

ITSs for Transnational Road Traffic Detection: An Opportunity for More Reliable Data

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Abstract. Reliable data collection is an unavoidable requisite for rigorous planning of transport policies that aim at achieving a more balanced modal split. This is particularly evident for long-distance road traffic, which in most cases involves two or more countries. Since each country adopts its own method for counting and classifying vehicles, the risk of using inconsistent data for common purposes is high. Intelligent Transport Systems may be a valid support for providing a standardized and effective method to solve this issue, provided that there is a preliminary agreement on the technological solutions and the location where to install them. This paper compares the methods currently adopted by different stakeholders and authorities in Italy and Austria to count transnational heavy and light vehicles along the Brenner corridor, which is one of the main European transnational axes in terms of traffic volumes. In line with this analysis, differences in the results could be noted, according to the adopted method and their position. Subsequently, a solution to achieve a more consistent dataset is proposed, based on common classification and shared technology to detect vehicles. This agreement is fundamental for policy purposes: the main aim of the Italian-Austrian Euregio Tyrol-South Tyrol-Trentino in the transport sector is to invert the current long-distance modal split by 2035, a result that can be achieved only if a correct and shared counting system is adopted.

Keywords: Traffic flow detection · ITS · Transport policies · Brenner corridor · Modal split

1 Introduction

In recent years, several transport policies have been proposed for the purpose of achieving a more balanced modal split. These policies are mainly directed at long-distance road traffic, which in most cases involves two or more countries. According to the White Paper on Transport [1], this type of journey is a typical target for a shift from road to rail, especially in delicate environmental and social contexts like the Alps [2]. Indeed,

© Springer Nature Switzerland AG 2021
O. Gervasi et al. (Eds.): ICCSA 2021, LNCS 12950, pp. 350–362, 2021.
https://doi.org/10.1007/978-3-030-86960-1_25

railway guarantees reduced externalities and less negative impacts for the communities crossed by its infrastructures. This holds particularly true for freight transport, where, on average, the economic difference in externalities between 1 tkm by road and rail is higher than 2€ [3]. By considering that in 2019 the total amount of freight that circulated by road along the Alps was 160.3 Mt and the length of transalpine corridors is more than 300 km (Brenner 415 km, Gotthard 288 km), the high external costs can be easily quantified.

Implementing modal shift policies in favour of rail in the Alps is one of the main targets of the Action Group 4 Mobility of EUSALP, the macro-regional strategy for the Alpine area [4]. However, to check progress in the modal shift, solid knowledge about road traffic volumes is a fundamental requisite. Detecting international traffic is not as trivial as it may appear, since each Country adopts its own method to classify and, consequently, to count vehicles [5]. Therefore, the risk of using inconsistent data and making analyses not based on shared values is concrete. When we refer to the transalpine transport, 5 countries (France-FR, Switzerland-CH, Austria-AT, Germany-DE and Italy-IT) and even more counting systems are considered. The latter may depend not only on the nation, but also on the data providers (e.g., regions, municipalities, companies that manage the motorways), on the scope of measurement (e.g., for fiscal or traffic monitoring reasons) and on the adopted methods (e.g., inductive loops or video detection systems).

Intelligent Transport Systems (ITS) could be a valid support for providing a standardized and effective method to solve this issue, provided that there is a preliminary transnational agreement about the technological solutions to be adopted and a shared definition of their location. The Directive 2010/40/EU [6] promotes the use of standardised information flows or traffic interfaces across borders, but in most cases alternative solutions coexist and are used alternatively.

The aim of this paper is to describe the condition of traffic detection along the Italian and Austrian sections of the Brenner corridor, the transalpine corridor with the highest traffic flows [7], and to propose a solution based on ITS to find more reliable values. The paper is structured as follows: after this introduction (Sect. 1), Sect. 2 discusses the role of ITS in traffic monitoring and management. Section 3 focuses on the Brenner corridor and identifies adopted methods for the classification of vehicles currently available. Section 4 analyses the road traffic volumes collected for the Brenner corridor, both for the Italian and Austrian motorways, showing differences in absolute values and in relation to specific subcategories of vehicles. Section 5 presents and discusses a potential solution to overcome the issue of trans-national traffic counting in this area.

2 Modern Technologies for Traffic Flow Detection

Among the wide variety of ITS and their applications both for passenger and freight transport, road traffic management systems can be helpful solutions to handle data collection [8]. Modern systems guarantee automatic classification of vehicles, which is essential for adopting adequate and immediate measures in case of unexpected impacts (e.g., road accidents, traffic congestion). According to [9], two main technologies for traffic flow detection can be identified: (i) intrusive sensors and (ii) non-intrusive sensors. The former are installed directly on or under the roadway surface (in-roadway

sensors), while the latter are mounted above the roadway on sign bridges or to the side of the roadway on poles or other structures (over-roadway sensors). According to the adopted technology, sensors can detect electromagnetic energy (infrared spectrum, radio frequency spectrum, visible spectrum, microwave spectrum, or millimetre-wave spectrum) or acoustic and ultrasonic energy. In addition, the sensors can be passive (P) if they detect reflected energy from a source, or active (A), if they both emit a pulse of energy and detect reflected energy. With respect to the above specifications, inductive loops (A), magnetometers (P) and magnetic sensors (P) are intrusive sensors, while video detection systems (P), microwaves, like presence-detecting radars (A), or doppler sensors (A), acoustic sensors (P), laser radar (A), passive infrared (P), ultrasounds (A) and technology combinations (A + P) are non-intrusive sensors. The adoption of a technical solution depends on several factors, including the costs of purchase, installing, operating, and maintaining the system, the details of the traffic information to be collected and its accuracy. For instance, information about traffic flow can be gathered according to highly selective vehicle classification, to distinguish different classes based on axle counts and accurate measurement of the distances between wheels and/or their speed detection.

The inductive loop sensors are less expensive. Being installed under the road surface, they require a lane closure for their installation and maintenance, but they have a long operational life and at the same time, being invisible, may overcome issues related to the perception of drivers. Vehicle magnetic acting on loop detector parameters allows to detect and count axles correctly even if an axle is lifted. Nowadays, this solution is widely applied in traffic data collection, in part because of institutional inertia and know-how, but also for the limited costs [10]. However, the risk of collecting incomplete or inaccurate data is not negligible [11]. On the other hand, non-intrusive sensors are rapidly evolving and becoming easier to use. Compared to the previous solution, their advantage lies mainly in the minimization of interference with traffic flow and reduction of safety risk. Furthermore, they represent a valid alternative in particular sections of the line (e.g., bridges and tunnels), where pavement cutting and boring is difficult or undesirable. Current non-intrusive sensors are more accurate than inductive loop sensors for detecting volume and speed data [12]. In both cases, sensitivity to environmental conditions, traffic flow and road design can challenge accuracy, reliability, and functionality of the detectors. This preliminary defines the most suitable solutions according to the characteristics of the area to be analysed.

3 The Brenner Corridor and the Measuring Stations Located Near the Border

The Brenner corridor, which is part of the TEN-T Scandinavian-Mediterranean European Core Corridor, is a transalpine multimodal (road-rail) axis that goes from Munich (DE) to Verona (IT). This corridor has the highest freight volumes transported per year (about 53.7 Mt in 2019) [7]. Its volumes are growing consistently: an increase by 28% has been recorded since 2010. The volumes transported by road over this period are about 40 Mt (+45% compared to 2010) and are twice as high as in the second transalpine corridor

in terms of volumes (Ventimiglia, 21 Mt). Thus, transalpine road freight traffic is an important component of overall volumes at Brenner.

Policies to invert the current modal share by 2035 constitute one of the pillars of the Euroregion Tirol-South Tyrol-Trentino [13], also based on the assumption that Heavy Goods Vehicles (HGVs) circulating are monitored regularly over time. In particular, for the purposes of modal shift it is fundamental to pinpoint the transalpine component. So far, reports and technical evaluations are based on Austrian data, but this simplified choice could have implications in terms of overall number of vehicles. The detection of HGVs that pass through the latest Austrian cross-border detection point but end their trip before the boundary could lead to an overestimation of the values. On the contrary, the presence of the RoLa terminal at Brennersee, which guarantees a combined transport service for the Austrian part of the infrastructure (daily connections with Wörgl) may lead to an underestimation of values, since the detection point is located before the terminal (southward direction). The ideal solution would be comparison of volumes registered at the traffic detection points that are closest to the Brenner border in AT and in IT, and to distinguish between Light Vehicles (LVs) and Heavy Vehicles (HVs). If values are similar, this would be a good indicator of the transalpine flows that circulate along the Brenner. Unfortunately, this is not the case, mainly due to the differences in counting and aggregating vehicles.

The stretches of the motorway A22 [14] that are used to compare AT and IT values are: i) the South-Tyrolean section of the A22-Autostrada del Brennero (IT) from the Brenner Toll station located near Vipiteno to the IT-AT border (16 km) and ii) the Tyrolean section of the Brennerautobahn A13 (AT) from the IT-AT border to Schönberg im Stubaital (25 km), the last toll station available in AT direction southwards. Available data are provided by A22-Autostrada del Brennero for the motorway A22 [15] and by ASFINAG for the motorway A13 [16]. State roads (i.e., SS12 in IT and B182 in AT) are not considered in our analysis. Besides the fact that they are not appropriate for long-distance travel, it would be not possible to consider them as a valid alternative: indeed, in AT there is a transit ban for vehicles above 3.5t; whereas in IT, some segments of the road are banned for vehicles above 20t (including the section between Brenner and Vipiteno, the object of our analysis).

Data are collected through different systems, which can be classified into five main categories (see Fig. 1). For each system, it is also indicated if it uses (i) intrusive and/or (ii) non-intrusive technology. In IT, A22 adopts two different methods, (ID1) toll stations and (ID2) on-road measurement systems. In AT, ASFINAG uses three different methods: (ID3) overhead sensors with triple technology, (ID4) on-road measurement systems and (ID5) toll stations. In detail:

- In IT, the solution adopted in A22 toll stations (ID1) combines intrusive (Weigh In Motion systems) and non-intrusive sensors (overhead devices that encode transit details) and classifies the vehicles according to the criterion "*assi-sagoma*" (axels-shape) [15]. It distinguishes among five classes: two for vehicles with two axles and three for vehicles or vehicle combinations with three or more axles. This system considers LVs as those belonging to ClassA–2 axles / height $\leq$ 1.3 m and HVs those belonging to Class B–2 axles / height $>$ 1.3 m, Class3–3 axles, Class4–4 axles and

Class5–5 or more axles. In this classification, cars with a trailer and articulated trucks belong to the same Class 4.

- In the A22 on-road measurement system (ID2), the number of vehicles circulating is detected by inductive loops (intrusive sensor) located along the motorway, which collect information on instantaneous speed and vehicle type (LVs or HVs). This system classifies all vehicles ≤ 5.25 m as LVs and all vehicles > 5.25 m as HVs. This means that cars above 5.25 m are considered as HVs.
- In AT, the overhead sensors with triple technology (ID3), i.e. the TDC3–8 device (non-intrusive sensor) [17] are installed in different sites located along the A13. This system controls traffic flows thanks to three sensors installed in one device, which combines ultrasounds (to detect vehicle height profile), passive infrared (to reveal vehicle width and lane position), and doppler radar (to provide information on vehicle speed). The TDC3–8 device, mounted on overhead structures above the centre lane, classifies vehicles into $8 + 1$ vehicle classes according to the standardized German TLS (Technical delivery terms for roadway stations): 1) other vehicles; 2) motorbikes; 3) cars; 4) vans; 5) cars with trailer; 6) buses; 7) HGVs; 8) HGVs with trailer; 9) HGVs articulated.
- The A13 on-road measurement system (ID4) detects the passage of vehicles through inductive loops (intrusive sensors) located along the motorway. The inductive loops classify the vehicle according to a derived shape profile, which can be compared with sample profiles. This system gathers information on instantaneous speed and vehicle type and counts vehicles on the basis of $8 + 1$ vehicle classes: 1) other vehicles; 2) motorbikes 3) cars; 4) vans; 5) cars with trailer; 6) buses with more than nine seats; 7) HGVs; 8) HGVs with trailer; 9) HGVs articulated; [18].
- Overhead devices (non-intrusive sensors) are mounted in the A13 Toll station (ID5) to recognize both LVs (i.e. all vehicles with a maximum permissible weight ≤ 3.5t) and HVs (i.e. motor vehicles with a maximum permissible weight > 3.5t). HGVs and buses must be equipped with a GO-Box, an electronic device that uses microwave technology to communicate with the toll portals. The overhead device classifies the vehicles according to 4 categories: 1) Category 1: all vehicles ≤ 3.5t (i.e. cars, motorbikes and light camper vans); 2) Category 2: motor vehicles with max. 2 axles; 3) Category 3: motor vehicles with max. 3 axles; 4) Category 4: motor vehicles with 4 and more axles [16].

Along the aforesaid stretch of the Brenner motorway, five measuring stations are available (see Fig. 2). Two stations are located along the motorway A22 (Brenner Toll station and Brennero-Vipiteno) and 3 measuring stations on the motorway A13 (Brennersee/A13, Matrei am Brenner and Schönberg Toll station). The measuring stations of Brennero-Vipiteno and Matrei am Brenner use intrusive sensors based on inductive loops installed in the respective motorway sections (ID2 and ID4). The Brenner Toll station combines intrusive and non-intrusive sensors (ID1), while the Schönberg Toll station and the station of Brennersee/A13 adopt two different methods based on non-intrusive sensors: respectively, the detection toll system (ID5) and a triple technology detector system (ID3). Therefore, all technical solutions presented in Fig. 1 are visible in our study area and the information each of them provides can be compared.

Solution (ID)	Traffic flow detection	Technology*	Classification of vehicles and distinction between LVs and HVs
1	A22 Toll station (IT)	i and ii	The vehicles are classified in 5 classes: 1) ClassA-2 Axles/Height≤1.3 m (LVs); 2) Class B-2 Axles/Height>1.3 m (HVs); 3) Class3-3 Axles (HVs); 4) Class4-4 Axles (HVs); 5) Class5-5 or more Axles (HVs).
2	A22 On road measurement system (IT)	i	The vehicles are classified in 2 classes: 1) All vehicles ≤ 5.25 m (LVs); 2) All vehicles > 5.25 m (HVs).
3	A13 Triple Technology Detector System (AT)	ii	The vehicles are classified in 8+1 classes: 1) Other vehicles; 2) Motorbikes (LVs); 3) Cars (LVs); 4) Vans (LVs); 5) Cars with trailer (HVs); 6) Buses (HVs); 7) HGVs (HVs); 8) HGVs with trailer (HVs); 9) HGVs articulated (HVs).
4	A13 On road measurement system (AT)	i	The vehicles are classified in 8+1 classes: 1) Other vehicles; 2) Motorbikes (LVs) 3) Cars (LVs); 4) Vans (LVs); 5) Cars with trailer (HVs); 6) Buses with more than nine seats (HVs); 7) HGVs (HVs); 8) HGVs with trailer (HVs); 9) HGVs articulated (HVs).
5	A13 Toll station (AT)	ii	The vehicles are classified in 4 classes: 1) All vehicles ≤ 3,5t (LVs); 2) Motor vehicles with max. 2 axles (HVs); 3) Motor vehicles with max. 3 axles (HVs); 4) Motor vehicles with 4 and more axles (HVs).
* intrusive (i) and/or non-intrusive technology (ii).			

Fig. 1. Main characteristics of the adopted method for classification of vehicles along the Brenner corridor.

The raw data, collected in real time by A22-Autostrada del Brennero and ASFINAG in each station is processed by the motorway operators and the information is then aggregated in different ways, depending on the source that publishes the data (motorway operator or Province/Land involved). The aim is to distinguish between LVs and HVs, but based on counting methods, results may vary. Figure 2 identifies for each ID the measuring station, specifying its distance from the IT-AT border and the different classification of vehicles according to the source. LVs are identified with x.1, HVs with x.2 and subclasses of HVs with x.2.y, where x stands for a letter between A and D and y is for a number, according to the number of available subclasses.

ID	Station (Nation)	Km + m	Source	LVs	HVs HVs subclasses
1	Brenner Toll station (IT)	15+ 850	A22	**A.1**: ClassA-2Axles/ Height≤1.3 m	**A.2**: All vehicles belonging to the classes B, 3, 4 and 5 **A.2.1**: Class B- 2 Axles/ Height >1.3 m **A.2.2**: Class 3-3 Axles **A.2.3**: Class 4 - 4 Axles **A.2.4**: Class 5 - 5 or more Axles
2	Brennero-Vipiteno (IT)	0+ 200	A22	**B.1**: All vehicles ≤ 5.25 m	**B.2**: All vehicles > 5.25 m
3	Brennersee/ A13 (AT)	5+ 800	ASFINAG Land Tyrol	**C.1**: All vehicles ≤ 3.5t **D.1** *	**C.2**: All vehicles > 3.5t **D.2**: HV-similar vehicles (such as car with trailer, van with trailer, buses with more than nine seats, HGVs with or without trailer, HVGs articulated) **D.2.1**: HVGs with or without trailer, HVGs articulated **D.2.2**: HVGs with trailer, HVGs articulated
4	Matrei am Brenner (AT)	18+ 800	ASFINAG Land Tyrol	**C.1**: All vehicles ≤ 3.5t **D.1** *	**C.2**: All vehicles > 3.5t **D.2**: HV-similar vehicles (such as car with trailer, van with trailer, buses with more than nine seats, HGVs with or without trailer, HVGs articulated) **D.2.1**: HVGs with or without trailer, HVGs articulated **D.2.2**: HVGs with trailer, HVGs articulated
5	Schönberg Toll station (AT)	23+ 400	Land Tyrol	**D.1** *	**D.2**: HV-similar vehicles (such as car with trailer, van with trailer, buses with more than nine seats, HGVs with or without trailer, HVGs articulated) **D.2.1**: HVGs with or without trailer, HVGs articulated **D.2.2**: HVGs with trailer, HVGs articulated

* LVs are not identified in the table of the traffic in Land Tyrol [17].

Fig. 2. Identification of the five measuring stations at the border section of the Brenner corridor and classification of vehicles.

4 Road Traffic Volumes Detected Along the Brenner Corridor

According to available traffic detection systems, it is now possible to quantify the number of LVs and HVs detected per day by each system and compare them. Figure 3 presents disaggregated information for the year 2019. The subdivision of vehicles in classes and subclasses is derived from the classifications identified in Fig. 2. Measuring stations in IT provide comparable data in terms of traffic for all vehicles (30,637 vehicles/day

for ID1 and 30,513 for ID2), while Austrian data are generally higher: the ID3 collects 32,375 vehicles/day (+6% compared to ID1 and ID2), whereas ID4 and ID5, which are farther from the boundary and include also traffic generated or headed to the Austrian villages located until the boundary, count 37,805 and 38,276 vehicles/day (respectively, +23.5% and +25% compared to ID1 and ID2). Passing from the absolute number to the subdivision between LVs and HVs, some interesting aspects should be noted (see Fig. 4). Italian detection points registered a number of HVs higher than 11,000; in AT this value is lower than 8,000 for ID3 - the exact number depending on the source: 7,377 according to ASFINAG, 7,979 according to Land Tyrol. Even in ID4 and ID5, which presented overall higher values of vehicles (see Fig. 4), the number of HVs is lower than in IT: 7,584 according to ASFINAG and 8,343 according to Land Tyrol (ID4). As previously mentioned, this may depend on the fact that the Italian systems count all those vehicles (or vehicle combinations) that are either longer than 5.25 m, or are higher than 1.3 m, as HVs. All cars with trailers, as well as large-size cars and SUVs are therefore classified as HVs, contributing to explaining the significant differences between IT and AT values.

ID	Station (Nation)	Source	LVs per day	HVs per day HV subclasses	LVs + HVs per day
1	Brenner Toll station (IT)	A22	**A.1**: 19,222	**A.2**: 11,415 **A.2.1**: 3,462 **A.2.2**: 861 **A.2.3**: 366 **A.2.4**: 6,726	**A.1+A.2**: 30,637
2	Brennero-Vipiteno (IT)	A22	**B.1**: 19,293	**B.2**: 11,221	**B.1+B.2**: 30,513
3	Brennersee/A13 (AT)	ASFINAG Land Tyrol	**C.1**: 24,998 **D1***: 24,396	**C.2**: 7,377 **D.2**: 7,979 **D.2.1**: 6,961 **D.2.2**: 6,548	**C.1+C.2**: 32,375 **D1+D.2**: 32,375
4	Matrei am Brenner (AT)	ASFINAG Land Tyrol	**C.1**: 30,225 **D1***: 29,466	**C.2**: 7,584 **D.2**: 8,343 **D.2.1**: 7,269 **D.2.2**: 6,724	**C.1+C.2**: 37,809 **D1+D.2**: 37,809
5	Schönberg Toll station (AT)	Land Tyrol	**D1***: n.a	**D.2**: n.a **D.2.1**: n.a **D.2.2**: 6,766	**D1+D.2**: 38,276

* LVs are calculated as the difference between Total Vehicles (D1+D2) and HV-similar vehicles (D.2).

Fig. 3. Road traffic volumes (vehicles/day) detected along the border section of the Brenner corridor – year 2019.

Repeating the same procedure for the entire period 2010–2019 produces the aggregate data presented in Fig. 5. All general comments related to the year 2019 are still valid, but some differences are also evident. In terms of total vehicles, the Italian counting systems presented higher differences in years 2010–2013, while in years 2014–2019, they registered roughly the same amount. Considering Austrian values registered at Brennersee/A13, which is the Austrian measuring station less influenced by domestic traffic, they are lower than Italian values until 2011, then they become higher. This could also

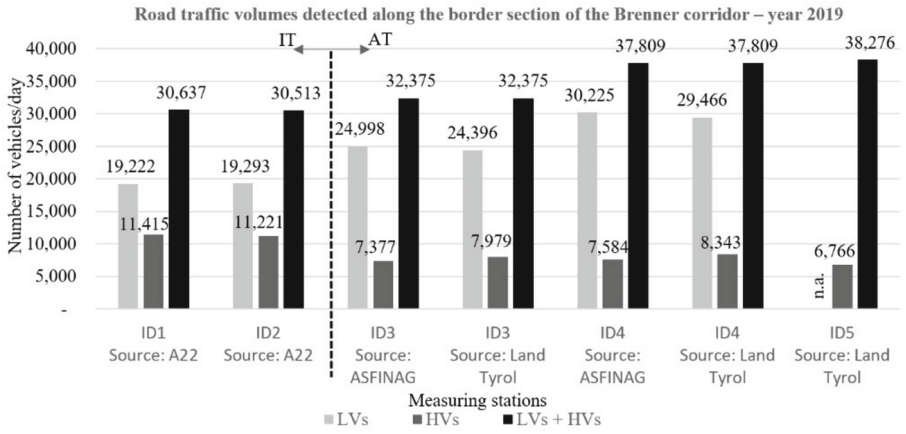

Fig. 4. LVs and HVs detected along the border section of the Brenner corridor – year 2019.

be due to the sectoral driving ban applied to the Austrian stretch of the Brenner motorway, valid only until 2011. Regarding LVs, values registered at Brennersee/A13 for year 2012–2019 are always higher than those of the two Italian measuring stations.

At a first glance, Italian data are more consistent: toll stations and road measurement systems differ by some tens or units, and this is likely due to the inaccuracy of the loops, rather than the toll system, which implies the passage from a protected toll gate. However, recalling the classification provided in Fig. 1, Italian data count all vehicles with more than 2 axles and heigh > 1.3 m (toll stations) or all vehicles longer than 5.25 m (on-road measurement system) as HVs. These categories also include passenger vehicles (with or without trailer) and buses that may not be assimilated to freight vehicles. Thus, the Italian method for classifying vehicles seems inappropriate for the purposes of this paper, and it is not possible to obtain a different classification derived from the available solutions.

On the other hand, the Austrian counting system is more rigorous in the classification of vehicles (accurate classes are used, and it is possible to consider HVs separate from passenger cars with trailers). However, some measuring stations (e.g., ID5) are quite far from the national boundary and domestic traffic or traffic with either origin or destination in the areas located along the stretch between Schönberg toll station or Matrei am Brenner and Brenner are also counted. For this reason, the counting system at Brennersee/A13, which is located after the last exit of the motorway A13 (Nößlach exit) before the Brenner Pass border, seems the best source for counting and classifying the vehicles on the Austrian side. However, there is a risk of ignoring those vehicles from the RoLa at the intermodal terminal of Brennersee (which is located close to the border, after the detection point), which provides about 20 daily connections from Brenner to Wörgl (and vice versa) during the week. From this analysis, for different reasons it is apparent that any of the systems currently available provide reliable information about the transalpine traffic flows.

ID	Station (Nation)	Km+ m	Source	Classification of vehicles	2009 ***	2010 ***	2011 ***	2012	2013	2014	2015	2016	2017	2018	2019
1	Brenner Toll station (IT)	15+ 850	A22 - Brenner Motorway	LVs	17,217	17,469	17,766	17,417	17,883	17,982	18,531	19,339	19,608	19,498	19,222
				HVs	8,064	8,462	8,536	8,545	8,642	8,971	9,308	9,842	10,818	11,220	11,415
				LVs + HVs	25,281	25,931	26,302	25,961	26,525	26,953	27,839	29,181	30,426	30,718	30,637
2	Brennero Vipiteno (IT)	0+ 200	A22 - Brenner Motorway	LVs	17,255	18,788	18,639	17,927	18,625	18,247	18,846	19,508	19,717	19,602	19,293
				HVs	7,746	8,255	8,708	8,792	8,781	8,608	8,908	9,568	10,573	11,010	11,221
				LVs + HVs	25,001	27,043	27,347	26,719	27,406	26,855	27,754	29,076	30,290	30,613	30,513
3	Brennersee/ A13 (AT)	5+ 800	ASFINAG	LVs	n.a.	18,069	18,235	22,624	n.a.	21,569	22,508	23,638	25,124	25,125	24,998
				HVs	n.a.	6,162	6,279	5,624	5,589	5,813	6,026	6,374	6,786	7,202	7,377
				LVs + HVs	n.a.	24,231	24,514	28,248	n.a.	27,382	28,534	30,012	31,910	32,327	32,375
			Land Tyrol	LVs*	18,604	18,007	18,235	n.a.	n.a.	n.a.	n.a.	22,748	24,037	24,363	24,396
				HVs	6,162	6,224	6,279	n.a.	n.a.	n.a.	n.a.	7,266	7,875	7,964	7,979
				LVs + HVs	24,766	24,231	24,514	n.a.	n.a.	n.a.	n.a.	30,014	31,912	32,327	32,375
4	Matrei am Brenner (AT)	18+ 800	ASFINAG	LVs	24,696	n.a.	25,469	25,156	29,122	27,899	28,714	29,755	31,219	30,581	30,225
				HVs	6,063	n.a.	6,514	5,611	5,545	5,840	6,065	6,482	6,996	7,461	7,584
				LVs + HVs	30,759	n.a.	31,983	30,767	34,667	33,739	34,779	36,237	38,215	38,042	37,809
			Land Tyrol	LVs*	24,696	n.a.	25,469	24,175	n.a.	27,315	27,982	28,979	n.a.	29,787	29,466
				HVs	6,063	n.a.	6,514	6,593	n.a.	6,425	6,798	7,259	n.a.	8,257	8,343
				LVs + HVs	30,759	n.a.	31,983	30,768	n.a.	33,740	34,780	36,238	n.a.	38,044	37,809
5	Schönberg Toll station (AT)	23+ 400	Land Tyrol	LVs*	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
				HVs**	4,363	4,600	4,760	4,875	4,821	5,090	5,292	5,707	6,180	6,637	6,766
				LVs + HVs	31,495	32,580	33,162	33,155	33,246	34,205	35,233	36,549	38,647	38,709	38,276

* LVs are calculated as the difference between Total Vehicles (D1+D2) and HV-similar vehicles (D.2); ** Only this data is published by Land Tyrol [17] for HVs (HV subclasse D.2.2); *** Online data published by ASFINAG is only available up to 2012. To complete the dataset, iMONITRAF! data was included for years 2009-2011.

Fig. 5. Road traffic volumes (vehicles/day) detected along the border section of the Brenner corridor per year (2009–2019).

5 Conclusion: Installation of a New Traffic Measuring Station at the Italian Side of the Brenner Corridor

This paper has illustrated the methods currently adopted in IT and in AT to detect road vehicles along motorways, showing the significant differences in counting LVs and HVs. Data are managed by the respective motorway companies and road departments of the Land/Regions involved, but there is not a real sharing of such data, except for when they are published. This poses urgent issues in terms of harmonization and adoption of common values, to be used as reference to monitor the effectiveness of the policies introduced on both sides of the boundary.

Coherently with the technical analysis that we have performed in the previous sections, the TDC3–8 device (ID3) based on a classification into 8 + 1 classes (as available in the station of Brennersee/A13, see Sect. 3), provides accurate knowledge about traffic composition, allowing better differentiation between LVs and HVs. However, the lack of correspondent Italian data and its use in a point that also includes part of the domestic traffic in AT have prevented obtaining real knowledge about the transalpine vehicles circulating at Brenner.

An integration of this system, also on the Italian side, is a valid solution to guarantee more reliable counting. The idea of installing a new measuring station of this type in IT, close to the Austrian border, was proposed within the Euregio Working Group on traffic monitoring, where all the technical aspects described in this paper were discussed. It was subsequently agreed upon by the Autonomous Province of Bolzano, the Land Tyrol, the motorway A22 and ASFINAG [19]. Data gathered by the new measuring

station can be easily compared with those of the station of Brennersee/A13, making accurate monitoring of the component of transit traffic crossing the Brenner corridor possible. The exact location of the new system, which classifies the vehicles in 8 + 1 classes according to TLS, is at km 0 + 130 of the A22, close to the boundary and the ID2 (km 0 + 200). Therefore, the domestic traffic is not detected, whereas the traffic from the RoLa at Brennersee is included, overcoming the main issues related to the Austrian counting stations. From a technical point of view, a new induction loop detector will be flanked by a TDC3–8 device and a system based on LiDAR sensors (2D laser scanners), which record the contour of the vehicles. All three detection systems provide traffic data according to 8 + 1 vehicle classes, allowing a comparison referred to the same point and a more coherent validation process. The installation of this system poses some management issues that are not trivial. Data collection, harmonization, and management are among them [20]. In this sense, the political agreement between local actors involved in this operation (ASFINAG, A22, Autonomous Province of Bolzano, Land Tyrol and Euregio) is an important step: it assigns the phases of data collection and harmonization to ASFINAG, with subsequent diffusion to all previously mentioned subjects. This should speed up the entire process, at the same time avoiding the risk of having different data depending on the source (a risk that cannot be ignored in this type of analysis, see Fig. 3 and Fig. 5). Regarding the economic aspects, the overall costs (labour + components) should obviously be considered in the evaluation. Costs for the system based on LiDAR sensors are almost four times higher than induction loops and TDC3–8 device, which, in turn, are of the same order of magnitude (10–15k€).

These ITS solutions could surely contribute to a more proper evaluation of the effectiveness deriving from the adoption of specific transport policies [21], in light of the ambitious objective of a modal shift mentioned in the introduction. Indeed, adequate and shared information about traffic flows can make it easier for policy makers to understand the impacts of specific transport measures and modify their mid- and long- term strategies accordingly, also considering an integration with the urban dimension [22]. Even if this is not the main purpose of our research, the proposed classification and counting of vehicles could also be helpful for daily traffic operations, especially during extraordinary weather conditions. In the geographic area in question, where extreme events are not unlikely (e.g., intense snowfalls in wintertime, severe rainstorms in summertime [23]), monitoring of hourly and daily vehicles that circulate could contribute to managing circulation and introducing appropriate temporary measures to reduce accident risks. Furthermore, this system could support traffic management in case of congestions. Again, this is a condition that is not negligible along the Brenner corridor, especially related to the transboundary section, mostly caused by the high number of HGVs. Thanks to rigorous detection of vehicles, adequate signals or even temporary closures of the toll stations could be foreseen, and information about parking areas located along the motorway could be provided.

The passage from technical to political issues is particularly relevant along the Brenner corridor, where in recent years the single provinces have often introduced specific measures valid only for their territories, but whose effects have also impacted neighbouring regions [24]. Sharing the vehicle counting system (at least at transalpine level)

and using common data could be a first step towards integrated policies, which should be the real overall objective of this initiative.

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