean' vehicles (e.g. newer EURO-6, hybrid or full-electric passenger cars) is, however, to be expected in the coming years; this trend must also be verified in future years in order to consider also the possible effects of the COVID-19 pandemic.

The exploitation plan proposed for the extensive application of VSLs considers these challenges. It aims to define a concrete replication output that expresses an optimised balance between expected impacts and investments needed. As far as VSLs for air quality purposes are concerned, the following methodology is proposed:

- calculate a detailed map of the average background pollutant concentrations, i.e. without the contribution produced by the traffic on the A22 motorway
- evaluate of the average air quality conditions in correspondence of the motorway.

The application of this methodology results in the activation of VSLs mostly in correspondence of the most populated areas (e.g. crossing of urban areas), subject to the most significant air quality issues.
As far as the VSLs in case of heavy congestion levels are concerned, the



plan is firmly based on the ambition of A22—to equip the infrastructure with a hard shoulder running (HSR) on both carriageways between the toll gates of Bolzano South and Verona North (approx. 140 km) and variable message signs (VMS) at close distance.

Conclusion

Five years of intense testing of VSLs applications on the A22 motorway, despite external issues such as the COVID-19 pandemic and current Italian regulation, have provided solid empirical evidence on the benefits of this kind of measure, i.e. the reduction associated environmental issues (in particular NO_2 and black carbon concentrations, CO_2 emissions) and the increase of the levels of service of the motorway during heavy congestion situations.

It is important to underline that these measures have also increased the already high road safety levels, with almost no accidents during the test activities. Field results strongly depend on the level of user compliance obtained: the more the drivers respect VSLs and have a smoother driving behaviour, the more significant are the benefits observed. The possible added value of enforcement systems has also been evaluated through scenarios.
Despite this evidence, the project experience has outlined the need to

A22 C-ITS INFRASTRUCTURE

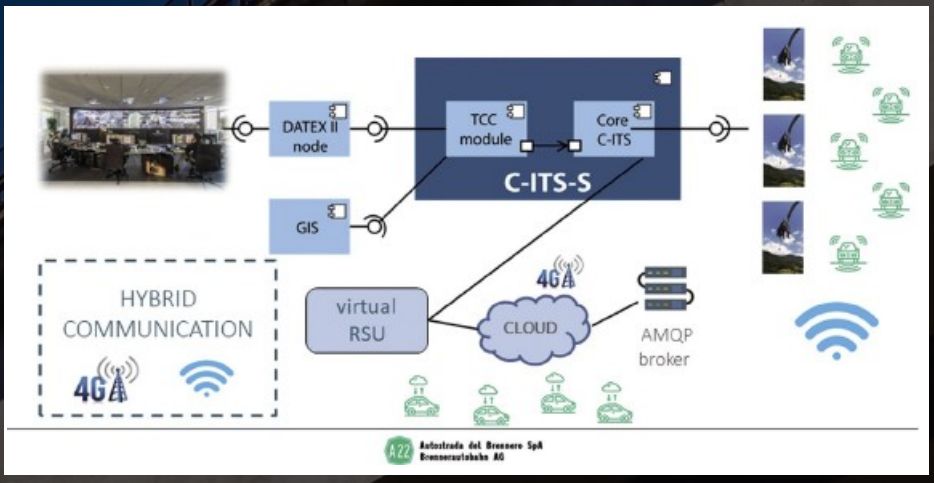


Figure 3: Screenshot example of the back-end system of A22 generating the cooperative messages for the connected vehicles.

foster a driving attitude that observes the proposed VSLs independently from the presence of enforcement systems. A rewarding initiative based on a gamification app—probably the first attempt of its kind worldwide in the motorway domain—has demonstrated the enormous potential to obtain the desired compliance.

The BrennerLEC results are the basis for the concretisation of the low-emission Brenner Digital Corridor, which aims to extensively replicate these and other measures on the entire A22 motorway, also benefitting from the future C-ITS hybrid infrastructure. A concrete exploitation methodology is proposed that will determine the most suitable motorway stretches to be managed with the BrennerLEC measures to optimise the balance between expected benefits and necessary roadside ITS investments (e.g. VMSs). This replication work will be exploited and harmonised on the entire Brenner Corridor in cooperation

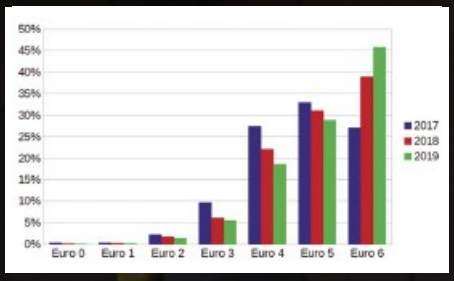


Figure 4: Evolution of the real circulating fleet on the A22 highway in the test stretch (detail of light vehicles).

with the Austrian and German motorway operators. Additional relevant topics will be explored, such as the usage of harmonised ramp metering logics for controlling the entering/leaving traffic flows. This harmonisation work between the current motorway situation present in different member states is also highlighting the need to upgrade/implement the reference EU regulation so that drivers can get a uniform experience while driving on the entire Brenner Corridor.

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PROJECT NAME

Brenner Lower Emissions Corridor (BrennerLEC)

PROJECT SUMMARY

The project is carried out with the aim of creating a concept of 'lower emissions corridor' (LEC) for the A22 motorway by implementing and validating a set of policies having the goal to provide clear environmental benefits in terms of air quality, climate protection and noise abatement, i.e. dynamic road capacity management, dynamic speed limits management and dynamic integrated traffic management.

PROJECT LEAD

Autostrada del Brennero is a public limited company operating under a public services scheme with the main aim of promoting, planning, constructing and operating tollways, including the A22 motorway.

It also promotes intermodal freight transport and railway transport and is sensible to environmental issues, fostering the construction of e-chargers and refuelling stations for alternative fuels (hydrogen, bio-LNG, CNG, LPG).

PROJECT PARTNERS

The project coordinator is Autostrada del Brennero (Brenner motorway), based in Trento. The other partners are the agencies for the environmental protection of the autonomous provinces of Trento and Bolzano; the Department of Civil, Environmental and Mechanical Engineering of the University of Trento; NOI Techpark, South Tyrol's technology park; and CISMA, a company specialised in solutions to solve environmental issues. Both NOI and CISMA are based in Bolzano.

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