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A novel concept of "Low Emission Corridor" empowered by ITS: the BrennerLEC project

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Abstract

This paper presents the details of a recently started LIFE project called "BrennerLEC", in which an advanced "environmental traffic management" system is going to be developed and applied on the Italian A22 (Brennero – Modena) highway, operated by Autostrada del Brennero Spa. This system is going to support the extensive testing and application of different dynamic policies, which range from (i) the temporary reduction of speed limits due to air quality; (ii) the combined use of variable speed limits (VSL) combined with temporary hard shoulder running (HSR) during highly saturated traffic conditions; and (iii) a more integrated usage of traveller information channels, in particular Variable Message Signs (VMSs) between the highway and the main urban areas crossed. Possible synergies with the roll-out of C-ITS technologies in the scope of the European C-ROADS initiative, as set by the European Strategy on C-ITS of the European Commission, are also deepened and discussed.

Keywords:

Environmental traffic management, proactive approach, cooperative speed limits notification

1. The targeted environmental issues

Trentino-South Tyrol is an autonomous region in Northern Italy, neighbouring with Austria and characterized by a strong alpine orography and unique environmental ecosystems, such as the Dolomites. The A22 highway, operated by Autostrada del Brennero Spa, is not only the main North-South transit route across the region: it is widely recognized as the most important road gate in the Alps for the transport of goods and passengers between Italy and the northern of Europe. The remarkable externalities of commercial traffic volumes are significantly amplified by strong tourist arrival peaks. Just to give a quantitative indication of this phenomenon, every year 7 million of tourists decide to spend their holiday in the region – an "occasional" population which is 7 times greater than the amount of inhabitants [1]. This number moreover does not take into account all flows of transit tourists coming from the North of Europe and deciding to spend their holidays in other regions of

Italy.

It is therefore not surprising that road traffic is responsible for about 60% of all NO_x emissions in the region, 41% of which being generated by highway traffic [2]. Air pollutant emissions generated by road traffic are the main cause of the exceedances of the annual NO_2 average law limits registered in the past years in the Autonomous Province of Bolzano (Figure 1): this situation is particularly critical since conditions of poor air quality mainly refer to locations where the majority of the inhabitants live.

Higher pollution levels are concentrated in a quite small part of the territory not only because of the road network, but also because the urban settlements as well as industrial areas are located along the valley floor. Orographic constraints finally explain why the average concentration maps resemble the emission pattern, with higher pollution levels on the main valley bottom and good air quality on the rest of the region.

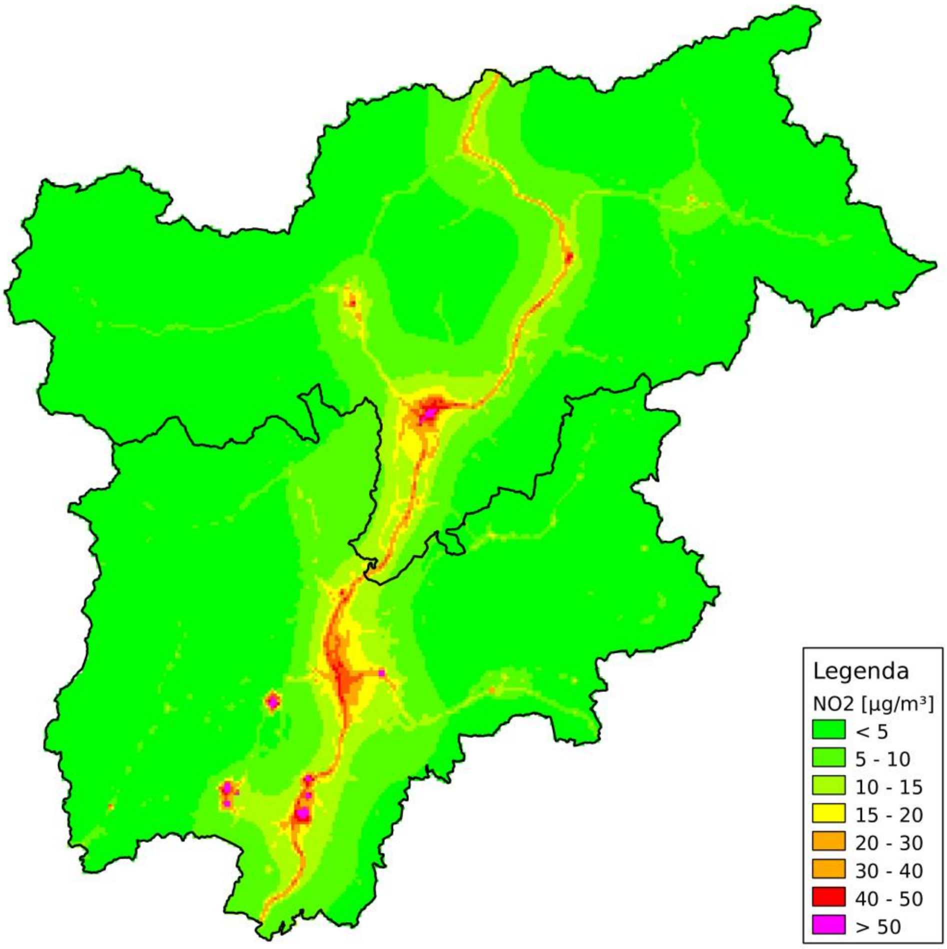

Figure 1 – Concentrations of NO_2 in the Trentino-South Tyrol region [1].

Local policies have demonstrated to be insufficient to guarantee alone the observance of the limit values set by law. Additional policies for reducing the environmental impact of the A22 highway traffic are therefore necessary in order to accomplish this goal, and must be taken in accordance with the reference national authorities. Air pollution is not the only environmental concern related to traffic: road traffic is indeed responsible for 42% of the overall CO_2 emissions generated in the region, 30% of which being generated by highway traffic. New actions must be therefore put in place in order to reduce the emissions of greenhouse gases and ensure a valuable contribution to the global targets of emissions' reduction.

2. The pilot policies

In order to cope with this increasing environmental pressure, Autostrada del Brennero Spa in cooperation with the Agencies for the Protection of the Environment in the Provinces of Trento and Bolzano as well as with the innovation centre IDM, the University of Trento and the local SME CISMA have started in September 2016 a new ambitious project called "BrennerLEC" (Brenner Lower Emissions Corridor), co-funded by the LIFE programme of the European Commission. The project, which has a budget of about 4.0 million Euros and is expected to finish in April 2021, aims at creating a holistic concept of "Low Emission Corridor" (LEC) for the A22 highway by implementing and validating a set of different dynamic traffic management policies having the goal to improve the current balance between traffic and environment.

2.1 BLEC-AQ: dynamic air pollution-induced policies

The first policy covers the dynamic management of speed limits, which are applied to light vehicles only. As confirmed by numerous and consolidated experiences in Europe and in other parts of the world, reducing speed limits on highways is one of the most effective measures from an environmental point of view. The dynamic management of speed limits is going to be tested on a specific test route of the A22 highway called "BLEC-AQ", a stretch of about 20 [km] located between the tolling gates of Egna/Ora and S.Michele (Figure 2). Reduced speed limits are going to be applied to light vehicles only since they represent the population of vehicles that can provide a remarkable environmental added value through a reduction of their speed: heavy vehicles already travel indeed at speeds in correspondence of the minimum of their emission curve. Their environmental impact is moreover targeted by integrated policies such as the application of the Directive 2011/76/EU "Eurovignette" and the promotion of the shift from road to rail of the transport of goods.

The final goal of this trial is to understand when this measure can determine the maximum improvement for the nearby air quality levels and limit the reduction of speed limits at only these situations, so to avoid significant negative impacts on the economy of the region. Empirical results obtained in nearby Austria have in fact confirmed that during 30% of the time in which dynamic speed limits were active it was possible to achieve 60% of the environmental benefit achievable by imposing reduced speed limits all over the year [3].

2.2 BLEC-ENV: dynamic traffic-induced policies

The second policy covers the dynamic management of road capacity during highly saturated traffic conditions, which will take place in the form of variable speed limits (VSL) combined with temporary hard shoulder running (HSR). In recent years, VSL and HSR have become a quite popular cost-effective way to increase the capacity of highways, limiting at minimum the improvements required on the existing infrastructure. Consolidated pilot experiences in Europe have already given proof of the benefits that such policies can determine. For example the usage of HSR on the TERN around Frankfurt has determined an increase of the road capacity of about 20%, with a significant reduction of the number of traffic breakdown [4]. In the UK, the combined use of HSR and VSL on a test area on the M42 highway has determined a decrease of the journey time by up to 30% and an increase of the peak throughput by up to 13% [5]. This concept is particularly suitable for the proposed case study, since the highway is characterized by recurrent but not constant problems of capacity, which are mainly localized during intense periods of tourist trips.

In the past years, Autostrada del Brennero Spa already improved the road stretch Trento South – Rovereto South so to make the application of HSR policies possible. Autostrada del Brennero Spa is planning for the next years to extend this stretch up to Verona, so to minimize the negative effects of traffic observed at the end of this pilot stretch when HSR is active, where vehicles are forced to travel again on two lanes instead of three. In BrennerLEC, the plan is to apply VSL and HSR policies on a specific test route of the A22 highway called "BLEC-ENV", a stretch of about 90 [km] located between the tolling gates of Bolzano North and Rovereto South (Figure 2). Tests are going to take place in south direction only, since the upgraded infrastructure for HSR is available only in this direction. The stretch between Bolzano North and Trento South has been added because the idea is to introduce the VSL upstream, when the first traffic perturbations are observed in the HSR test area. However, HSR policies are going to be limited to selected well-known situations, in correspondence of which a remarkable amount of traffic leaves the highway in correspondence of the tolling gate Rovereto South in order to reach the Garda lake.

The final goal of this trial is to identify the optimal modalities of usage of the combined VSL and HSR policies in relationship to the different patterns of nearly-saturated traffic conditions. In particular, the objective is to understand when VSL have to be activated and de-activated, and which is the optimal speed to be set in order to maximize the fluency of traffic and as a consequence reduce the emissions generated by vehicles, in particular those that take place during stop-and-go situations.

2.3 BLEC-LEZ: integrated highway-urban policies

The third policy covers the dynamic integrated traffic management between the highway and the main urban areas crossed, which will take place in the form of an improved cooperation between the different traffic management centres and an integrated usage of traveller information channels, in particular Variable Message Signs (VMSs). This operational and technical enhancement mainly focuses on foreseeable or sudden perturbations to normal traffic conditions, namely accidents, roadworks or traffic jams which can take place on both the "urban" corridor of the highway as well as on important urban and inter-urban routes controlled by the city / regional traffic authorities. The concept to better re-route traffic flows aiming to enter an urban area from the highway, despite rather new, has been more deeply investigated, even from an environmental perspective. In particular, in the scope of the EU project CARBOTRAF, travellers on the highway approaching the Austrian city of Graz were recommended through VMSs to enter the city by exiting at a specific tolling gate, dynamically selected on top of the suggestions provided by an automatic decision support system (DSS) according to both traffic and environmental criteria, confirming a non-negligible potential for emission reduction [6].

In BrennerLEC, integrated traffic management policies are going to be tested and applied within three test areas called "BLEC-LEZ" in correspondence of the cities of Bolzano, Trento and Rovereto (Figure 2). The final goal of this trial is to find empirical methodologies that can contribute to minimize the environmental impact of the overall traffic in correspondence of these areas, given the same surrounding conditions. During the execution of the tests the ambition of the policies is going to increase step by step, including also recurrent situations without events and in particular the issues related to the transit of the most polluting vehicles through the cities.

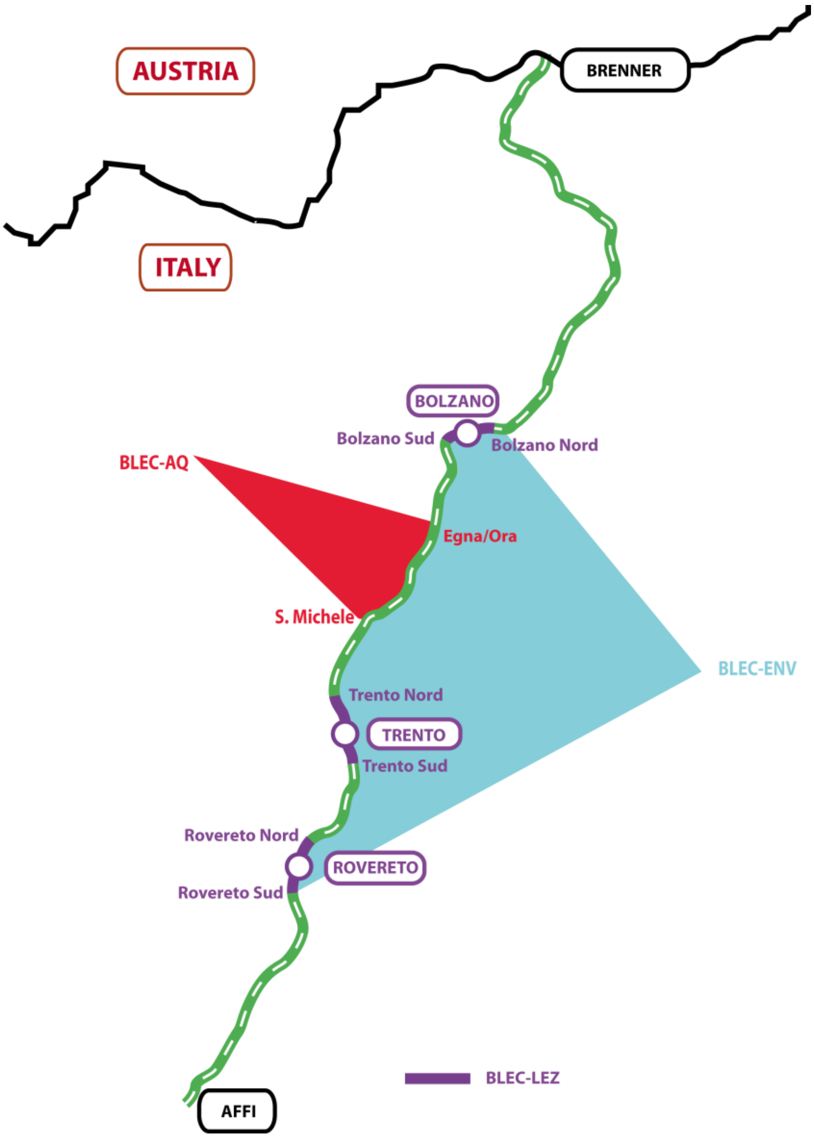

Figure 2 – Test areas of the BrennerLEC project.

3. The contribution of ITS: sense and react proactively

This ambitious set of policies is going to be aided by an intense use of modern ITS technologies applied at different layers and with a stepwise approach, so to allow an immediate start of pilot activities. The reference high-level ITS architecture that the project aims to put in place is schematically presented in Figure 3, and is drawn on top of the previous positive experience carried out in the city of Bolzano in the scope of the EU-funded project “INTEGREEN” [7]. The architecture is characterized by four different layers:

- the **monitoring** layer, which provides a variety of real-time traffic and environmental data thanks to a wide set of roadside stations coupled with mobile probes;
- the **remote computation** layer, which automatically validates the received data, provides a complete overview of the current situation and draws short-term forecasts of the possible scenarios;
- the **traffic control centre** layer, in which the results of the elaborations are presented to the operators of the traffic control centre of the A22 highway through a new Decision Support System (DSS), and targeted policies are activated in a supervised way;
- the **actuation** layer, which receives the instructions from the traffic control centre layer and physically put in place the selected policies.

This ITS architecture is characterized by different elements of innovation, in particular as far as the integration with the environmental domain is concerned. Environmental monitoring will take advantage of a network of sensors installed along the highway, aiming at getting a complete spatial representation of meteorological and air quality conditions. Air quality monitoring will be performed using both conventional and innovative low-cost sensors, in particular for measuring NO_2 and NO concentrations (Figure 4). In fact, traditional instruments for the measurement of these species are very accurate, but are not suitable to be used in densely distributed monitoring networks, due to their high purchase costs and demanding management. For this reason a number of innovative and low-cost sensors have been recently developed and are currently available on the market. However, evaluation of the performance of these instruments is still limited and mainly based on laboratory experiments. During the project the performance of this kind of sensors under true ambient conditions will be continuously monitored, by comparing their measurements against the conventional stations, providing the basis for enhanced understanding of the accuracy of these instruments in changing environmental conditions. Another innovative aspect connected to environmental monitoring is the measurement of black carbon (BC), which will be performed using aethalometers working at different wavelengths, in order to discriminate between BC emitted from traffic and from wood combustion, extensively used in the region during the winter period. BC is currently not included in the air quality legislation, but it will probably become in the near future one of the standard for air quality assessment. This effort goes in the direction of recent European projects, such as the already mentioned CARBOTRAF project.

The core of the remote computation layer will be an advanced modelling chain, composed of integrated meteorological, air quality and traffic models, which will take advantage of all measurements performed at the monitoring layer. Building on the positive results obtained in other experiences of application of VSL and HSR, BrennerLEC aims at moving a step forward, implementing a proactive system, in order to maximize the benefits of the policies tested, by putting in action measures only when necessary and anticipating environmental and traffic issues.

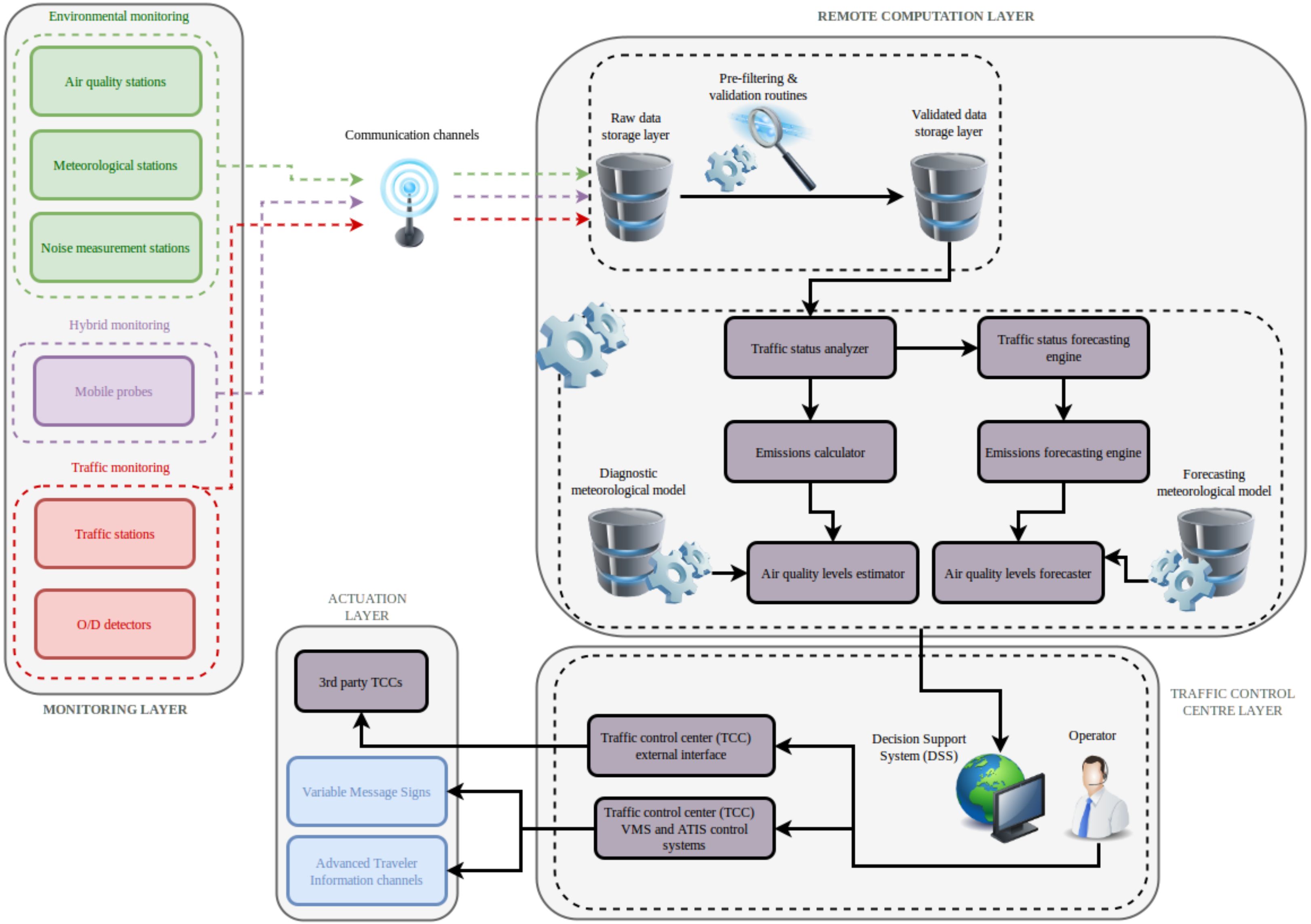

Figure 3 – The reference ITS architecture used in the BrennerLEC project.

The objective is to obtain the best compromise in terms of environmental benefits, quality of service (including road safety) and user acceptance.

Figure 4 – Combination of conventional (left) and innovative low-cost (right) air quality monitoring stations in the BrennerLEC pilot test site.

The execution of the pilot activities is scheduled as a function of the planned implementation of this ITS architecture and the complete preparation of the pilot test site, as summarized in Table 1. An increased number of Variable Message Signs (VMSs) is in fact needed in order to properly advise road users about the temporary presence of a dynamic policy in all various use cases. In the BLEC-AQ pilot area, an additional intermediate testing phase is considered, focused on the empirical assessment of the effects of the "reactive" approach (i.e. the dynamic activation of the temporary speed limits driven by the monitored exceedance of air pollutants).

Table 1 – Temporal plan for the pilot testing of the dynamic policies.

	Phase 1 (Sep. 2016 – Feb.2018)	Phase 2 (Mar. 2018 – Feb 2019)	Phase 3 (Mar. 2019 – Sep. 2019)	Phase 4 (Oct. 2019 – Apr. 2021)
BLEC-AQ	Initial tests on reduced stretch without DSS	Extensive tests on complete stretch with DSS in testing mode	Intermediate tests with DSS in "reactive" mode	Final tests with DSS in "proactive" mode
BLEC-ENV	Initial tests on reduced stretch without DSS	Extensive tests on complete stretch with DSS in testing mode		Final tests with DSS in "proactive" mode
BLEC-LEZ	Initial tests based on better coordination of existing traffic management procedures	Extensive tests based on completed interfacing between traffic management centers and DSS in testing mode		Final tests focused on joint minimization of environmental impact of transit traffic through urban areas

4. Conclusions and future perspectives

The BrennerLEC project is a demonstration of a possible set of traffic management measures aided by mature ITS technologies and novel concepts that road operators and environmental agencies can together put in place in order to smooth the environmental impact of transit traffic, which can integrate the implementation of other demand-oriented policies promoting a gradual shift of traffic from road to rail. The main expected results associated to the implementation of this set of dynamic policies can be summarized as follows:

- reduction of emissions of about 10-20% (with peaks up to 40% in cases of highly saturated traffic);
- reduction of NO_2 concentrations of about 5% (with peaks of 30% at the most exposed sites);
- improvement of the state-of-art efficiency of existing policies (in terms of amount of hours with dynamic policy in place versus environmental benefit observed);

However, since the temporal scope of the project goes beyond 2020, the expected impacts of the project can be significantly amplified if the roll-out of the dynamic traffic management policies is wisely combined with the roll-out of cooperative and autonomous ITS technologies, which are expected to significantly improve road safety, traffic efficiency and comfort of driving, by helping the driver (or the vehicle itself) to take the right decisions and adapt to the traffic situation.

In 2016 the European Commission has adopted a European Strategy on C-ITS, a milestone initiative towards cooperative, connected and automated mobility. The objective of the C-ITS Strategy is to facilitate the convergence of investments and regulatory frameworks across the EU, in order to see deployment of mature C-ITS services in 2019 and beyond. This deployment is going to take place in a continuous coordination, in a learning-by-doing approach, with the C-ROADS platform, an initiative started in 2016 in order to link C-ITS deployment activities, jointly develop and share technical specifications and verify interoperability through cross-site testing. In a C-ITS architecture, every unit, being mobile or standing roadside, exploits the data received from other devices to generate strategic warnings, tactical advices and driver information. While vehicle units broadcast data about their position, speed and driving direction (via Cooperative Awareness Message - CAM) or event-driven information, such as an obstacle or changing environmental conditions (via Decentralized Environmental Notification Message - DENM), roadside units deliver local data such as speed limits, signal phases and timing of traffic lights or information about traffic re-routing. What is of particular interest for the project’s goals is that one of the three use cases selected within the C-ITS Platform is “regulatory speed limits notification”, i.e. the cooperative exchange of information related to speed limits between vehicles and the road infrastructure, with signage applications such as “in-vehicle signage” and “in-vehicle speed limits” being in the list of the Day 1 services to be implemented on European roads. Autostrada del Brennero SpA is increasingly involved and committed in the C-ROADS activities, with large-scale pilots of C-ITS technologies planned for the next years on the A22 highway.

This combination of efforts therefore opens the doors for the implementation of a more ambitious architecture for BrennerLEC, with monitoring and actuation units capable to more effectively exchange the current information and/or speed limitations to road users. The design of such an architecture already from this initial stage can provide a key contribution to the achievement of the expected impacts, since one of the most challenging elements to cope with relates to the compliance by the road users of the dynamic policies, in particular as far as the reduced speed limits are concerned. On the other side, this issue will be inevitably solved by the large-scale diffusion of autonomous driving functionalities on-board of the vehicles, which is expected to take place in the next years, especially on the highways. Such an integration of initiatives can be seen as a valuable example of how current implementation projects driven by concrete and pressing needs can today fit with the on-going roll-out of C-ITS in Europe, with the perspective to optimize the time needed for observing the promised benefits of these technologies on safety, mobility and environment.

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