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Environmental Footprint of Heavy Vehicles Phase III: Comparison of Footprint and Heavy Vehicle Fee (LSVA) Criteria

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Forschungsauftrag ASTRA 2010/019 auf Antrag des Bundesamtes für Strasse (ASTRA) und 2005-02150/01/06/05/07 des Bundesamtes für Umwelt (BAFU)

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Zusammenfassung

Während den Monaten März, September und November 2011 wurden an der Footprint Monitoring Messstelle Oberbuchsiten an der Autobahn A1 Bern-Zürich je rund 100'000 schwere Güterfahrzeuge erfasst und hinsichtlich ihrer SWISS10 Fahrzeugkategorie, des Gesamtgewichts, der Achslast, der akustischen Emission (maximaler Vorbeifahrtpegel), der EURO Emissionskategorie, des deklarierten Gewichts sowie weiterer Parameter ausgewertet. Aus den Daten lassen sich folgende Ergebnisse ableiten:

1. Die Resultate sind im Monatsvergleich konsistent, sowohl was die Anzahl Fahrzeuge betrifft als auch die Maxima, Minima und Medianwerte der ausgewerteten Grössen.
2. Die erfassten Fahrzeuge setzen sich hauptsächlich aus den SWISS10 Kategorien 8, (Lastwagen), 9 (Lastenzüge) und 10 (Sattelzüge). Die EURO Emissionskategorien verteilen sich mit 66% auf EURO-V, 10% auf EURO-IV und 19% auf EURO-III.
3. Die überwiegende Mehrheit der Fahrzeuge hält die 40 t Gewichtslimite ein, allerdings verkehrt eine nicht zu vernachlässigende Anzahl Fahrzeuge mit mehr als 40 t Gesamtgewicht.
4. Der Vergleich des von der WIM Anlage erfassten aktuellen Gewichts mit dem zulässigen Gewicht aus der LSVA Datenbank ergab, dass weniger als 0.6 % der Fahrzeuge überladen waren. Das Maximum wurde im Monat November erreicht mit 0.6 % von 105'037, entsprechend 617 Fahrzeugen.
5. Die Aufschlüsselung nach Achslasten ergab, dass im Mittel das Maximum bei der zweiten Achse erreicht wird, allerdings dicht gefolgt von der ersten Achse. Die geringsten Achslasten zeigten Fahrzeuge der SWISS10 Kategorien 5 (Lieferwagen) und 6 (Lieferwagen + Anhänger). Busse (Kategorie 1) wiesen ähnlich hohe Werte auf wie die Fahrzeuge der Kategorien 7 (Lieferwagen+Aufleger), 8 (Lastwagen), 9 (Lastenzüge) und 10 (Sattelzüge).
6. Die mittlere Achslast betrug in allen Kategorien rund 5 t und lag damit unterhalb der vorgeschriebenen Limiten von 11.5 t für die Antriebsachse und 10 t für die übrigen Achsen. Allerdings wurden diese Grenzen in praktisch allen Kategorien von einzelnen Fahrzeugen überschritten.
7. Die akustischen Messungen lieferten im Monatsvergleich keine Hinweise auf erhöhte Emissionen durch Winterreifen.
8. Es zeigten sich keine systematischen Abhängigkeiten der akustischen Messwerte von der EURO Emissionskategorie, insbesondere waren die EURO-V Fahrzeuge nicht leiser als EURO-IV bzw. –III. Die Fortschritte auf der Abgasseite widerspiegeln sich damit nicht unmittelbar in der akustischen Emission.
9. Die an einer Stichprobe von 42 zufällig aus dem Verkehr herausgegriffenen Fahrzeugen untersuchte Gegenüberstellung der beobachtbaren Merkmale Motorenleistung, Reifenprofiltiefe und Reifendruck einerseits und der akustischen Emission andererseits ergab keine signifikante Korrelation.
10. Basierend auf den akustischen Messwerten wurde ein verfeinertes Emissionsmodell abgeleitet, welches eine Vorbeifahrtpegelschätzung anhand bekannter bzw. beobachtbarer Fahrzeugparameter, die über die Fahrzeug-ID erschlossen werden können, erlaubt.
11. Es wurden zwei Modelle zur Berechnung eines Gesamt-Footprints entwickelt. Dieser umfasst die Aspekte Gewicht, Lärm und Luft. Hierbei zeigt sich eine bedeutende Streuung im Sinne, dass in allen Kategorien einzelne Fahrzeuge mit sehr hohem Gesamt-Footprint auftreten.

Die Ergebnisse können als Grundlage für die Entwicklung eines Bonus/Malus Mechanismus dienen, der gegenüber der heutigen Regelung ein verfeinertes Verursacherprinzip etabliert, mit dem Ziel umweltfreundliche Fahrzeuge zu fördern. Wie sich gezeigt hat, verursachen moderne Fahrzeuge nicht unbedingt tiefere akustische Emissionen. Es wäre deshalb wünschenswert, dass der bisher unberücksichtigte aber hinsichtlich externer Kosten sehr bedeutende Lärmaspekt in einer künftigen Verkehrsabgabe-Regelung (LSVA) berücksichtigt würde.

Résumé

Chaque mois 100'000 données validées sur les véhicules lourds, comprenant le poids total autorisé en charge, la charge par essieu, le bruit, la catégorie d'émission Euro, la classe de véhicule selon la classification Swiss 10, le poids déclaré ainsi que d'autres paramètres, ont été récoltées aux mois de mars, septembre et novembre 2011 sur le site de monitorage de l'empreinte environnementale du trafic routier situé sur l'autoroute A1 Bern-Zürich sur le Plateau suisse. Les conclusions tirées de l'analyse de ces données sont les suivantes:

1. Les données de ces trois mois sont consistantes et répétables tant pour ce qui est du nombre de véhicules, des valeurs maximales, minimales et des valeurs médianes des paramètres examinés.
2. La flotte de véhicules est composée en majorité de véhicules des classes Swiss 10, 9 et 8 avec des moteurs en majorité de la catégorie Euro-V (env. 66%), Euro-IV (env. 10%) et Euro-III (env. 19%).
3. La majorité des véhicules analysés présentaient un poids total inférieur à la limite de 40 t applicable en Suisse, avec un nombre faible mais significatif de véhicules d'un poids dépassant les 40 t.
4. Une comparaison des poids réels enregistrés par les capteurs de pesée dynamique (WIM, weight in motion) avec les poids autorisés tirés de la banque de données de la RPLP a montré que moins de 0.6% des véhicules étaient surchargés. La majeure partie de ces surcharges se sont produites au mois de novembre avec 0.6 % de 105'037 véhicules, soit 617 véhicules.
5. La valeur de la charge moyenne par essieu était la plus élevée pour le 2e essieu suivie de près par celle du 1er essieu. Les classes Swiss 5 et 6 présentaient les charges par essieu les plus faibles. Les autocars (classe Swiss 1) présentaient des charges par essieux aussi élevées que celles des véhicules des classes Swiss 7, 8, 9 et 10.
6. Bien que la moyenne de la charge par essieu, avec une valeur de 5 t sur toutes les classes, se situe dans les limites permises de 11.5 t pour les essieux moteurs et de 10 t pour les autres essieux, on trouve dans la majorité des catégories des véhicules qui dépassent ces limites.
7. Les résultats des mesures du bruit montrent qu'il n'y a aucun effet additionnel dû au pneumatiques d'hiver qui auraient été utilisés aux mois de septembre et novembre.
8. Il n'existait aucune dépendance systématique entre les émissions de bruit et les classes d'émissions de polluants Euro, cela pour toutes les classe de la classification Swiss 10. Ceci montre que les véhicules de la classe Euro-V ne sont pas forcément moins bruyants. Toutefois, les véhicules des classes Swiss 9 et 10 sont plus bruyants que ceux des autres classes. Ces données montrent que bien que la flotte de véhicule soit devenue plus respectueuse de l'environnement pour ce qui est des émissions de polluants, elle ne l'est pas pour ce qui est des émissions de bruit.
9. On a encore étudié la corrélation éventuelle entre la profondeur du profil des pneumatiques, la pression des pneumatiques, la puissance du moteur et le niveau de bruit maximum lors d'un passage normalisé pour une vitesse de 80 km/h. Les résultats obtenus sur 42 véhicules choisis au hasard dans le flux du trafic indique que ces paramètres n'exercent pas d'influence significative sur la génération du bruit.
10. Le modèle d'émission de bruit développé à cet effet permet d'estimer l'empreinte, sonore à partir de paramètres connus ou observables. Ces données peuvent être obtenues à partir de l'identification du véhicule pour calculer ses émissions de bruit.
11. Deux modèles sont proposés pour le calcul de l'empreinte environnementale totale des véhicules lourds qui permettent d'utiliser une approche holistique tenant compte d'une combinaison de toutes leurs empreintes individuelles. Les résultats montrent que bien que la valeur médiane de l'empreinte totale soit basse dans toutes les classes, on trouve dans presque toutes les classes des véhicules présentant une empreinte environnementale globale très élevée.

Les résultats de ce projet peuvent s'utiliser pour développer un mécanisme de bonus/malus basé sur le principe du pollueur-payeur afin de réduire à la source l'impact environnemental des véhicules. Comme le bruit a des effets nocifs importants sur les habitants et que les mesures effectuées dans ce projet montrent que les modèles récents des véhicules lourds ne sont pas nécessairement moins bruyants, il est recommandé de procéder à la révision de la RPLP afin de tenir compte des coûts externes dus au bruit du trafic routier comme le prévoit l'UE. Il est de plus conseillé d'appliquer des redevances différenciées sur les émissions de bruit afin de récompenser l'usage de véhicules moins bruyants.

Summary

Each month ca. 100’000 valid heavy vehicle data on gross vehicle mass, axle load, noise, Euro emissions category, Swiss 10 vehicle category, declared mass as well as other parameters was collected for March, September and November 2011 at the Footprint monitoring site on the A1 motorway Bern-Zürich in central Switzerland. From the analysis of this data the following was concluded:

1. The data for the three months are consistent and repeatable, both in the number of vehicles, maxima, minima and median values of the parameters investigated.
2. The vehicle fleet is mostly Swiss category 10 (articulated freight trucks), 9 (freight trucks with trailer) and 8 (freight trucks) with engine categories that are mostly Euro-V (ca. 66%), Euro-IV (ca. 10%) and Euro-III (ca. 19%).
3. The majority of vehicles analyzed carry below the allowable in Switzerland of 40 t, however there is small but significant number of vehicles carrying more than 40 t.
4. A comparison of the actual weight carried obtained from weigh in motion (WIM) sensors and the allowable weight according to the LSVA databank showed that less than 0.6% of vehicles have been overloaded. The most number of overloads happened in November with 0.6 % of 105’037 vehicles or 617 vehicles.
5. The mean axle load values for axles 2 was the highest with axle one following closely. Swiss categories 5 and 6 have the lowest axle loads. Buses (Swiss cat 1) have axle loads as high as Swiss 7 (delivery pickup with trailer), 8 (freight truck), 9 (freight trucks with trailer) and 10 (articulated freight trucks).
6. Although the mean at about 5 t axle load in every category is within the allowable limit of 11.5 t for drive axle and 10 t for other axles. There are vehicles within most categories that bypass this limit.
7. Noise measurement results show no additional effect due to winter tires which would be seen between September and November.
8. There was no systematic dependence of the noise emissions on the Euro emissions classes for each Swiss 10 category. This shows that the Euro-V emissions classes are not necessarily less noisy. However, the larger vehicles Swiss 9 and 10 are noisier than the other categories. This data indicate that although the vehicle fleet is becoming more environmentally friendly with respect to pollutant emissions, it is not more environmentally friendly with respect to noise emissions.
9. Possible correlation between the tire profile depth, tire pressure, engine power and the measured maximum pass-by level, normalized for 80 km/h was investigated. The results using 42 random vehicles from the traffic stream indicate no significant influence of these parameters on noise generation.
10. With the help of the noise emission model developed, the individual footprint of a vehicle can be estimated from parameters that are known or observable. Such data can be obtained from the vehicle ID and used to calculate a vehicles’ noise emissions.
11. Two models are proposed for the calculation of the total footprint of heavy vehicles, enabling using a holistic approach taking into account a combination of all their individual footprints. The results show that although the median value of the total footprint in all categories is low, in almost every category there are vehicles with a very high combined footprint.

   The results of the project can aid in developing a bonus/malus mechanism based on the "polluter pays principle" in order to reduce the environmental impact of vehicles at source. Due to the important adverse effects of noise on residents and as the measurements this project have shown, newer heavy vehicle models are not necessarily quieter, it is recommended that the LSVA should be revised in order to account for external costs due to traffic based noise as provided by the EC. It is further recommended to use differentiated noise charges to reward the use of quieter vehicles.

1 Introduction

1.1 Background

All data indicates that the number of heavy vehicles is on the rise. For a sustainable transportation system there is an urgent need to develop means to reduce the environmental impact of these vehicles at source.

The European cooperative project Eureka Logchain Footprin E!2468 [www.eureka.be, Poulikakos 2007, Mayer 2009] has developed methods to identify environmentally friendly vehicles for road and rail transport modes. At the same time the Swiss heavy vehicle fee (HVF) or LSVA (the German acronym) has developed a bonus/malus system in order to encourage road vehicles with a small environmental footprint [Krebs 2012].

Detail examination of vehicles chosen from the traffic stream as part of the Footprint phase II project [Poulikakos 2010] has indicated that the parameters encouraged by the LSVA method are indeed at or below environmentally friendly limits whereas the additional parameters defined by the Footprint project are not affected. Footprint II has shown that there are vehicles on the road with very high axle loads but gross vehicle weights that are within limits. There are vehicles with high noise emissions but engines that are up to the latest available technical standards for gaseous emissions. In summary, it was shown that vehicles that based on LSVA would pay a reduced fee because of the engine type approval rating are not necessarily environmentally friendly when all the footprint parameters are considered. Parameters that are currently controlled and their reduction encouraged such as gaseous emissions, axle loads and gross weight are for the most part below or close to acceptable limits. However other important parameters such as tire pressure and noise remain to be higher than acceptable limits.

In August 2009, WIM sensors where built parallel to an LSVA monitoring site on the A1 motorway, one of the main east west arteries in Switzerland at Oberbuchsiten. This provides a unique opportunity to combine many of the Footprint parameters with parameters available in the LSVA databank. The goal of this project was to provide detail analysis of sample of data in order to give clear indication on whether or not the LSVA encourages environmentally friendly vehicles for a larger sample size than in Fooprint II.

The following statements are made based on the experience gained through the first two phases of the Footprint project [Poulikakos 2007, 2010]:

- Footprint monitoring has added to the understanding of the evolution in road/vehicle interaction and how this will affect infrastructure design and management.

- The environmental footprint of heavy vehicles defined as dynamic load, noise, vibration and pollutant emissions was measured based on criteria set by the European project Eureka Logchain Footprint. The data showed that on weekdays ca 6000 heavy vehicles over three tonnes pass the footprint site out of which approximately 10% could be overloaded.

- In order to accurately identify overloaded vehicles, detailed vehicle information is needed. To this end, during a measurement campaign the footprint parameters were measured statically and dynamically for freight vehicles selected from the traffic stream and results were compared to the criteria set up as a result of current Swiss policy.

- The data showed that identifying the environmental footprint of heavy duty vehicles (HDVs) is not straight forward. Based on a sample of the data it was shown that vehicles that based on LSVA would pay a reduced fee are not necessarily environmentally friendly when the footprint parameters are considered.

- Parameters that are currently controlled and their reduction encouraged such as gaseous emissions, axle loads and gross weight are for the most part below or close to acceptable limits. However other important parameters such as tire pressure and noise remain to be high.

• Footprint monitoring has led to histograms showing the distribution of the parameters. As shown each parameter has to be quantified in situ and compared to environmental limits leading to a rating for that parameter. Once a vehicle is rated for each parameter the individual rating can be added to produce a total footprint index. This index in turn can lead to an environmental label.

• Vehicles that are not environmentally friendly can also be potentially unsafe.

• The in-situ measurement of gaseous emissions of individual road vehicles at one single engine operating state in the framework of a Footprint Monitoring Station does not accurately reflect the representative emissions of that vehicle. Ideally, the average emission factors (g/km) for different classes of HDVs should be found. In addition, driving pattern, road gradient and loading should be taken into account.

• The large difference of more than 10 dB measured during Footprint monitoring between the loudest and the most silent vehicle shows the large potential for possible improvements regarding noise impact.

• Ground borne vibration caused by heavy vehicles are below threshold of human perception at the footprint monitoring site. However this can change depending on traffic characteristics and pavement condition.

• Using a footprint monitoring site can allow monitoring of 60 tonne mega trucks if they are introduced in the future and assure compliance with the allowable limits.

• Environmental labeling allows the internalization of external costs and produces solutions that support policy

1.2 Project Goals

The overall goal of this follow up project is to monitor the following parameters of interest: axle load, gross weight, noise and engine type, in order to develop an overall footprint of individual heavy vehicles for a statistically significant sample. The results of the project can aid in developing a bonus/malus mechanism based on the "polluter pays principle" in order to reduce the environmental impact of vehicles at source. Furthermore, the heavy vehicle fee in Switzerland is based on admissible weight (vehicle and load), not actual weight, and it is suspected that some vehicles are overloaded and therefore heavier than allowed and paid for. Therefore one of the goals of this project is to quantify these vehicles.

1.3 Work plan

In order to accomplish the goals identified in section 1.2, nine tasks were identified and listed below and discussed in detail in the following chapters:

Task 1: Initial data evaluation WIM+LSVA

Sample data from LSVA and WIM was analyzed in order to investigate patterns in the data and to develop an algorithm for general data evaluation. Furthermore a strategy was developed on how LSVA, WIM and noise data can be synchronized in order to get coherent information about each single vehicle.

Task 2: Installation, operation and evaluation of noise monitoring

The acoustical footprint of a vehicle passing by was determined by evaluating the maximum sound pressure level received at a microphone installed in a distance of 7.5 m from the traffic lane in accordance to ISO [EN ISO 11819-1] and Eureka Footprint criteria. A compensation strategy was applied to eliminate the disturbing influence of neighbor vehicles in order to get a maximum percentage of vehicles that can be evaluated [Heutschi 2008]. The noise monitoring was installed only temporarily. A noise monitoring period covered four weeks with an expected number of more than 50'000 analyzed heavy vehicles that could be attributed a noise label. Three or four periods distributed over one year were planned to guarantee a representative sample of the typical vehicle park.

Task 3: In-situ measurements of all parameters including tire pressure in cooperation with ASTRA WIM calibration

The WIM monitoring site is calibrated usually yearly in the Fall. The project team in cooperation with the WIM calibration team collected axle load, gross weight, vehicle engine, vehicle tire and particle filter information. Data was acquired statically and dynamically to allow for later analysis. In addition this was the only opportunity to measure tire pressure statically. Noise data for the calibration vehicles was collected dynamically.

Task 4: Analysis of calibration vehicles

The data acquired in task 3 was analyzed.

Task 5: Analysis of sample LSVA+ WIM+ Noise data

For the relevant time periods, LSVA, WIM and noise data was assembled and analyzed. It was checked what possible vehicle information can be made available. Possible relations between vehicle parameters and WIM and noise data was evaluated. Results for footprint I and II have shown that depending on the month and day of week ca. 1500 to 6000 heavy vehicles pass this site daily. The evaluation of data for one month i.e. 150000 vehicles gave a good statistically representative sample.

Task 6: Policy options

As a result of the outputs of task 5 policy options were investigated and recommended in order to reduce the overall footprint of heavy vehicles at source.

Task 7: Participation in Eureka meetings

The project partners of the Eureka Logchain Fooprint project are interested in further cooperation. Initial project outline has been developed (Appendix 1). Swiss partners are interested in further cooperation as only through a European consensus can policy be developed and implemented to reduce the impact of heavy vehicles at source.

Task 8: Identification of sample of environmentally unfriendly vehicles

Results of task 4 and 5 will be used to identify a sample of heavy vehicles with a high footprint.

Task 9: Final Report

Project results are summarized in a final federal report. In addition the results were disseminated in international forums such as the international conference on weigh in motion (ICWIM 6) [Poulikakos 2012] and Euronoise [Heutschi 2012] and further scientific publications are in progress.

1.4 Outputs

The following topics were addressed in this project:

- Analysis of individual parameters

- Analysis of combined parameters
- Which vehicle classes have a higher total footprint
- Footprint of domestic vehicles versus transit vehicles
- How many vehicles are carrying more than they have declared?
- Are noisy vehicles domestic or foreign?
- Develop noise categories (labels)
- What are average noise emissions of EURO categories?
- Seasonal variations
- Variations in day-night

2 Swiss Heavy Vehicle Fee

Effective 1st of January 2001, certain vehicles are required by law to pay the heavy vehicle fee in Switzerland. The heavy vehicle fee is based on declared weight not actual carried weight. Table 2. 1,*Table 2. 2* and *Table 2.3* show all LSVA vehicle codes and definitions used in the information provided by the databank. As shown in Table 2. 1, some heavy vehicles such as farming vehicles, police vehicles and ambulances are exempt from paying a fee. As of 2012 vehicles with EURO II and EURO III engines that are fitted with a particle filter receive a 10% discount in the heavy vehicle fee. As of July 1st 2012, vehicles with EURO-VI emissions category also receive a 10% discount in the fees.

Table 2. 1 LSVA Vehicle codes showing the list of definitions of data provided by the enforcement office

Code	Fahrzeug	Befreit	LSVA	PSVA	Meldepflicht
01	Personenwagen			X*	Anhängelast >3,5t
02	Schwerer Personenwagen			X	Alle
10	Leichter Motorwagen			X*	Anhängelast >3,5t
11	Schwerer Motorwagen - für den Personentransport - andere		 X	 X	Alle
20	Gesellschaftswagen			X	Alle
21	Kleinbus			X*	Anhängelast >3,5t
22	Gelenkbus			X	Alle
30	Lieferwagen			X*	Anhängelast >3,5t
35	Lastwagen		X		Alle
36	Leichtes Sattelmotorfahrzeug		X	X**	Alle
37	Schweres Sattelmotorfahrzeug		X	X**	Alle
38	Schwerer Sattelschlepper > 3,5t **Leichter Sattelschlepper <= 3,5t**	 **X*** **	X **X*** **		Alle Alle***
42	Traktor			X	Gesamtgewicht oder Anhängelast >3,5t
43	Landw. Traktor	X			Mit TAG
50	Arbeitsmaschine	X			Mit TAG
51	Arbeitskarren	X			Mit TAG
52	Landw. Arbeitskarren	X			Mit TAG
6.	Motorrad und ähnliche	X			Nicht melden
80	Motorkarren			X	Gesamtgewicht oder Anhängelast >3,5t
81	Landw. Motorkarren	X			Mit TAG
82	Motoreinachser			X	Gesamtgewicht oder Anhängelast >3,5t
83	Landw. Motoreinachser	X			Mit TAG
84	Landw. Kombinationsfahrzeug	X			Mit TAG
85	Landw. Anhänger	X			Daten von OZD verlangt
87	Landw. Arbeitsanhänger	X			Daten von OZD verlangt
88	Sattelwohnanhänger			X	Anhänger >3,5t – alle Anhänger ≤3,5t – Sattelanhänger aller Art – andere, wenn Daten von OZD verlangt werden
89	Sattelanhänger (VTS Art. 20, Abs.1)		X		
90	Sachentransportanhänger		X		
91	Personentransportanhänger			X	
92	Wohnanhänger			X	
93	Sportgeräteanhänger		X		
94	Arbeitsanhänger	X			
95	Sattelsachentransportanhänger		X		
96	Sattelpersonentransportanhänger			X	
97	Sattelsportgeräteanhänger		X		
98	Sattelarbeitsanhänger	X			
99	Anhänger (VTS Art.20, Abs. 1)		X		
	Fahrzeug mit Militärkontrollschildern	X			Nicht melden
	Polizeifahrzeug	X			Je nach Fahrzeugart
	Fahrzeug der Feuer-, Öl- und Chemiewehr	X			Je nach Fahrzeugart
	Ambulanz	X			Je nach Fahrzeugart

Table 2. 2 shows the definition of all data in the LSVA databank. Some of this data was used in the analyses in the following chapters. Particularly of interest for the current analysis was the allowed mass (WIM_ZUK_GEW) and EURO emissions class (ZFZ_EUROCLASS). These two sets of data allowed identification of emissions of each vehicle as well as if they were overloaded as defined in detail in the following chapters. As of 2012 there are 15 LSVA monitoring sites as shown in Figure 3. 1. The LSVA sites and WIM sites are currently not combined except at the Footprint monitoring site as discussed in chapter 3. *Table 2.3* shows the more detailed LSVA vehicle classifications, however, in this report the SWISS10 classification was used (Appendix II).

Table 2. 2 definition of data from the enforcement office (V4, 20110420).

Bezeichnung alt	**Beschreibung**	**Bezeichnung neu**
FZDATEN_ID	eindeutige Nr. des Datensatzes / der Durchfahrt gemäss Enforcementsystem	Fzdaten Id
STAMM_NO	eindeutige Nr. eines Fahrzeuges	Stamm No
	Passagentyp gemäss Enforcementsystem 0 = ohne elektronisches Erfassungssystem 1 = mit einfachem elektr. Erfassungssystem (TAG) 2 = mit Schweizer Erfassungsgerät (OBU)	Passagentyp
WIM_VEHICLE_NUMBER	Erfassungsnummer der WIM	Wim Vehicle Number
WIM_Durchfahrtszeit	Durchfahrtszeit gemäss WIM	Wim Detectiontime
FAR_CODE	Fahrzeugcode gemäss Stammdaten	Far Code
ZFZ_CTR_CD	Ländercode gemässs Stammdaten (iso-alpha-2)	Zfz Ctr Cd
WIM_SWISS10	Swiss10-Klasse gemäss WIM	Wim Swiss10
VE_CLASS	Fahrzeugklasse gemäss Scannersystem	Ve Class
ZFZ_GESGEW_ZUG	zulässiges Gesamtgewicht des Zuges	Zfz Gesgew Zug
GEW_ANH_HKUSER	Gewicht des Anhängers (plausibilisiert)	Gew Anh Hkuser
ANH_LEERGEW	Leergewicht des Anhängers	Anh Leergew
ZFZ_EUROCLASS	Euroklasse gemäss Stammdaten	Zfz Euroclass
WIM_ZUL_GEW	zulässiges Gewicht des Fahrzeuges / Fahrzeugkombination	Wim Zul Gew
WIM_MASS	Gewicht gemäss WIM (ohne jede Toleranz)	Wim Mass
WIM_SPEED	Geschwindigkeit gemäss WIM in km/h	Wim Speed
Geschwindigkeit_Scanner	ALT: Geschwindigkeit gemäss Scanner in km/h NEU: Geschwindigkeit gemäss Scanner in m/s	Ve Velocity
WIM_LANE	Fahrspur gemäss WIM	Wim Lane
WIM_NUMAXLES	Anzahl Achsen gemäss WIM	Wim Numaxles
ZFZ_GESGEW_ZFZ	zulässiges Gesamtgewicht des Zugfahrzeuges	Zfz Gesgew Zfz
ZFZ_LEERG	Leergewicht des Zugfahrzeuges	Zfz Leerg

Table 2. 3 LSVA Scanner vehicle classes

		z.B.: 44 [5cm] = 220cm
VE_CLASS	NUMBER(10,0)	Ermittelte Fahrzeugklasse (Scanner – Fahrzeugklasse) 1 = Motorrad 2 = PKW / Multivan 3 = Kleinbus, Geländefahrzeug, PKW mit Dachträger 4 = Kleintransporter, Klein – LKW 5 = sehr kurzer LKW mit grossem Laderaum 6 = kurzer LKW > 3,5 t 7 = LKW > 3,5 t 8 = Sattelschlepper (Zugfahrzeug) 9 = Autobus 101 = Motorrad mit Anhänger 102 = PKW mit Anhänger 103 = Kleinbus, Geländefahrzeug, PKW mit Dachträger mit Anhänger 104 = Kleintransporter, Klein – LKW mit Anhänger 105 = sehr kurzer LKW mit grossem Laderaum mit Anhänger 106 = kurzer LKW > 3,5 t mit Anhänger, Kleinsattelschlepper 107 = LKW > 3,5 t mit Anhänger 108 = Sattelschlepper mit Aufleger 109 = Autobus mit Anhänger

3 Footprint Monitoring Site

The Footprint Monitoring Site (FMS) shown in Figure 3. 1 and Figure 3. 2, is located at one of the major east-west arteries in Switzerland as demonstrated by the thickness of the red line in Figure 3. 1. It is located in Oberbuchsiten between Bern and Zürich, direction Zürich. As of August 2009, this site is a prototype combining WIM and LSVA allowing to bring together various monitoring activities. The original motivation for such a site was that in Switzerland as discussed in chapter 2, the heavy vehicle fee is based on declared weight not actual carried weight, and it is suspected that some vehicles may carry more than they have declared and paid for. Therefore one of the goals of this project was to quantify these vehicles.

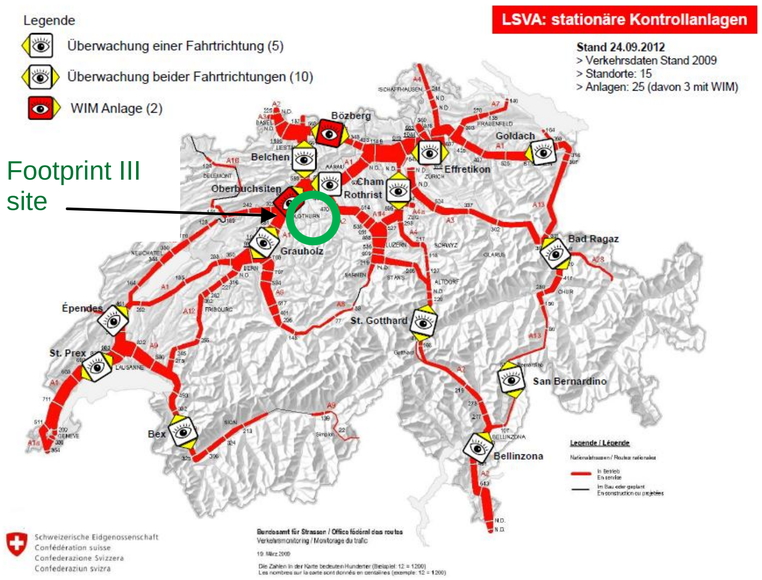


Figure 3. 1 Location of LSVA monitoring sites including the Footprint site combining LSVA+WIM measurements in Oberbuchsiten

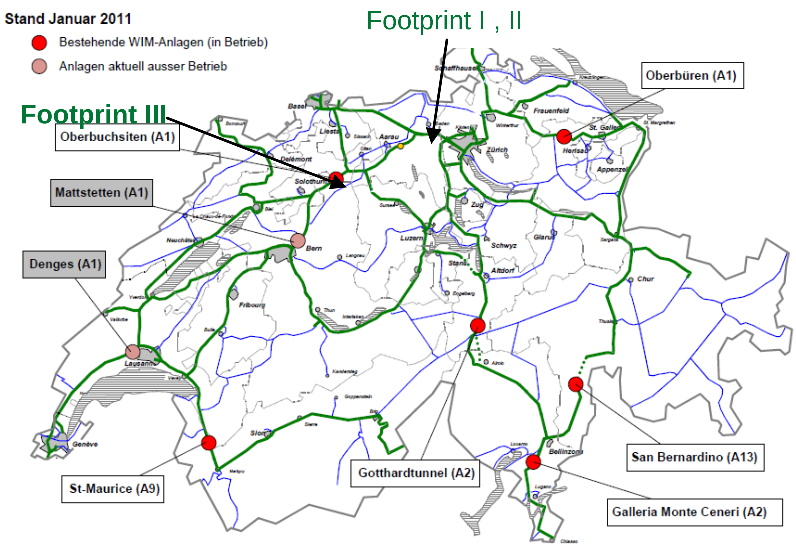


Figure 3. 2 Location of WIM stations in Switzerland and Footprint I, II and III

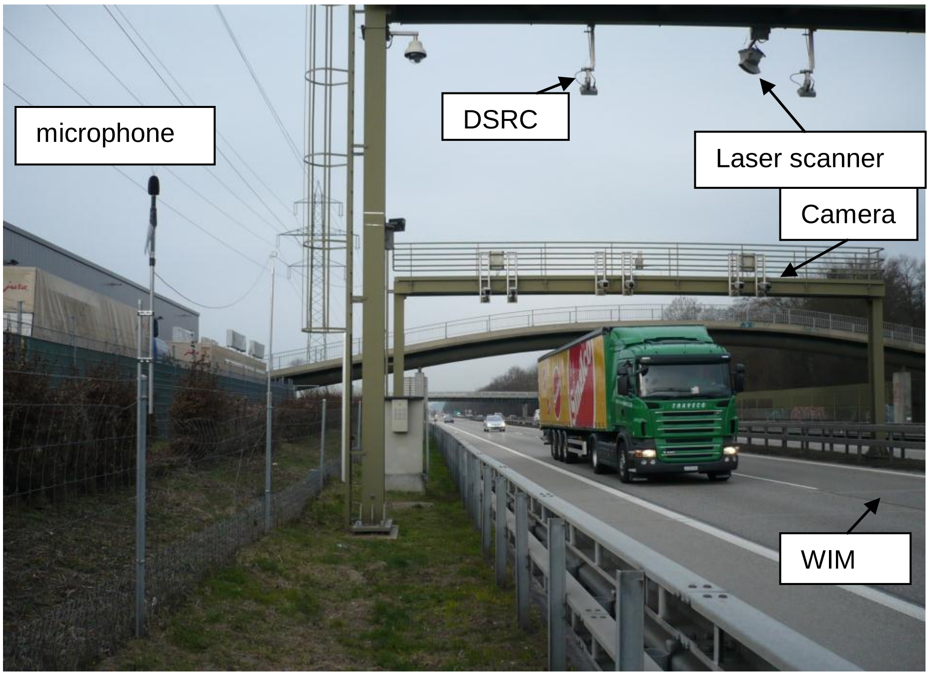
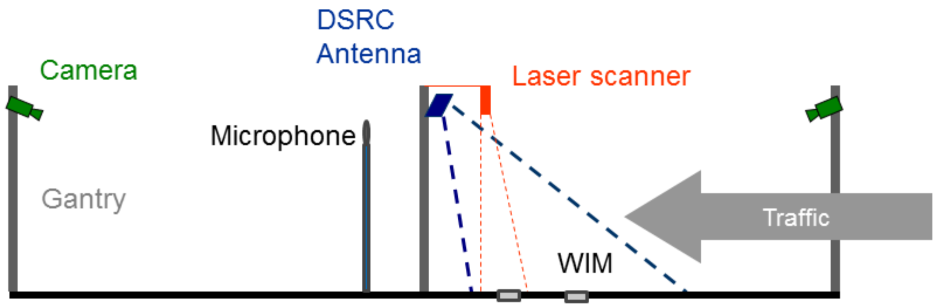


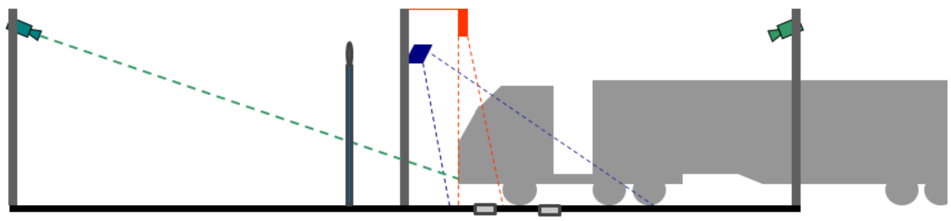
Figure 3. 3 Footprint III monitoring site

As of 2011 there are six WIM sites operating in Switzerland. Figure 3. 2 shows the WIM sites with a red dot as well as Footprint I, II and III monitoring sites.

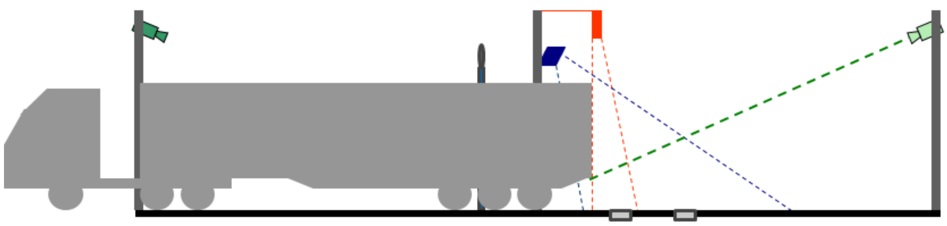
The photograph in Figure 3. 3 shows a vehicle passing the Footprint III site. The schematic diagram in Figure 3. 4 shows how a vehicle is detected at the Footprint site. Several sensors are located on the gantry as shown in the figure. Cameras are used for recording front and back views as well as the license plate. The Dedicated Short Range Communication (DSRC) Antenna is used for communication with the LSVA on board unit (OBU). The Laser scanner is used for vehicle detection and classification. At the same time the WIM sensors register the vehicle information such as gross weight, axle load, axle distance and SWISS 10 vehicle classification as discussed in detail in chapter 5 and the microphone registers the sound pressure level as discussed in detail in chapter 6.



a) Various sensors are involved in data acquisition



b) As the vehicle enters the monitoring site the DSRC communicates with the OBU. The laser scanner is triggered and begins classification of the vehicle and the cameras record a photograph of the front of the vehicle. WIM measures the transported weight, dimensions and classifies the vehicle. The microphone records the noise emissions.



c) Final stage of monitoring is the rear photo including license plate

Figure 3. 4 Monitoring process (courtesy: Swiss Federal Customs Administration)

4 Footprint Parameters

The Footprint III monitoring site allows the combination of various parameters as shown in *Table 4. 1*. The WIM sensors deliver axle load, number of axles, gross weight, speed, axle distance and SWISS 10 vehicle classification. The microphone delivers the sound pressure level for each passing vehicle and the LSVA sensors deliver the vehicle European engine pollutant emissions category (EURO-0 to VI), origin of vehicle, declared gross weight and speed. During the WIM calibration additional information was obtained from the driver and the vehicle documentation about age, and whether or not they have a particle filter as well as other parameters as listed in the table and discussed further in chapter 9.

Various parameters could be important factors influencing various aspects of a vehicles footprint. For example particle filter information is important for pollutant emissions whereas tire profile is primarily important for noise emissions.

Table 4. 1 Footprint Parameters

Sensor	Parameter	Comments
WIM:	Axle load	Individual axle load in in kg
	Nr Of axles	1 - 9
	Gross weight	Total weight of vehicle in kg. Maximum 99999 kg; Minimum 3500
	Speed	km/h
	Axle distance	m
	SWISS 10 category	1 - 10
Microphone	Sound pressure level	dB
LSVA	Gaseous emissions class EURO 0-V	1 – 5, < EURO I As of 1 July 2012 also EURO-VI
	Domestic/Foreign	Country code (CH, D, A, F etc.)
	Declared gross weight	CH-veh: Weight as in veh. ID (Fahrzeugausweis) Foreign veh: Weight that LSVA is paid for (GLSVA)
	Speed	m/s
Other	Particle filter info	Obtain during WIM calibration
	Age	Obtain during WIM calibration
	Engine horse power	Obtain during WIM calibration
	AdBlue*	Obtain during WIM calibration
	Type of tire profile(Block/Rib)	Obtain during WIM calibration
	Tire profile depth	Obtain during WIM calibration
	Rain	Swiss meteorological information

*Adblue is a German trademark used to reduce emissions of a diesel engine.

5 WIM Monitoring

The weigh in motion (WIM) sensors used at this footprint monitoring site are quartz base piezo electric sensors called Lineas® by the Swiss company Kistler. They are placed flush within the road surface and deliver the following parameter: Axle load, axle distance, vehicle total mass, vehicle length, SWISS 10 vehicle category (Appendix II) and speed. The WIM sensors at this site are calibrated yearly usually in the Fall. The 2011 calibration indicated that the WIM sensors fulfill the requirements of A(5) [Kienast 2011]. This rating means that this site has an accuracy of 5% in GVM, 8% in individual axle load, 8% in axle of a group and 7% in group of axles.

Occasionally there are errors in the WIM data. An example is when the maximum WIM mass reading is 99999. All vehicles that weigh more than this value will also deliver this value such as the heavy special transport in *Figure 5. 1*. Special vehicles such as this are not included in the current analysis as they pay special fees based on the weight they carry.

Figure 5. 1 Example of special transport weighing over the maximum registered by WIM

6 Noise Monitoring

The noise measurements are made according to the European and International standards (EN ISO 11819-1) using a pressure microphone. The microphone is mounted at a height of 3.0 m in a distance of 7.5 m from the center of the inner lane as shown in Figure 3. 3. The microphone environment was essentially free of reflecting objects. The measurement equipment was operating during the months March, September and November 2011.

The microphone signal was evaluated in octave bands and as A-weighted 100 ms maximal levels with time constant FAST. To account for the interfering effect of neighbor vehicles, the compensation strategy developed in a predecessor Footprint project [Heutschi 2008] was applied.

Wet or rainy weather has a direct effect on the noise emissions. All data used in this study use dry pavement conditions.

7 Pollutant Emissions Monitoring

Pollutant emissions of on-road heavy duty engines in Europe (and in some countries in Africa, and in the near and far east) are limited according to Euro categories. These pollutant emissions are measured on engine test benches where the engine is directly coupled to a dynamometer. The engine is driven in exactly defined load patterns; engine speed and engine torque versus test time and defined ambient conditions. The emissions are limited in a work-specific manner expressed as grams of emissions per kilowatt-hour of engine work. Figure 7. 1 shows such a setup at Empa's heavy duty test bench. The dynamometer is depicted on the left side and the engine on the right side.

Figure 7. 1 Heavy duty engine test bench at Empa showing the dynamometer on the left side and the engine on the right side

Starting in 2013, new engines sold in Europe will have to meet the most stringent emission limits ever (Euro-VI) according to the EC Regulation 595/2009. Euro-VI will not only tighten the limits for all "classical" pollutants (carbon monoxide, hydrocarbons, oxides of nitrogen and particle mass) but also a particle number emission limit is introduced which forces the use of highly efficient wall-flow particle filters. Figure 7. 2 depicts a cut through such a filter. The exhaust gas flow from the engine is forced to pass through a filter wall consisting of cordierite or silicon carbide. This results in a highly efficient particle filtering where a soot cake is built up at lower exhaust temperatures and burned (regenerated) at higher exhaust gas temperatures.

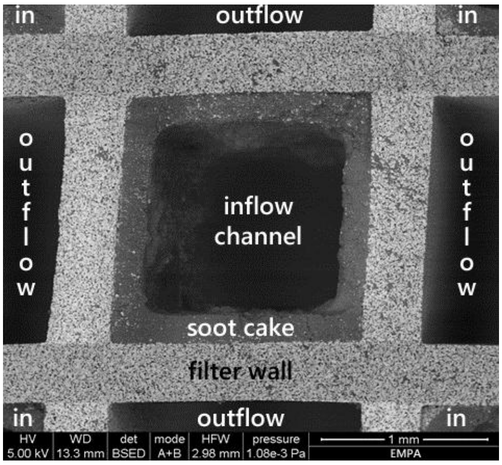


Figure 7. 2 Electron microscopic image of a wall-flow particle filter

Since the dilution of the exhaust gases leaving the vehicle's tailpipe is unknown and cannot be measured, the gaseous pollutant emissions cannot be quantified using remote sensing techniques. To allow executive authorities to perform in-use compliance of heavy duty vehicles without the need to dismount engines and putting them on engine dynamometers, the Euro VI regulation has foreseen the possibility of using portable emission measurements. To do so, the engine has to deliver certain data from its control which allows an emission measurement system installed on the vehicle to calculate in-use emissions during certain driving and ambient conditions.

Figure 7. 3 depicts the emission limits from Euro-I to Euro-VI for the most important pollutants NOx and particulate matter (PM). It has to be mentioned that the test pattern from Euro-I to Euro-VI changed several times so that the numbers cannot be directly compared in an exact sense. However, it can be said in an approximate manner that five Euro-VI vehicles will produce about the same NOx emissions as one Euro-V vehicle. Accordingly the reduction of particle number emissions, which are believed to have severe impacts on living organisms, is estimated to be even more pronounced: about 100 Euro-VI vehicles will emit about the same number of particles as one Euro-V vehicle without a particle filter.

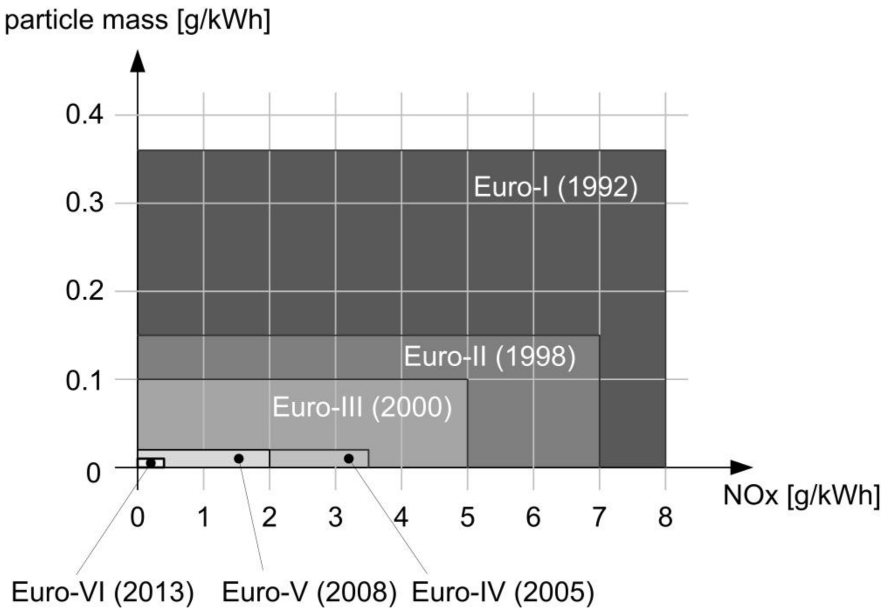


Figure 7. 3 Nox and particle limits for heavy duty engines for the Euro-I to Euro-VI stages

The SCR (selective catalytic reduction) process was originally developed to remove NO_x (nitrogen oxides) from the flue gas of power plants with ammonia as reducing agent. Due to its toxicity and its difficult handling properties, pure ammonia may be replaced by urea, which is non-toxic and decomposes to ammonia and carbon dioxide. Urea-SCR, a well-established NO_x reduction technique for stationary diesel engines, is increasingly relevant for heavy-duty vehicles and naval engines and it is starting to be applied in passenger cars. Starting with the Heavy Duty Euro VI standard, all engine manufacturers will use SCR technology to meet the stringent NOx limits.

In order to avoid difficulties associated with the handling of pure ammonia, a water-urea solution is used (commercially known as “Adblue”) which is converted into ammonia (and other components) directly in the hot exhaust gas stream.

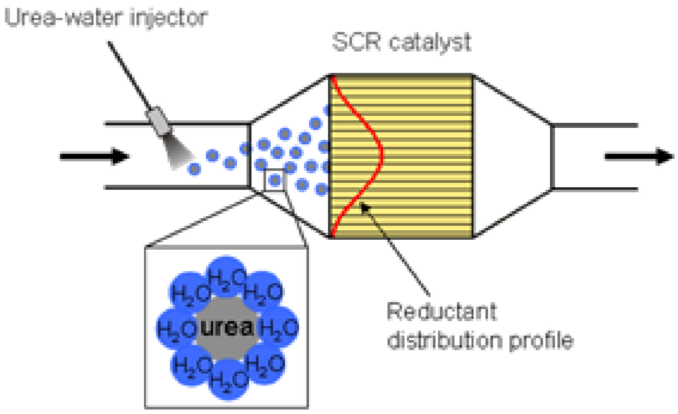


Figure 7. 4 SCR system setup

NO_x emissions not only affect personal health, but also lead to tropospheric ozone (O_3) formation and perturb the hydroxyl radical (OH) field, and hence the lifetime of methane (CH_4). These global effects negatively influence the Earth's radiation budget as O_3 and CH_4 are greenhouse gases. In addition, particulate matter (PM), e.g. ammonium nitrate is formed from ammonia and nitric acid, which is produced after atmospheric oxidation of emitted NO_x. A reduction in NOx emission will therefore also help in reducing PM concentrations under most atmospheric conditions.

The overall goal of this project was to identify vehicles by their total footprint as discussed in detail in chapter10. In order to use the NOx and particle mass (PM) emission limits to identify environmentally friendly or harmful vehicles the following method is used. As a first step Euro-III is identified as the most environmentally friendly without any retrofitting or alterations to the engine with a footprint rating of +1 with equal contributions of NOx and PM each being 0.5. On the other hand as the most environmentally friendly standard EURO-VI is given a total of gaseous emissions rating of -1 with NOx and PM each -0.5. The other EURO categories (EUx) are calculated using the following formula:

FP= (-EU3-EU6)/(2*(EU3-EU6)) + 1/(EU3-EU6) * Eux

Plugging in the corresponding values results in the following:

FP_NOx=-0.59 + 0.22 kWh/g * NOx(EUx)

FP_PM=-0.61 + 11.11 kWh/g * PM(EUx)

Euro-0 describes vehicles which were put in circulation before the Euro emission limits were introduced and they are estimated to have the same pollutant emission level as Euro-I vehicles. To quantify the pollutant emissions footprint, one possible method is to attribute equal contribution of PM and NOx based on the emission limits which results in numbers listed in Table 7. 1.

Table 7. 1 Emission limits and Footprint rate for gaseous and particle emissions

Euro-Cat.	NOx [g/kWh]	PM [g/kWh]	Footprint NOx	Footprint PM	Poll. emiss Footprint total
0	N/A	N/A			4.54
I	8	0.36	1.15	3.39	4.54
II	7	0.25	0.93	2.17	3.1
III	5	0.1	0.5	0.5	1
IV	3.5	0.02	0.17	-0.39	-0.21
V	2	0.02	-0.15	-0.39	-0.54
VI	0.4	0.01	-0.5	-0.5	-1

8 Monitoring Results

8.1 Gross mass, axle load, pollutant emissions

During the course of the monitoring and data analysis process it became clear that there exists some errors in the data. Table 8. 1 shows a sample of data from March 2011. The data from March was used to gain more insight into the specifics and in order to develop strategies to improve data quality. For example as shown in this initial analysis 3.24% of vehicles had more than 5 axles. The final data excludes these vehicles as they are not common in Switzerland and this can be an error in WIM data. The final data reduction is done as outlined in Table 8. 2.

The 2011 WIM calibration (chapter 9) indicated that the WIM sensors fulfill the requirements of A(5) [Kienast 2011]. This rating means that this site has an accuracy of 5% in GVM, 8% in individual axle load, 8% in axle of a group and 7% in group of axles. Therefore the threshold for overloaded vehicles was set at 7%.

Table 8. 1 Summary of data March 2011 (first stage evaluation for data reduction)

	Item	Nr.	%	Comment
	Total Vehicles	120643		
a	GVM=0	2264	1.9	error in WIM
b	GVM=99999	39	0.03	Special Veh.
c	GVM>40'000	5631	4.7	
d	GVM>40'000 cleaned	5592	4.6	
e	GVMallowed=0	4763	3.9	No LSVA data
f	Nr. Overloaded	7884	6.5	Excluded a, b, e
g	Nr Overloaded by 7%	2318	1.92	Excluded a, b, e
h	Nr axles>5	3907	3.24	
i	Nr Vehicles speed<70km/h	3409	2.83	Not optimal for noise measurements

Data was collected for March, September and November 2011. Each month ca. 100’000 valid vehicle measurements were collected which reflected a statistically representative sample of data for further evaluation. The exact number of validly measured vehicles is listed in Table 8. 3. The quality of data for the three months was improved following the steps indicated in Table 8. 2. The data are consistent and repeatable, both in the number of vehicles and maxima, minima and median values calculated for the different parameters of interest.

As shown in the representative pie charts for March in Figure 8. 1 and Figure 8. 2, the vehicle fleet is mostly Swiss category 10, 9 and 8 with pollutant emission categories that are mostly EURO-V, EURO-IV and EURO-III. Comparisons for all three months are shown in Figure 8. 3 and Figure 8. 4 and they indicate good repeatability of the data.

Table 8. 2 Data quality improvement strategy

Item	Data not incorporated in the analysis	Reason
1	GVM=0	Error in WIM data
2	GVM=99999	Special vehicle which has most likely paid for a special permit
3	GVMallowed=0	No LSVA Data ex. Bus
4	Nr. Axles>5	Not common in Switzerland. Mostly special vehicles or WIM error
5	WIM Speed< 70 km/h	Not freely moving traffic , not optimal for noise measurements
6	Lp=-99.9	Noise data is not valid
7	EUROVI	EURO VI vehicles were not on the road in 2011 therefore this is considered as a mistake in the data
8	Axle load>40t	This is either due to error in WIM data or oversized vehicles that are not considered here

Figure 8. 5 shows a typical histogram showing the distribution of gross vehicle mass (GVM) for March 2011. This distribution can be easily compared for all vehicle categories using the boxplots in Figure 8. 6, Figure 8. 7 and Figure 8. 8. On each box, the central mark is the median, the edges of the box are the 25th and 75th percentiles, the whiskers extend to the most extreme data points not considered outliers, and outliers are plotted individually.

The box plots shown in Figure 8. 6, Figure 8. 7 and Figure 8. 8 show that the majority of vehicles analyzed carry below 40 t, however there is small but significant number of vehicles from every SWISS10 category except SWISS 5 (delivery pickups) which carry more than 40 t. Furthermore on average Swiss category 9 and 10 transport more tonnage than other categories.

As a further step, a comparison of the measured carried weight obtained from WIM sensors and those allowed according to the LSVA databank was done. Results shown in Table 8. 3 indicate that less than 0.6% of vehicles have been overloaded. The most number of overloads happened in November with 0.6 % of 105’037 vehicles or 617 vehicles as shown in *Table 8. 3*.

The distribution of axle one to five loads per SWISS 10 category is shown in Figure 8. 10 Figure 8. 11, Figure 8. 12, Figure 8. 13 and Figure 8. 14. It can be seen that the variance for axle one is lower than the other axles. This is the reason that this axle is used for automatic calibration in some countries. The mean axle load values for axles 2 is the highest with axle one following closely. Swiss categories 5 and 6 have the lowest axle loads. Buses (Swiss cat 1) have axle loads as high as Swiss 7, 8, 9 and 10. As seen in the boxplots although the mean at about 5 t in every category is within allowable limit of 11.5 t for drive axle and 10 t for single axles, there are vehicles within every category that bypass these limits.

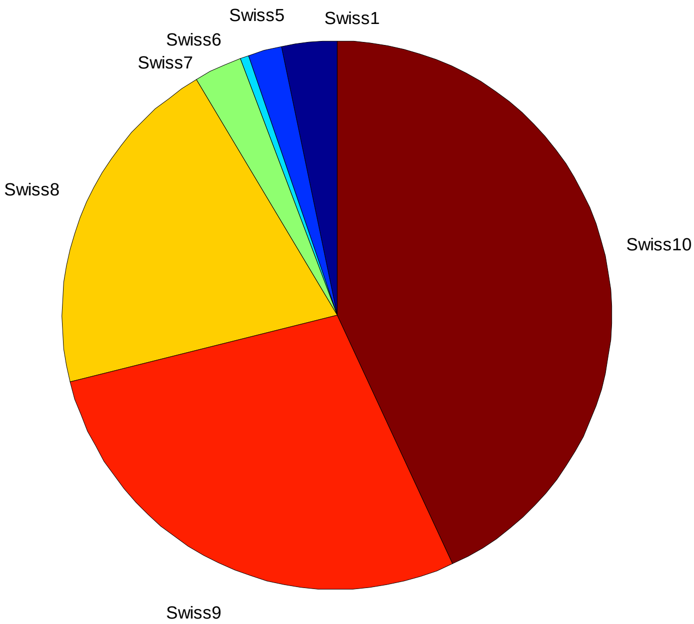


Figure 8. 1 Pie chart showing the distribution of Swiss 10 categories in percent in March 2011

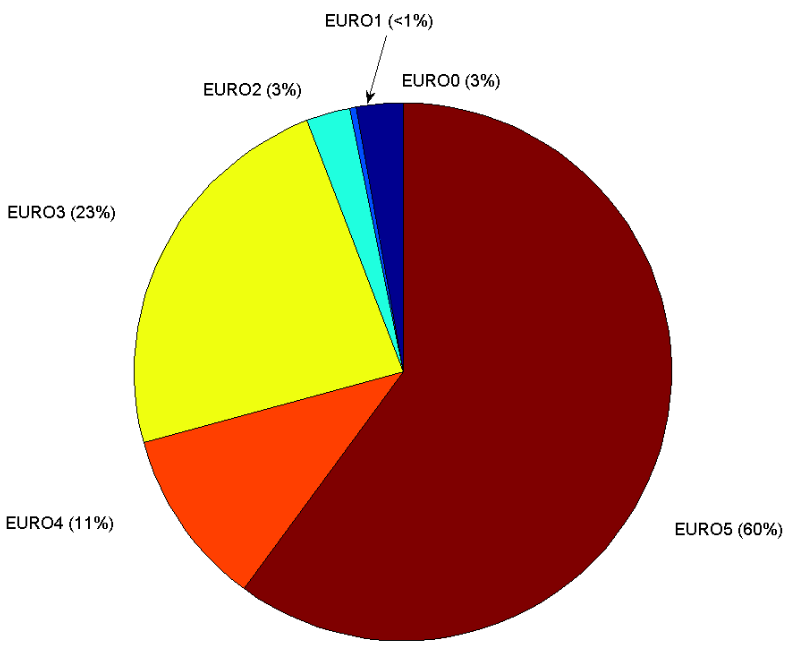


Figure 8. 2 Pie chart showing distribution of EURO categories in percent, March 2011

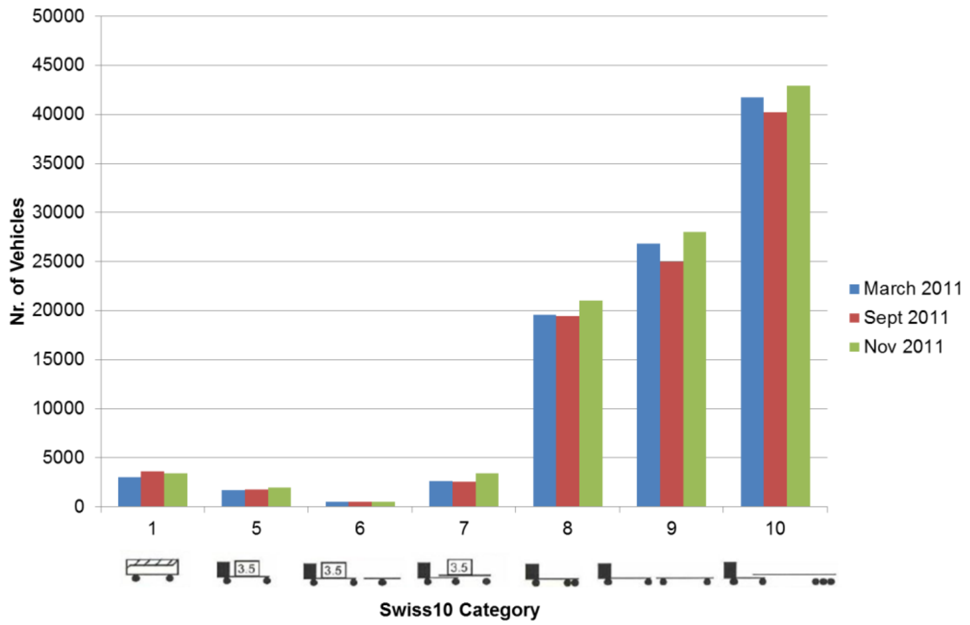


Figure 8. 3 Number of vehicles per Swiss 10 category

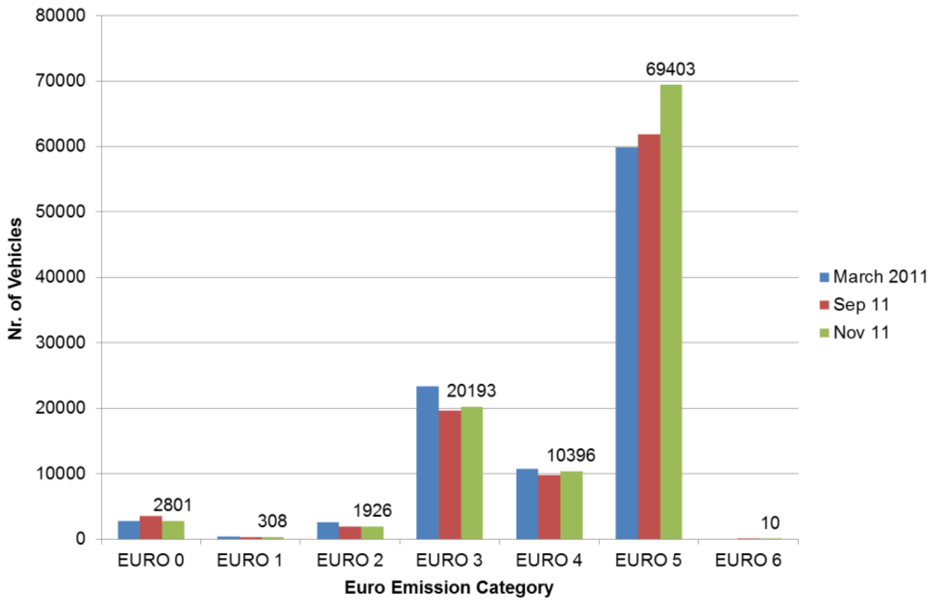


Figure 8. 4 Number of vehicles per Euro emissions category

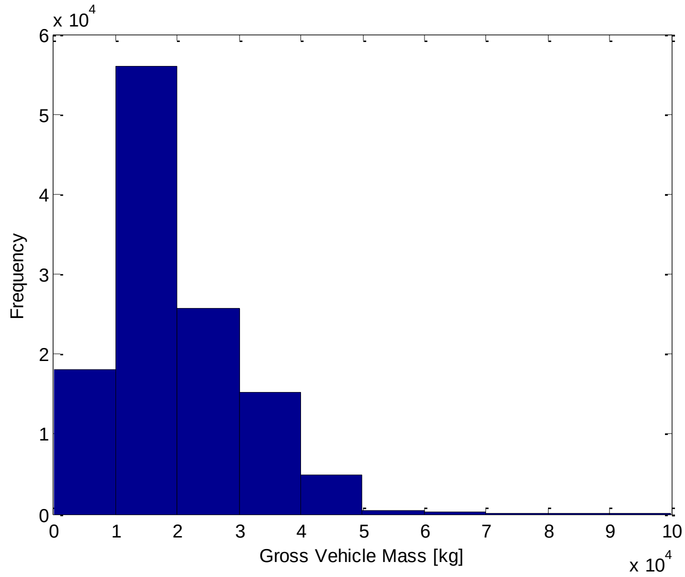


Figure 8. 5 Typical histogram showing the distribution of gross vehicle mass for all vehicles, March 2011

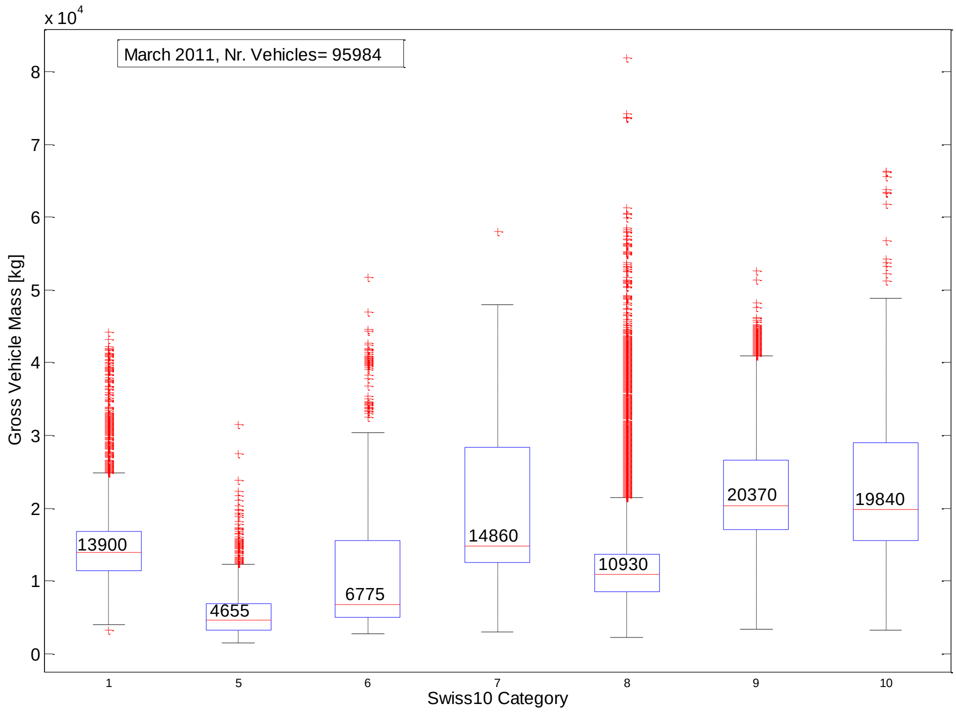


Figure 8. 6 Box plot showing gross vehicle mass (GVM) distribution and median values for each Swiss 10 category, March 2011

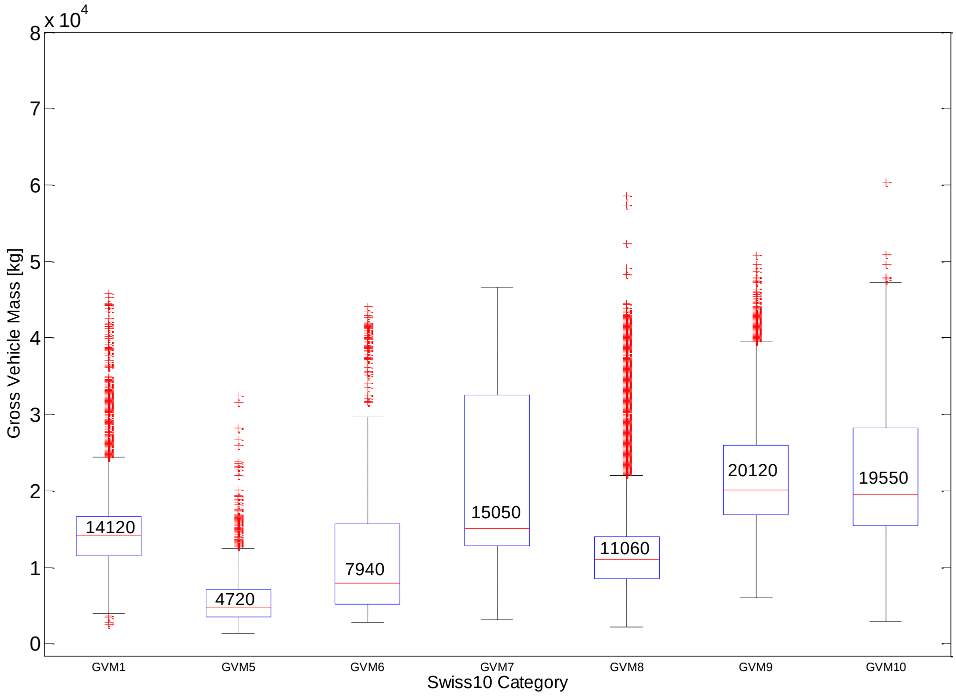


Figure 8. 7 Boxplot showing distribution and median of gross vehicle mass GVM for each Swiss 10 category, Sept 2011

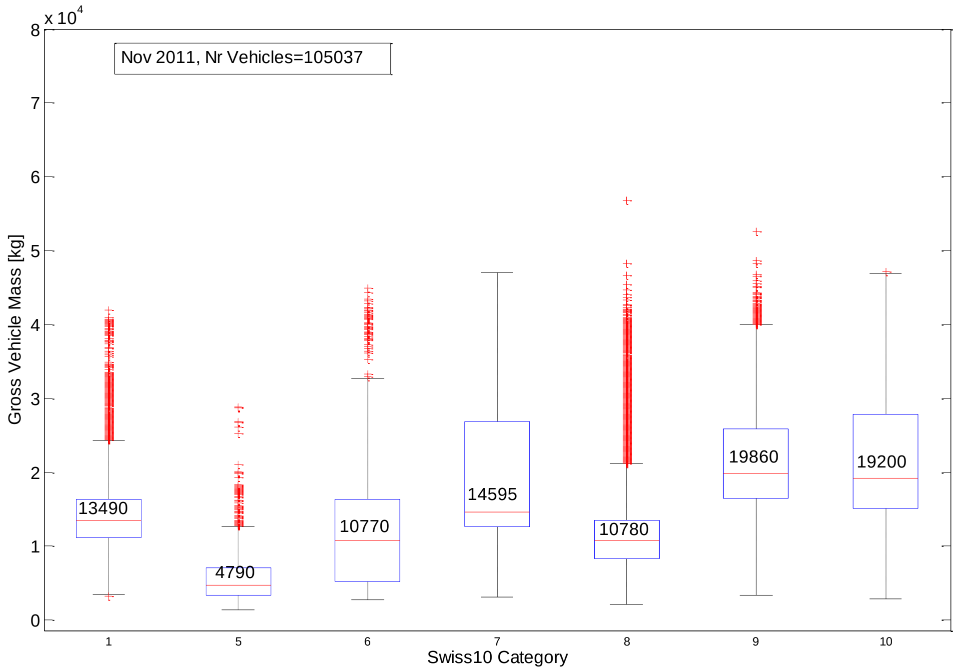


Figure 8. 8 Boxplot showing distribution and median gross vehicle mass GVM for each Swiss 10 category, Nov 2011

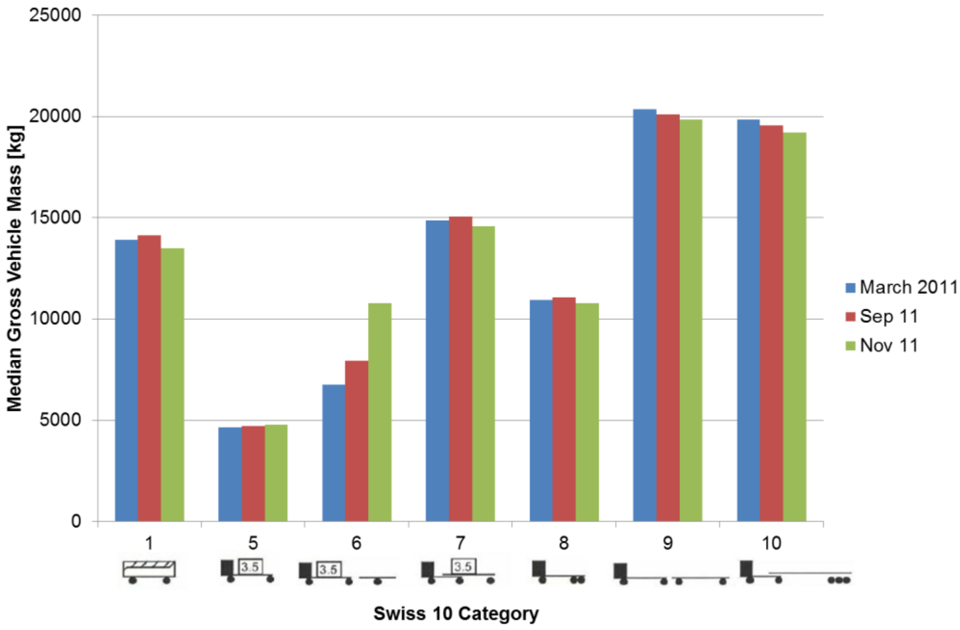


Figure 8. 9 Median gross vehicle mass per Swiss 10 category

Table 8. 3 Number valid vehicles monitored and number of overloaded vehicles per month

	Nr. Vehicles analyzed	Nr Overloaded	% Overloaded
Mar 2011	95984	78	0.08
Sep 2011	93019	82	0.09
Nov 2011	105037	617	0.59

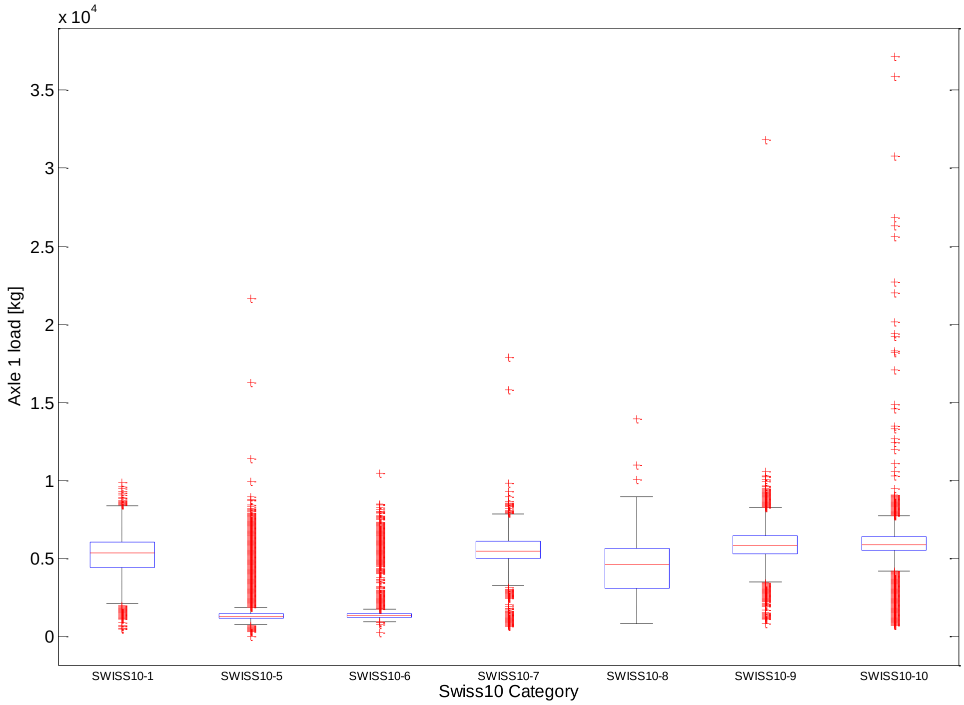


Figure 8. 10 Box plot showing the distribution of axle 1 loads for all SWISS 10 categories, November 2011

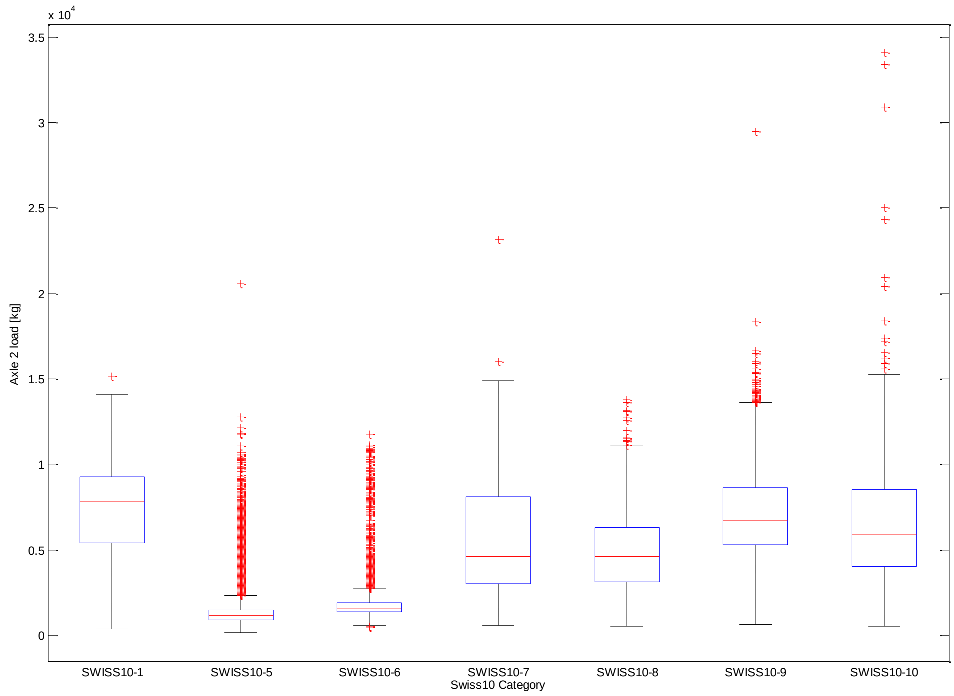


Figure 8. 11 Box plot showing the distribution of axle 2 loads for all SWISS 10 categories, November 2011

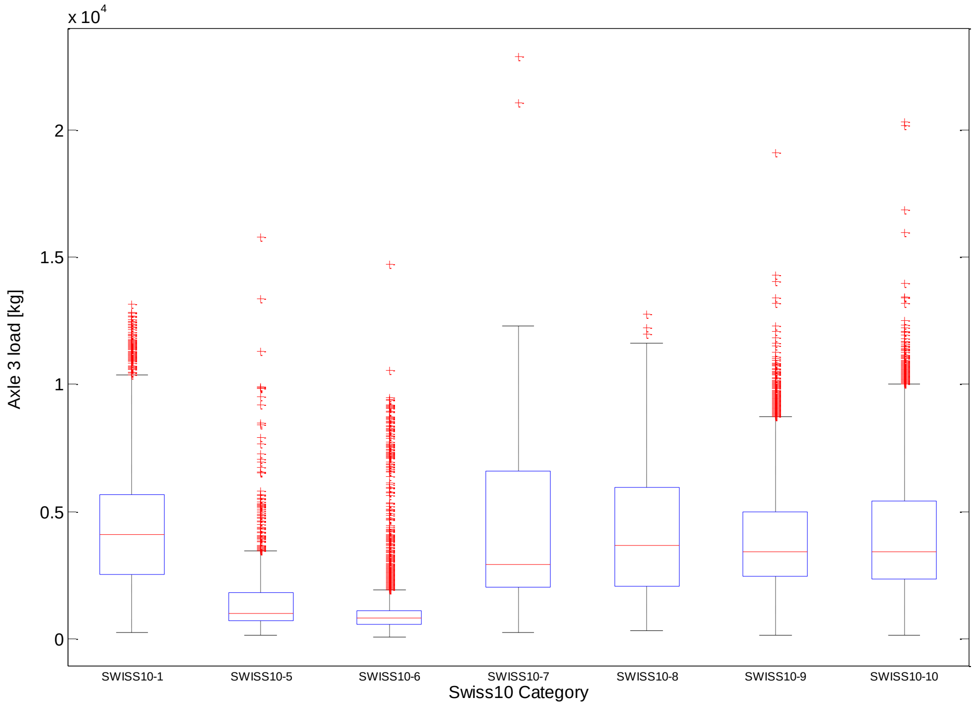


Figure 8. 12 Box plot showing the distribution of axle 3 loads for all SWISS 10 categories November 2011

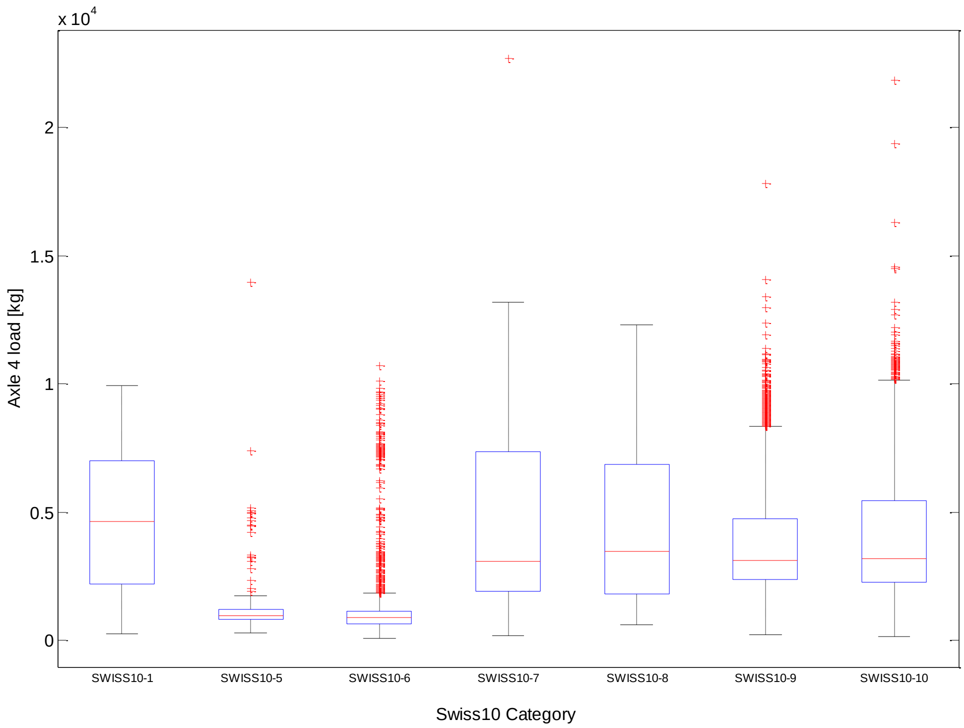


Figure 8. 13 Box plot showing the distribution of axle 4 loads for all SWISS 10 categories, November 2011

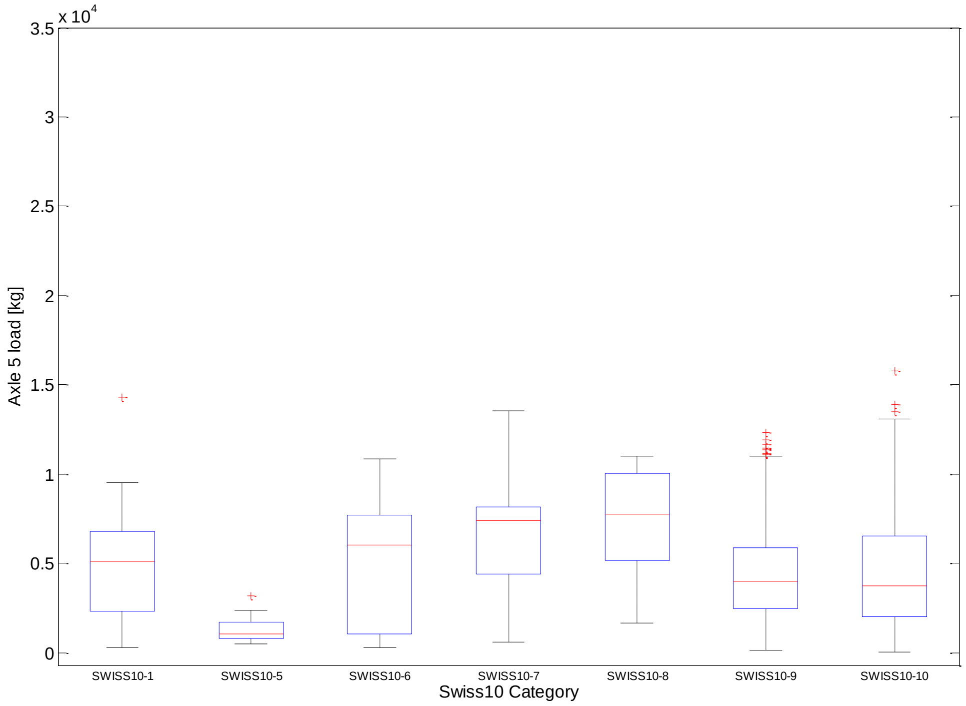


Figure 8. 14 Box plot showing the distribution of axle 5 loads for all SWISS 10 categories, November 2011

8.2 Noise

8.2.1 Relations with observed parameters

As a first step, relations between measured pass-by levels and observed parameters were investigated. Hereby, only measurement periods with dry road conditions were selected. To remove the "trivial" influence of vehicle speed on the emission level, all measurements have been normalized for a speed of 80 km/h based on the following equation:

$$L_{\max} = A + 30 \cdot Log_{10}\left(\frac{v}{80 km/h}\right)$$

Figure 8. 15 shows the average noise emission per SWISS10 category for the three measurement months. As can be seen, the September values are systematically 0.5 dB(A) lower than the March or November data. This can be attributed to the higher temperatures in September, which lowers rolling noise. The results indicate no additional effect of winter tires.

Table 8. 4 Representative sound pressure levels

Sound pressure level [dBA]	Representative source
0	Threshold of human hearing
60	Human voice in 2 m distance
70	Road traffic in 10 m distance (1000 vehicles/h, 80 km/h)
120	Jet plane in 100 m distance

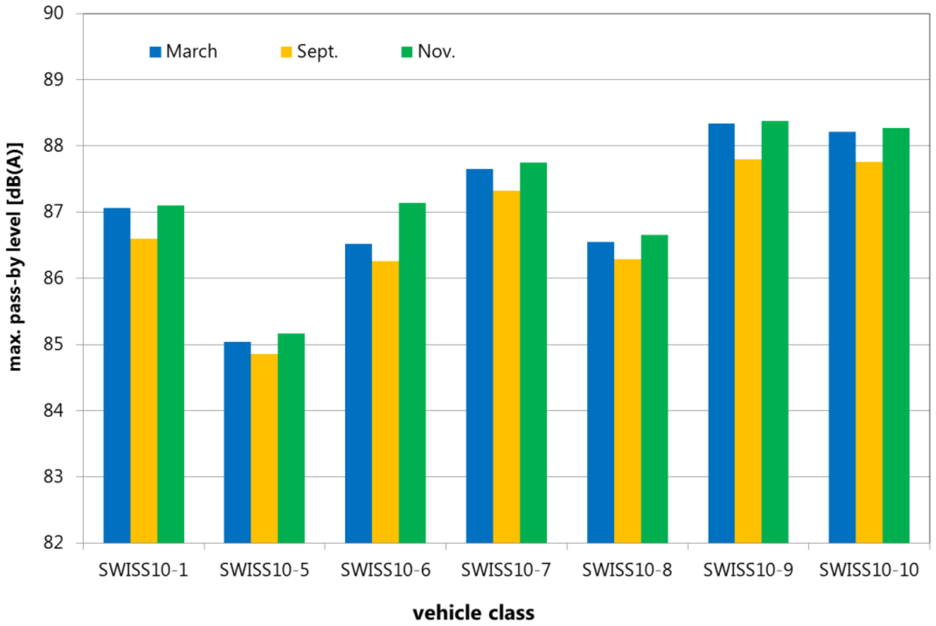


Figure 8. 15 Average noise emissions during the three measurement months for each Swiss 10 category

Figure 8. 15 to Figure 8. 17 investigate the influence of Euro gaseous emissions categories on noise emission. The results show that there is no systematic dependence of the Euro emissions classes. In particular Euro 2 and Euro 3 classes are not necessarily noisier than classes 4 and 5. However, the larger vehicles Swiss 9 and 10 are noisier than the other categories.

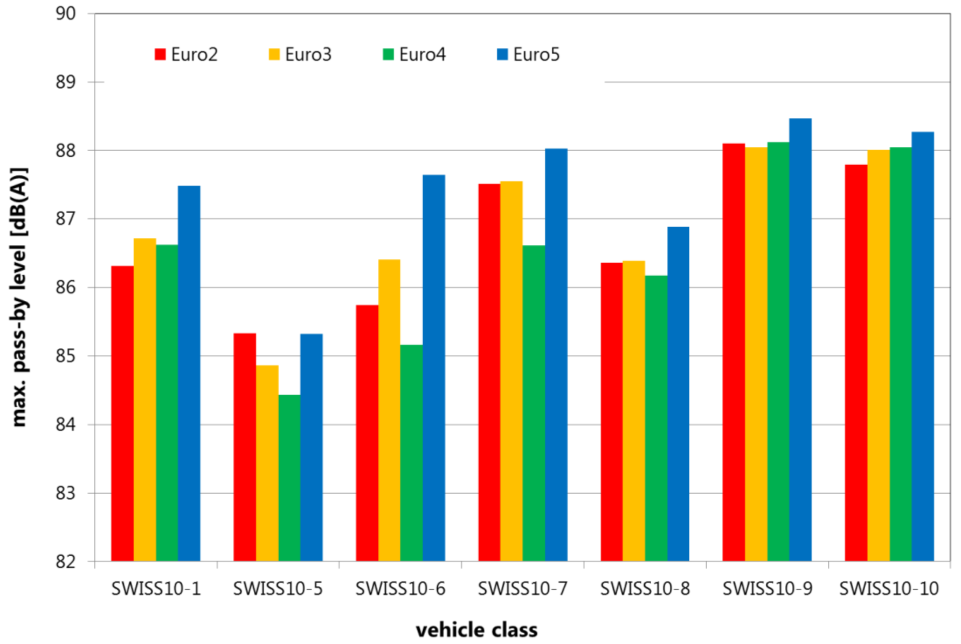


Figure 8. 16 Influence of Euro class on the average noise emission for March 2011

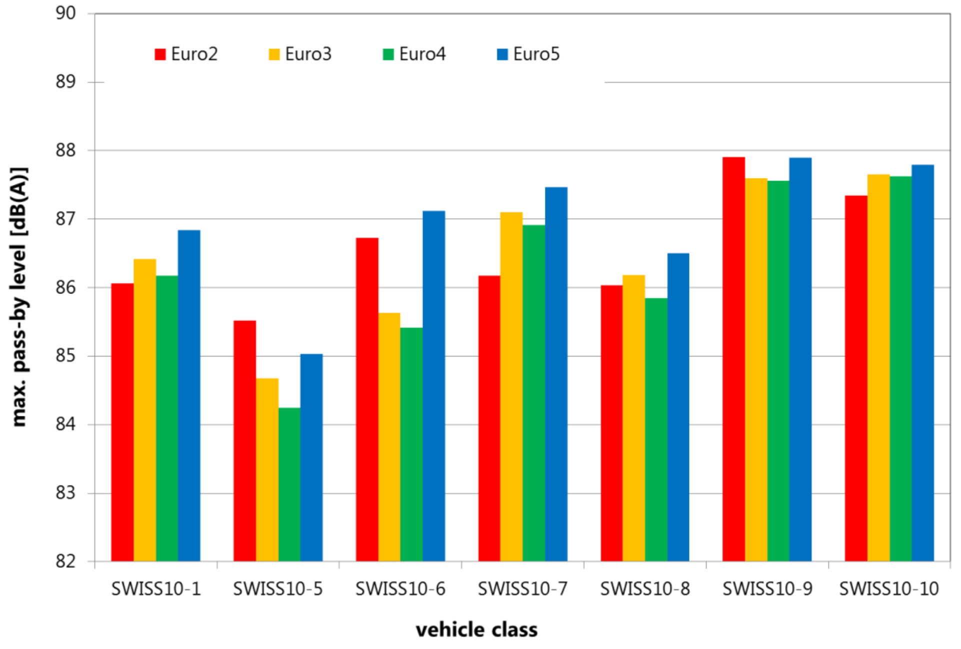


Figure 8. 17 Influence of Euro class on the average noise emission for September 2011

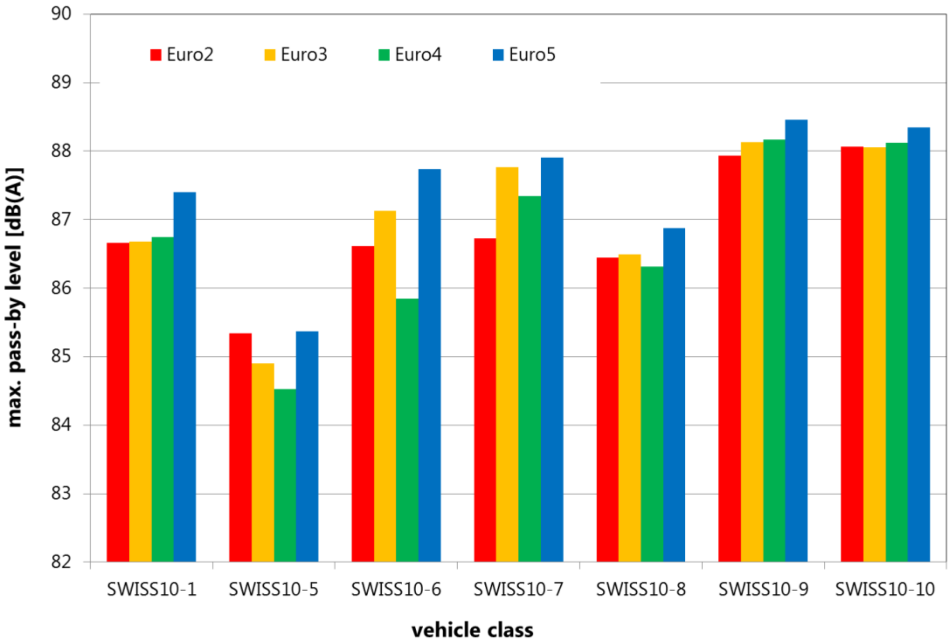


Figure 8. 18 Influence of Euro class on the average noise emission for November 2011

Figure 8. 19 to Figure 8. 21 show the difference in noise emissions during day (6:00-22:00) and night (22:00-6:00) .The results reveal that the vehicles fleet regarding noise emissions does not differ systematically from day to night.

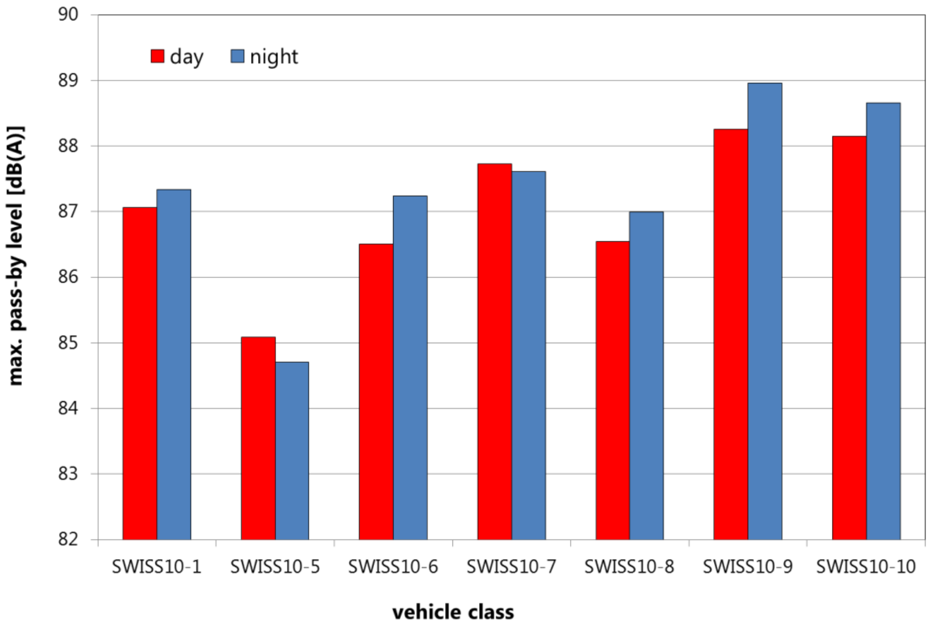


Figure 8. 19 Difference in day and night average noise emissions for March 2011.

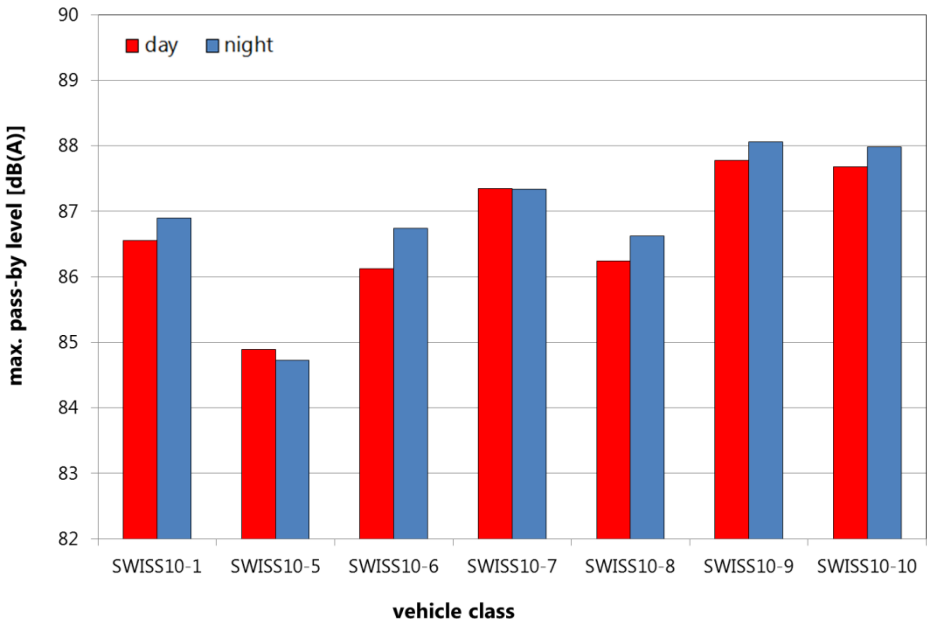


Figure 8. 20 Difference in day and night average noise emissions for September 2011

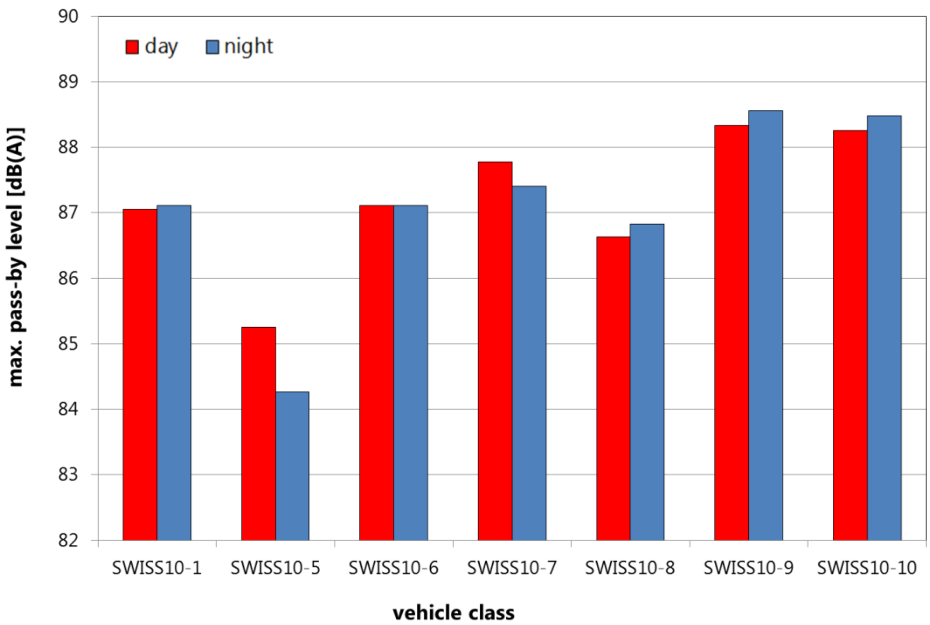


Figure 8. 21 Difference in day and night average noise emissions for November 2011

Finally, the influence of origin was examined by evaluating the emission in the categories “Swiss” and “foreign”. Figure 8. 22 to Figure 8. 24 show that the Swiss vehicles are systematically 0.5 dB(A) louder than foreign vehicles. This can probably be attributed to the fact that the Swiss fleet contains a significant fraction of noisy trucks that operate construction sites.

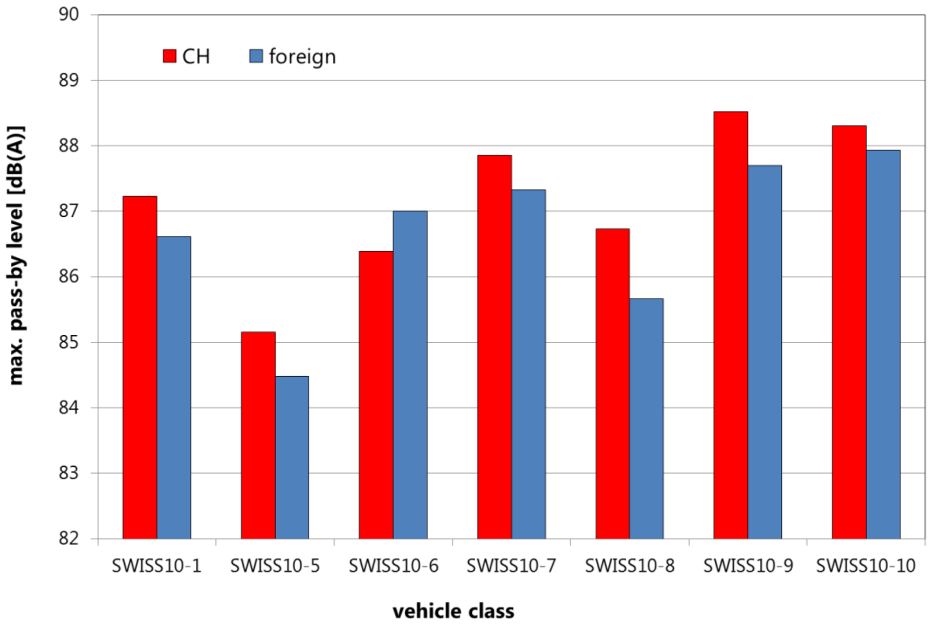


Figure 8. 22 Average noise emissions of vehicles with respect to their origin in March 2011

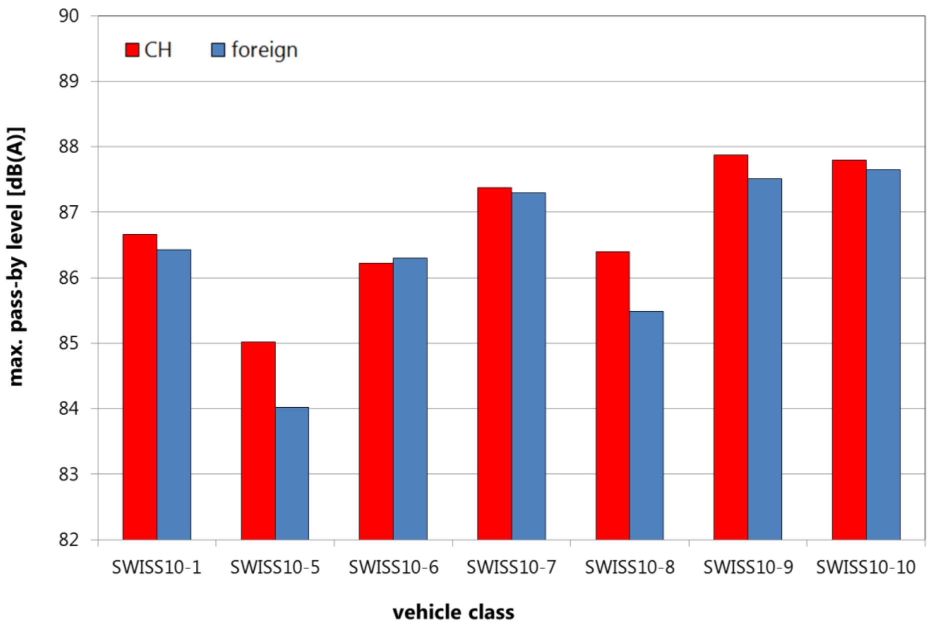


Figure 8. 23 Average noise emissions of vehicles with respect to their origin in September 2011

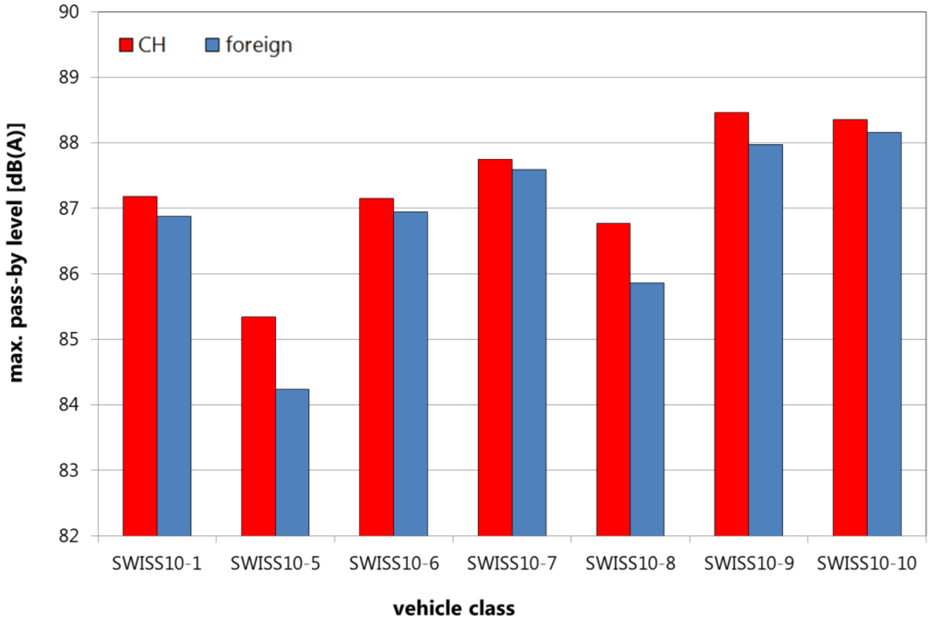


Figure 8. 24 Average noise emissions of vehicles with respect to their origin in November 2011

8.2.2 Vehicle noise emission model

In a second step a model was developed to predict the A-weighted maximal pass-by level of a vehicle considering the observed parameters [Heutschi 2012]. As a model function the following formula was used:

$$L_{\max} = A + 30 \cdot Log_{10}(\frac{v}{80km/h}) + C \cdot we + D \cdot wa + E \cdot Log_{10}(n)$$

where v is vehicle speed [km/h], we is total weight [kg], wa is allowable weight [kg] and n is the number of axles. A,C,D,E are factors individually set for each vehicle category. Factor A depends on site specific factors such as pavement type and pavement temperature and thus may vary.

It should be noted, that the terms introduced in the above formula are not necessarily independent from each other. A heavy vehicle is characterized by high effective and allowable weight (we, wa) and at the same time has with high probability a high number of axles n.

The factors A,C,D,E were determined in three steps for best fit with respect to the measurements. In step 1, A and E were adjusted, leaving C and D zero. In step 2, E was used as determined before and A and C were adjusted. Finally in step 3, A and D were determined, using E and C as found before. Table 8. 5 shows the factors. As demonstrated in [Heutschi 2012] the number of axles is the most relevant vehicle parameter. For a simplified model it is thus appropriate to ignore weight information (parameters we and wa).

Table 8. 5 Model factors for the SWISS-10 categories 1 and 5-10

Cat	E	C	D
1	5.1	5.33E-5	2.00E-5
5	10.9	1.15E-4	6.50E-5
6	13.1	4.00E-5	1.83E-5
7	5.7	3.50E-5	1.67E-5
8	6.1	7.67E-5	2.50E-5
9	6.5	2.33E-5	1.50E-5
10	4.5	2.50E-5	5.00E-5

With the help of the noise emission model developed above, the individual footprint of a vehicle can be estimated from parameters that are known or observable. As soon as the EU label (EU Regulation 1222/2009) is introduced, additional information about the tires can be included in a footprint factor.

8.2.3 Influence of weight on acoustical emission

With the above presented model, the maximum pass-by levels of all vehicles observed during March, September and November 2011 were calculated using the allowable and total weight and the number of axles. The evaluation as a function the total (= effective) weight is shown in Figure 8. 25. The relation between maximum level and vehicle weight can be approximated by a logarithmic function. On average, a doubling of vehicle weight increases the maximum level by 1.2 dB(A). This results suggest, that – from an acoustical point of view – the heavy goods should be transported by a few large trucks instead of many small delivery trucks.

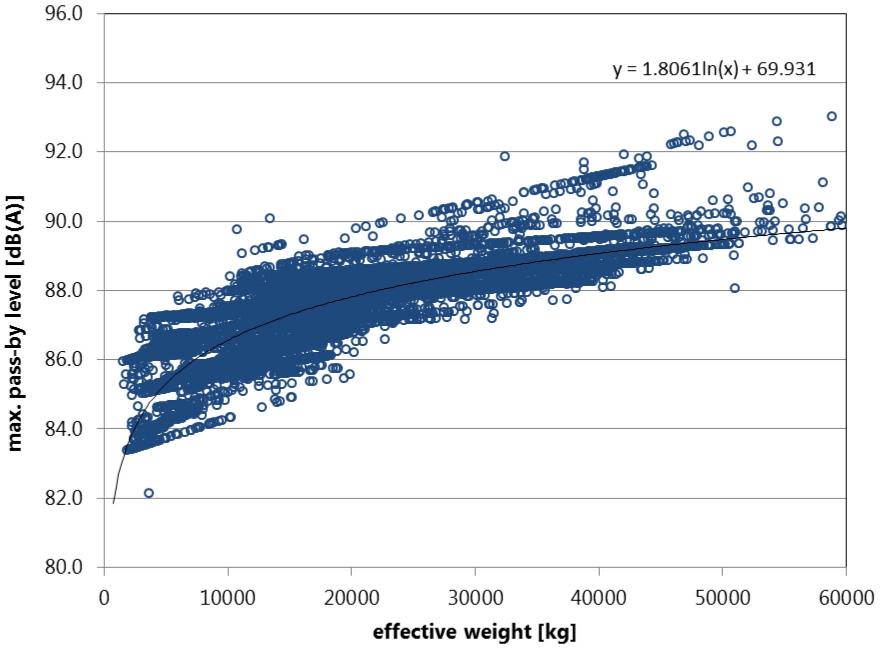


Figure 8. 25 Maximum pass-by level calculated for the vehicles observed in March, September and November as a function of effective vehicle weight.

9 Case Studies

On September 22nd 2011, 42 vehicles were evaluated statically and dynamically at the Oberbuchsiten site in cooperation with the WIM calibration team. The WIM calibration team includes personnel from Empa, ASTRA and the police department of Canton Solothurn. Following the guidelines set by ASTRA [Molinari 2001], axles that are less than 2 m apart are not included in the calibration procedure. Table 9. 1 shows the parameters measured and their maximum, average and minimum values. As shown, axle 2, is on the average carrying more weight than the other axles. Figure 9. 6 shows the Euro category of vehicles monitored, indicating that most vehicles measured were EURO-V which was the best engine on the market in 2011. One vehicle had an engine with a EURO-VI pollutant emissions classification. The pressure of the tire on the second axle right side of vehicle was measured and shown in Figure 9. 7. Similarly on the same tire the tread was measured (Figure 9. 5). It can be seen that one vehicle (Nr. 25) had the minimum tread depth of 2mm. Total vehicle mass shown in Figure 9. 2 indicates that in three cases the difference between dynamic and static measurements exceeded 7%. The calibration performed on this day indicated that the WIM sensors fulfill the requirements of A(5) [Kienast 2011]. This rating means that this site has an accuracy of 5% in GVM, 8% in individual axle load, 8% in axle of a group and 7% in group of axles. Figure 9. 11 shows the most extreme cases.

Table 9. 1 Summary of the measured parameters

		Max.	Avg.	Min.
Mass/Length static	Gross Vehicle Mass [t]	40	19.36	7.55
	Axle 1 Mass [t]	7.55	5.51	2.8
	Axle 2 Mass [t]	11.4	7.08	3.15
	Axle 3 Mass [t]	8.45	4.44	0.6
	Axle 4 Mass [t]	8.4	4.44	1.85
	Axle 5 Mass [t]	7.4	5.56	2.85
	Length [cm]	1905	1377	790
Tire	Tread Depth [mm]	20	8	2
	Tire Pressure [bar]	10	8.5	4.9
Engine	EURO Cat.	6	4.2	1
	Hourse Power [HP]	540	403	180

Table 9. 2 Engine and tire information

		Y	N	No Info
Engine	Ad Blue	23	15	3
	Particle filter	2		
Tire	Tread type	Block	Rib	
		34	7	1

Figure 9. 1 Example of different tire profiles: Rib tire from Michelin left, and block tire from Bridgestone right

AdBlue is a German trademark that is used for improvements of gaseous emissions of diesel engines as discussed in more detail in chapter 7. As shown in Table 9. 2, a majority of vehicles investigated had AdBlue. The tire tread can have two shapes as shown in Figure 9. 1. As shown in Table 9. 2, most 2^{nd} axle tires from the group studies had block type tires.

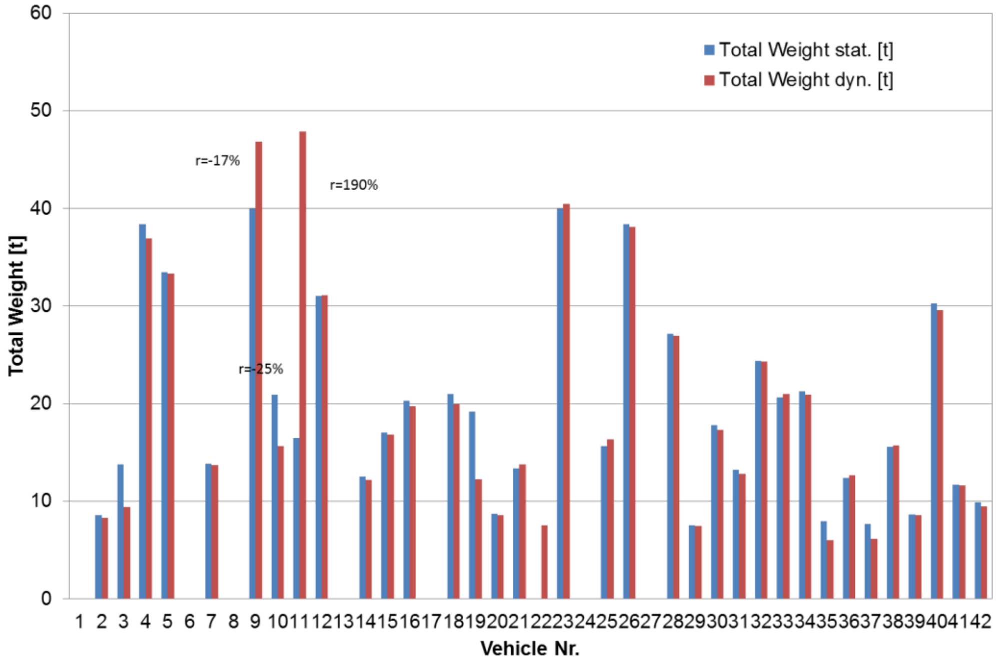


Figure 9. 2 Total vehicle mass of the 42 vehicles investigated shows that 93% of the measurements were within 7% tolerance

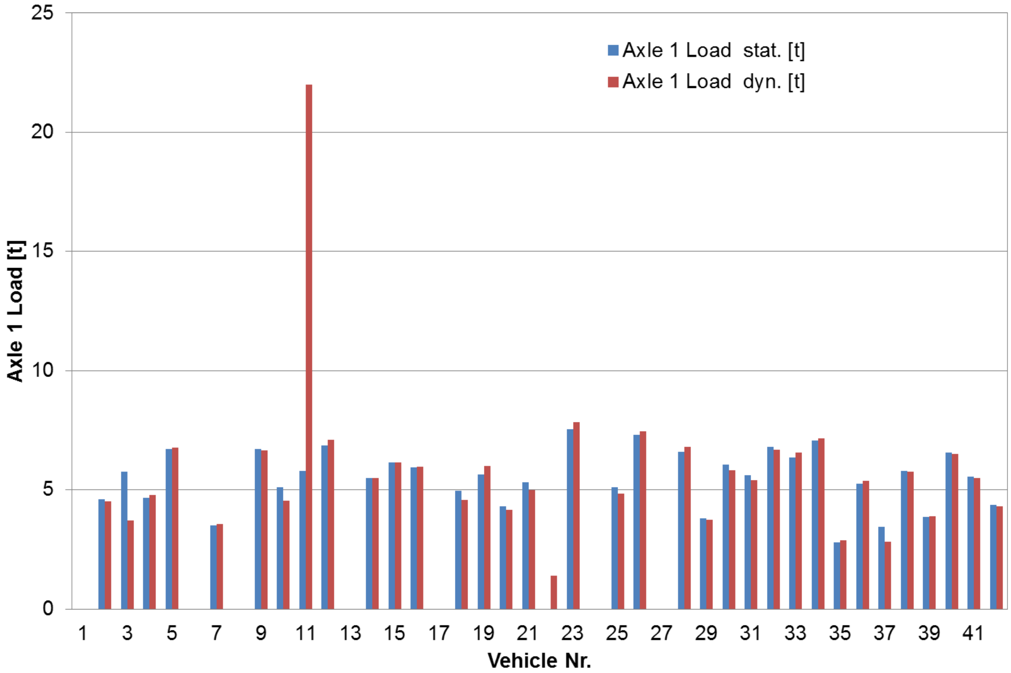


Figure 9. 3 Axle 1 loads

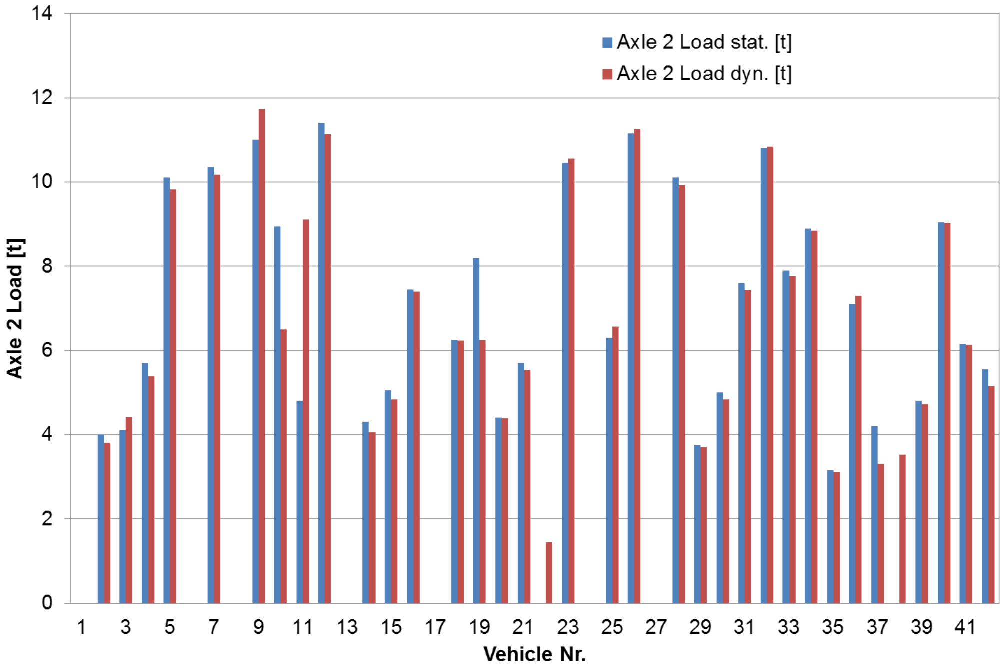


Figure 9. 4 Figure Axle 2 load

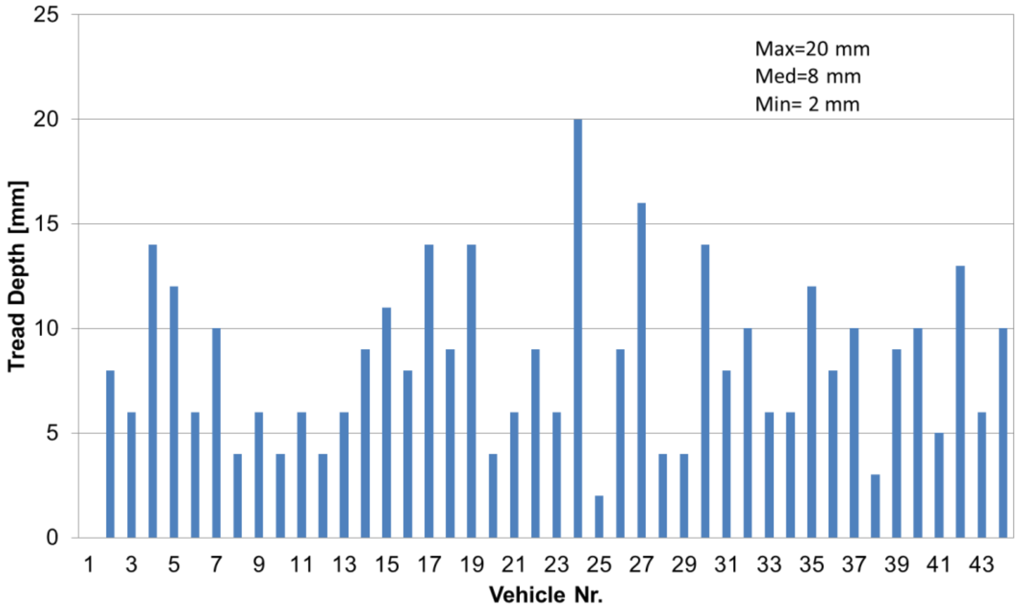


Figure 9. 5 Thread depth of the tire of second axle

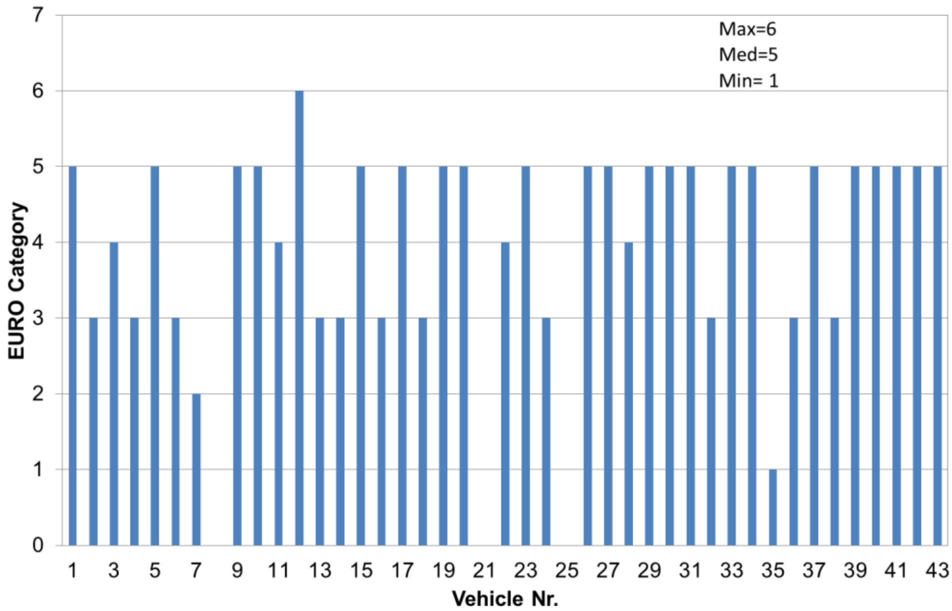


Figure 9. 6 EURO category per vehicle

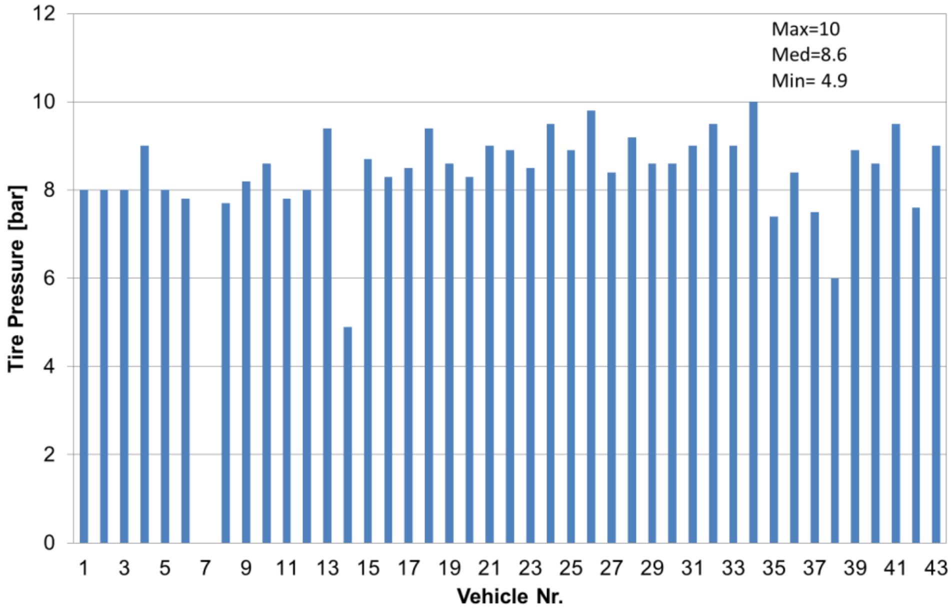


Figure 9. 7 Pressure of second axle tire right hand side of vehicle

In addition possible correlation between the tire profile depth, tire pressure, engine power and the measured maximum pass-by noise level, normalized for 80 km/h was investigated. As can be seen in Figure 9. 8 to Figure 9. 10, the coefficient of determination R^2 is below 0.1 for the correlation with profile depth and tire pressure. This suggests that these two parameters have no significant influence on noise generation. The correlation between engine power and maximum pass-by level is clearly higher with $R^2 = 0.27$. However the result does not prove causality between engine power and noise. Trucks with higher engine power have typically more axels and thus more tires which increases tire noise emission.

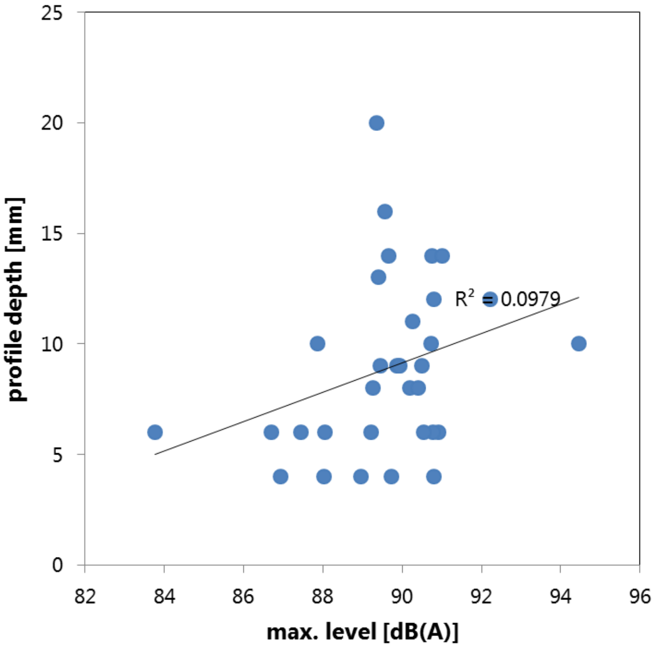


Figure 9. 8 Correlation between noise emissions and tire profile depth

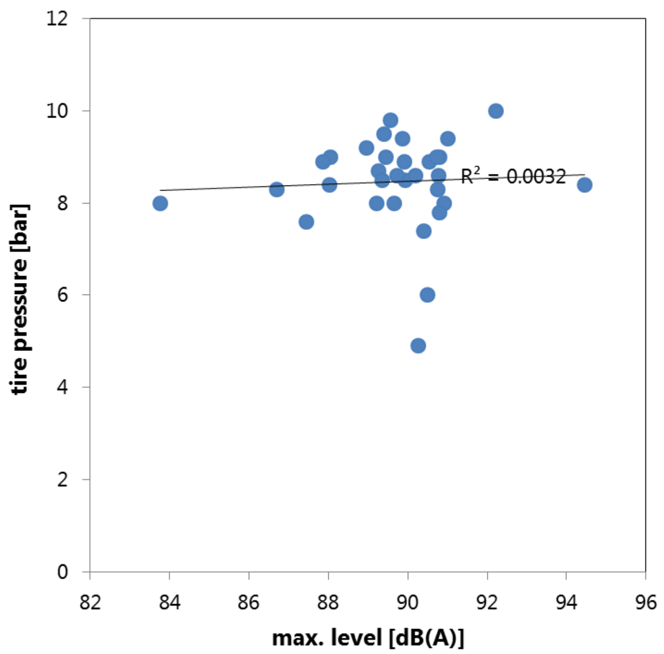


Figure 9. 9 Correlation between noise emissions and tire pressure

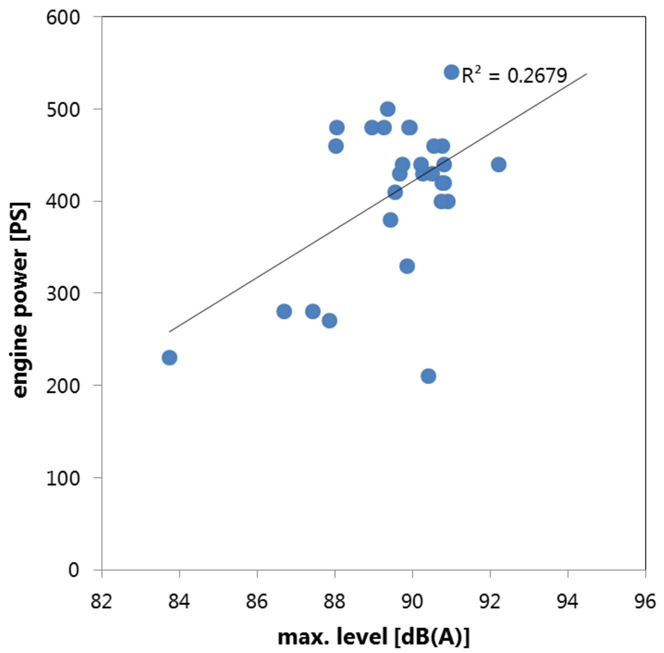


Figure 9. 10 Correlation between noise emissions and engine power

Oldest vehicle and least environmentally friendly engine:
17 years and EURO-I

Smallest tire tread depth: 2mm

Most environmentally friendly engine:
EURO-VI

Highest Gross vehicle mass: 40 t

Highest axle 2 load: 11.4 t

Figure 9. 11 Photographs showing the extreme cases among 42 vehicles studied

10 Total Footprint

In the previous chapters it was shown that it is possible to measure individual Footprint parameters for each heavy vehicle or retrieve some parameters from a data base. It was also shown that vehicles can be environmentally friendly in one category and not in another. Therefore in order to derive a holistic impression of the footprint of a vehicle it is necessary to find a method to combine these individual footprints. In this chapter two methods are developed and discussed. Data was improved and reduced as defined in Table 8. 2. Noise emissions for the calculation of total footprint are defined as actual noise not normalized for 80 km/h.

10.1 Method 1

Method 1 considers Gross vehicle mass, noise and euro emissions category.

Noise and mass Footprints are calculated using the median value for each category and the interquartile range as follows. In this way the further the individual value is from the median the more it’s footprint for that category.

Δ= interquartile range i.e. difference between 25% und 75% value in the data distribution,

Lp_{50}, GVM_{50} = Median values for noise and gross vehicle mass

Noise Footprint: $(Lp-Lp_{50})/ \Delta L$ Example: (90-85)/10=0.5

Gross vehicle mass Footprint: $(GVM-GVM_{50})/ \Delta GVM$ Example: (30-20)/10=1

Gaseous emissions footprints are calculated as shown in *Table 7. 1* that is:

Gaseous emissions footprint for EUROV= -0.54

The total Footprint of the example vehicle from above with Noise=90 dB, GVM=30 t, EURO-V is:

Total Footprint=0.5+1-0.54=0.96

Using method 1, the total footprint has been calculated for three vehicles as shown in Table 10. 1. Figure 10. 1 to Figure 10. 3 show the total footprint for all valid measurements in March, September and November 2011. As shown using method 1, in every category there are vehicles with a high total footprint although the median is close to zero. In the examples of Table 10. 1 it is demonstrated that although all three vehicles had a EURO-V engine, they had very different total Footprints. The category 10 vehicle with GVM=16’260 had a lower footprint (-0.06) than the category 10 with a GVM=42’090 with footprint of 1.38. The category 8 vehicle had the highest footprint even though it was carrying similar weight (41’830 kg) and had the same engine type (EUROV) as one of the category 10 vehicles. The reason for this is that the median weight for category 8 at 10’930 kg is much smaller than the median weight for category 10 vehicles at 19’840 kg.

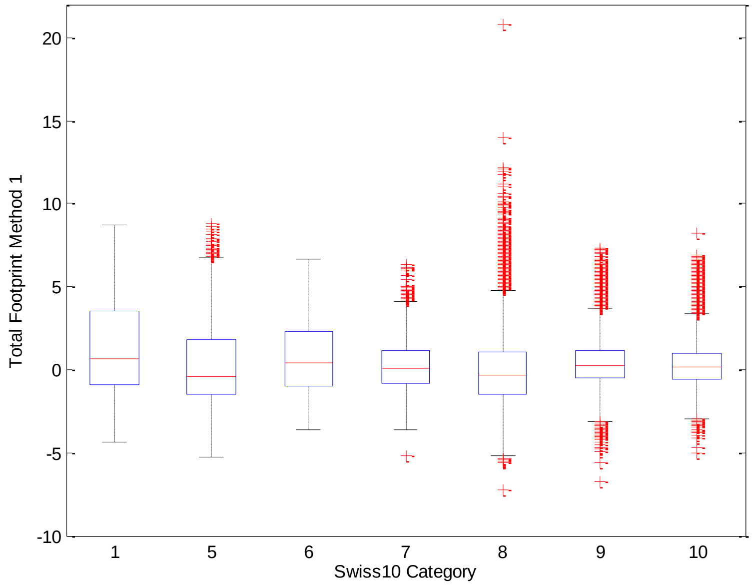


Figure 10. 1 Distribution of total footprint per Swiss 10 category using method 1, March 2011

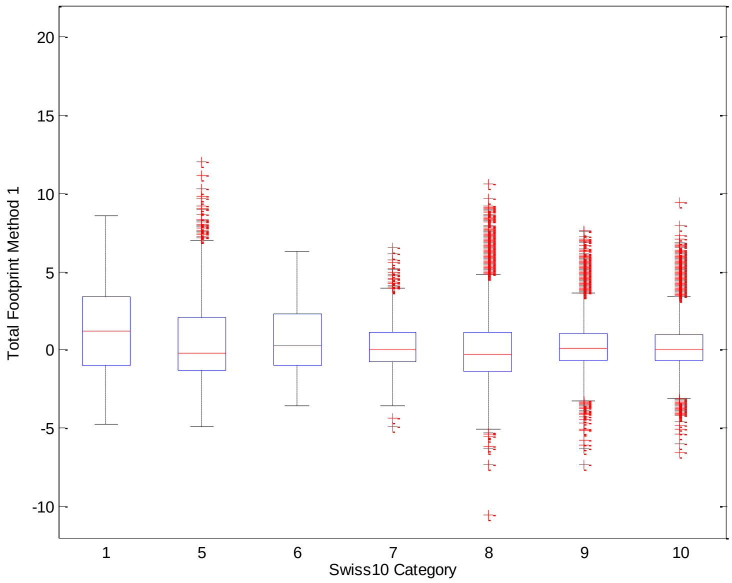


Figure 10. 2 Distribution of total footprint per Swiss 10 category using method 1, September 2011

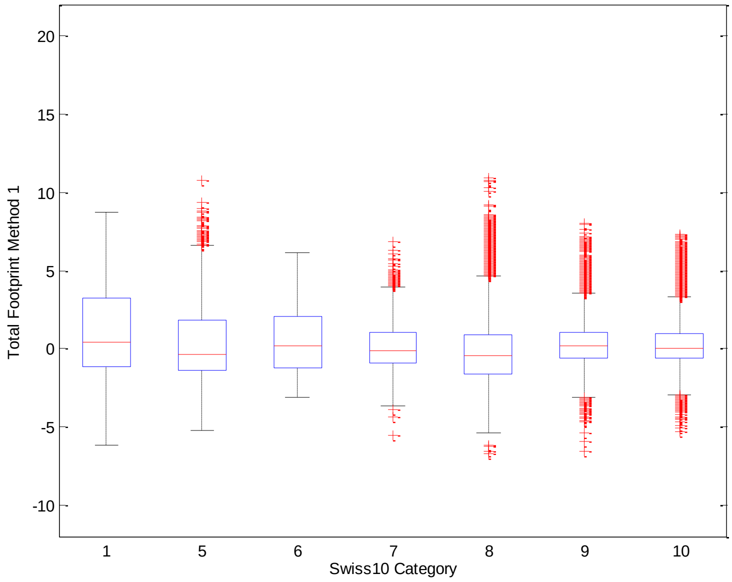


Figure 10. 3 Distribution of total footprint per Swiss 10 category using method 1, November 2011

Table 10. 1 Three examples of total footprint calculations using method 1

Vehicle ID	**Veh. Cat.**	**Gas.**	**Weight**			**Noise**			**Footprint**			
	SWISS10	EURO	GVW	GVM_{50}	irqGVM	Lp	Lp_{50}	iqrLp	gas	weight	noise	Total
209275521	10	5	42090	19840	13360	89.1	88.4	2.8	-0.54	1.67	0.25	1.38
663419122	8	5	41830	10930	5190	88.2	88.9	2.1	-0.54	5.95	-0.33	5.08
664404588	10	5	16260	19840	13360	90.5	88.4	2.8	-0.54	-0.27	0.75	-0.06

10.2 Method 2

Method 2 considers Axle load, noise and euro emissions category. The same procedure as method 1 is used for the calculation of noise and axle load Footprint as shown below. In this case the vehicles have up to five axles, therefore the footprint for each axle in each Swiss 10 category is determined and the maximum axle load footprint is used to calculate the total footprint.

Δ= interquartile range i.e. difference between 25% und 75% value in the data distribution,

Lp_{50}, AL_{50} = Median

Noise Footprint: $(Lp-Lp_{50})/\Delta L$ Example: (90-85)/10=0.5

Vehicle axle x load Footprint: $(ALx-ALx_{50})/\Delta ALx$ Example: (10-5)/5=1

Axle load Footprint: Max of individual axle load footprints

Gaseous emissions are calculated as shown in Table 7. 1. In this case the gaseous emissions footprint for a EURO-V engine is -0.54.

The total Footprint of the example vehicle from above with Noise=90 dB, AL=10 t, EURO-V is:

Total Footprint=0.5+1-0.54=0.96

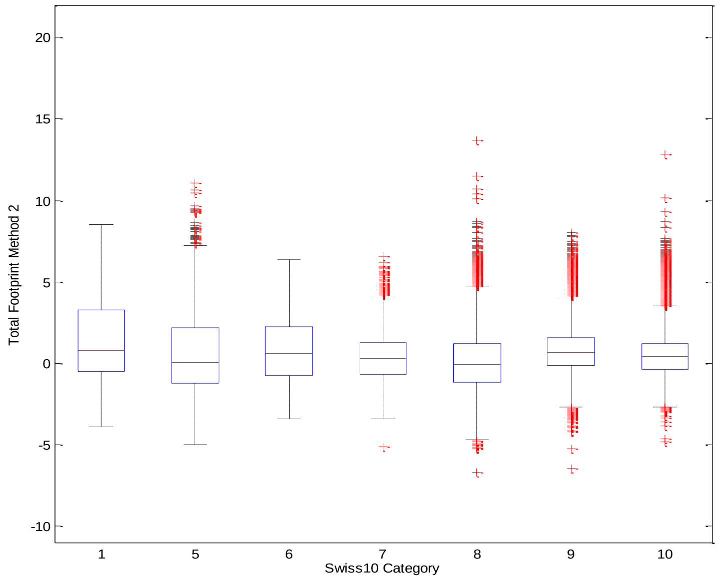


Figure 10. 4 Distribution of total footprint per Swiss 10 category using method 2, March 2011

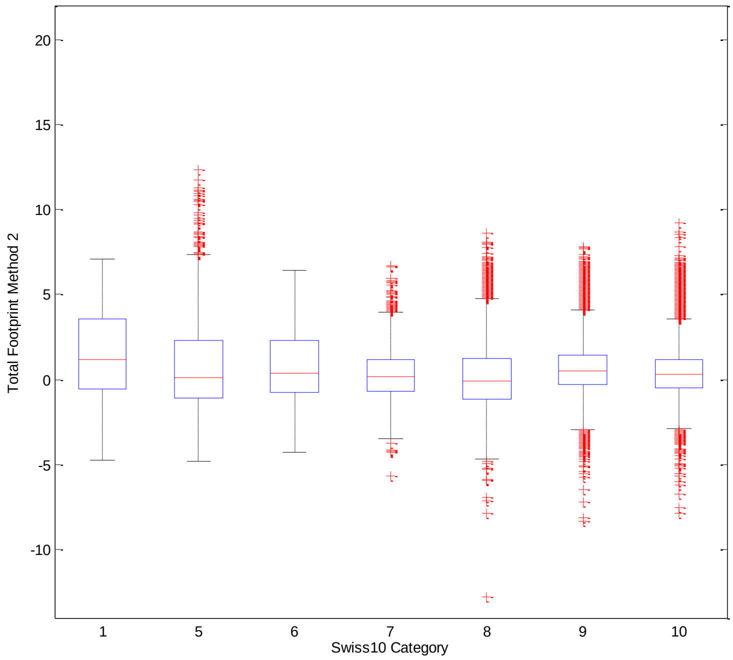


Figure 10. 5 Distribution of total footprint per Swiss 10 category using method 2, September 2011

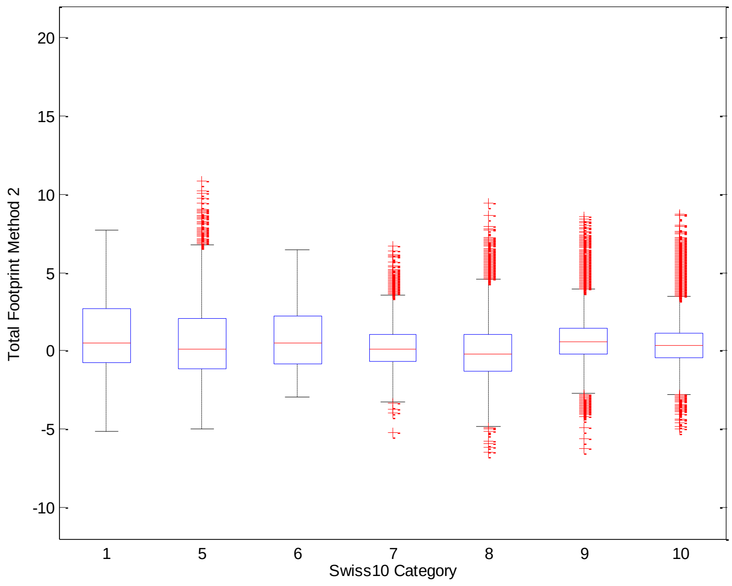


Figure 10. 6 Distribution of total footprint per Swiss 10 category using method 2, November 2011

The distribution of total footprint calculated with method 2 is shown in Figure 10. 6. This method shows that although the median footprint for each category is around zero, in every category there are vehicles with a high footprint. Method 1 resulted in total footprint values between -11 and +22, whereas method 2 resulted in values ranging from -7 to +12. Comparison of method 1 and method 2 indicate a smaller distribution of footprint using method 2 which can be attributed to the smaller distribution of axle loads in comparison to gross vehicle mass.

11 Policy Options

Heavy vehicle data analyzed during this project has shed some light on the sources of environmental footprints of HDVs. Comparison of carried weight with weight from the LSVA databank has shown that there is a small but significant number of vehicles that are overloaded for example in November 2011 this was 617 vehicles or 0.56 % of the population of vehicles examined.

Considering the total footprint of vehicles obtained by combining weight, noise and pollutant emissions data it was seen that in almost every Swiss category there are vehicles that have a high total footprint.

Noise monitoring has confirmed previous findings that the EURO V category vehicles that are environmentally friendly regarding their engines are not necessarily environmentally friendly with respect to noise emissions. Europe wide policies should be placed in order to encourage vehicles with a low total footprint that includes noise, emissions and load. This can be achieved by cooperation in European projects such as Ecovehicle (Appendix I).

Directive 1999/62/EC of the European Commission is in place for harmonization of levy systems and fair mechanisms for charging for infrastructure costs in order to eliminate distortions of competition between transporters in member states [EC DIR 1999]. It is explicitly stated in this directive that minimum rates should be set for vehicle taxes and that road-friendly and less polluting vehicles should be encouraged through differentiation of taxes or charges. Below are some excerpts that are relevant in the framework of the current project:

- Charges should be based on duration of use of infrastructure.
- Member states should be able to attribute to environmental protection a percent of the user charge.
- Costs of infrastructure or infrastructure improvements may include any specific expenditure on infrastructure designed to reduce nuisance related to noise.
- ‘external-cost charge’ means a charge levied for the purpose of recovering the costs incurred in a Member State related to traffic-based air pollution and/or traffic-based noise pollution;
- ‘cost of traffic-based air pollution’ means the cost of the damage caused by the release of particulate matter and of ozone precursors, such as nitrogen oxide and volatile organic compounds, in the course of the operation of a vehicle;
- ‘cost of traffic-based noise pollution’ means the cost of the damage caused by the noise emitted by the vehicles or created by their interaction with the road surface.
- the member states may establish differentiated noise charges to reward the use of quieter vehicles.

Annex IIIb of the directive lists the Maximum chargeable noise costs as shown in Table 11. 1.

A recent report by the World Health organization (WHO) indicates that in the EU and Norway, traffic noise is the second biggest environmental problem affecting health after air pollution. This new health evidence highlights the urgency of adopting more stringent EU vehicle noise standards. Further evidence by WHO indicate that noise can disturb sleep, cause cardiovascular and psychophysiological effects, reduce performance and provoke annoyance responses and changes in social behaviour. Traffic noise alone is harming the health of almost every third person in the WHO European Region. One in five Europeans is regularly exposed to sound levels at night that could significantly damage health [WHO 2012]. The European Commission is expected to release a proposal to update the Vehicle Noise Directive 70/157/EEC in 2012.

Table 11. 1 Maximum chargeable noise cost [EC DIR 1999]

Euro cent/vehicle.kilometer	Day	Night
Suburban roads (including motorways)	1.1	2
Interurban roads (including motorways)	0.2	0.3

Due to the important adverse effects of noise on residents as listed above and as seen in this project that newer heavy vehicle models are not necessarily quieter, it is the consensus within this project that the LSVA should be revised in order to account for traffic based noise as provided by the EC. It is recommended to use differentiated noise charges to reward the use of quieter vehicles.

It is further recommended that instruments should be explored that encourage vehicles with a low total footprint on secondary roads where residents typically live closer to traffic sources.

12 Summary, Conclusions and Outlook

Heavy vehicle data on gross vehicle mass, axle load, noise, EURO emissions category, SWISS 10 category, declared mass as well as other parameters was collected for March, September and November 2011 at the Footprint monitoring site at Oberbuchsiten in central Switzerland. Each month ca. 100'000 valid vehicle measurements were collected which reflected a statistically representative sample of data. From the analysis of this data, using algorithms developed within this project, the following was concluded:

1. The data for the three months are consistent and repeatable, both in the number of vehicles and maxima, minima and median values obtained for the various parameters of interest.
2. The vehicle fleet is mostly Swiss category 10, 9 and 8 with engine categories that are mostly Euro-V (ca. 66%), Euro-IV (ca. 10%) and Euro-III (ca. 19%).
3. The majority of vehicles analyzed carry below the allowable in Switzerland of 40 t, however there is small but significant number of vehicles carrying more than 40 t.
4. On average Swiss category 9 and 10 transport more tonnage than other categories.
5. The heavy vehicle fee in Switzerland is based on declared weight not actual carried weight, and it is suspected that some vehicles may carry more than they have declared and paid for. A comparison of the actual weight carried obtained from WIM sensors and the allowable weights according to the LSVA databank show that less than 0.6% of vehicles have been overloaded. The most number of overloads happened in November with 0.6 % of 105'037 vehicles or 617 vehicles.
6. The mean axle load values for axles 2 was the highest with axle one following closely. Swiss categories 5 and 6 have the lowest axle loads. Buses (Swiss cat 1) have axle loads as high as Swiss 7, 8, 9 and 10.
7. Although the mean at about 5 t axle load in every category is within the allowable limit of 11.5 t for drive axle and 10 t for other axles. There are vehicles within most categories that bypass this limit.
8. The variance for axle one load was lower than the other axles. This is the reason that this axle is used for automatic calibration in some countries.
9. The September noise values were systematically 0.5 dB(A) lower than March or November. This was attributed to the higher pavement and tire temperatures and softening of the asphalt in September.
10. The results show no significant difference resulting from summer and winter tires which would be seen between September and November.
11. It was seen that there is no systematic dependence of the noise emissions on the Euro emissions classes for each Swiss 10 category. This shows that the Euro-V emissions classes are not necessarily less noisy. However, the larger vehicles Swiss 9 and 10 are noisier than the other categories. Although the vehicle fleet is becoming more environmentally friendly regarding pollutant emissions, with respect to noise emissions there is no improvement.
12. The difference in noise emissions during the day (6:00-22:00) and night (22:00-6:00) for dry road conditions and normalized for 80 km/h show that the vehicle fleet regarding noise emissions is not different during the day or at night.
13. Noise measurements show that the Swiss vehicles are systematically 0.5 dB(A) louder than foreign vehicles. This can be probably attributed to the local vehicle traffic from construction sites.
14. Possible correlation between the tire profile depth, tire pressure, engine power and the measured maximum pass-by level, normalized for 80 km/h was investigated. The results using 42 vehicles from the case studies indicate no significant influence on noise generation.
15. The relationship between noise emissions and vehicle mass indicate that from a noise point of view it is advantageous to transport more tonnage on larger vehicles than the reverse. From the infrastructure point of view it is advantageous when the tonnage is distributed among many axles and the value remains below 10 t per single axle and 11.5 t for drive axle.

16. With the help of the noise emission model developed, the individual footprint of a vehicle can be estimated from parameters that are known or observable. Such data can be obtained from the vehicle ID and used to calculate the noise emissions of individual vehicles.
17. Two models are proposed for the calculation of the total footprint of heavy vehicles. With the help of the total footprint models developed, heavy duty vehicles can be evaluated using a holistic approach taking into account a combination of all their individual footprints. The results show that in almost every category there are vehicles with a very high combined footprint.

The results of the project can aid in developing a bonus/malus mechanism based on the "polluter pays principle" in order to reduce the environmental impact of vehicles at source. Due to the important adverse effects of noise on residents and as seen in this project that newer heavy vehicle models are not necessarily quieter, it is the consensus within this project that the LSVA should be revised in order to account for costs of traffic based noise as provided by the EC. It is recommended to use differentiated noise charges to reward the use of quieter vehicles.
To this end, a follow up project is recommended that would have as its goal the following:

- Revision to the LSVA to include noise in the calculation of external costs of heavy vehicles.
- Cooperation in the European project Ecovehicle E!7219 (Appendix I) in order to reach European consensus in further developing the user pays principle for road and rail infrastructure
- To encourage vehicles with a low total footprint on secondary roads where residents typically live closer to traffic sources

Appendixes

I European Project Ecovehicle

I.1 Summary

The concept of a vehicle's environmental footprint has been developed in the Eureka project Footprint (2001 to 2008) in which the size of the footprint has been related to its impact with the infrastructure and the environment and its external (social/environmental) cost. Methods of measurement have been developed as and data collected and assessed to determine its reliability and reproducibility.

In the Ecovehicle project, the measurement campaign for monitoring the environmental impact of road and rail vehicles will be extended. Common methods of analysis will be formulated and the data will then be analysed to identify those vehicles which are being operated outside regulatory and safe working limits. Methods of informing drivers and operators will be developed working with local authorities.

From such analyses it will be possible to determine the proportion of any vehicle type that has high impacts and vehicles that have low impact. Appropriate criteria will then be proposed for environmentally friendly road and rail vehicles and to determine possible parameter limits. The final task will consider how these environmental impacts can be costed. Within any one class of vehicles, it should be possible to identify an incentive (bonus) for vehicles with a low footprint and a penalty (malus) for vehicles with a large footprint. This would be in accord with the polluter pays principle as set out in the EU Green Transport package of 2008.

I.2 Background

The Eureka project Footprint (2001 – 2008) investigated the relation of the environmental footprint of a vehicle to the lifetime cost of maintaining the infrastructure and the environment. Methods have been developed to measure in situ the dynamic impact of vehicles with the infrastructure and the environment for both road and rail vehicles in a way that allows the impacts of the two modes to be compared. Such data sets have then been analysed to quantify the impacts in a transparent manner. From such analyses it should be possible to develop the concept of a vehicle’s environmental footprint and then to decide which vehicles can be classified as environmentally friendly. One way of reducing the environmental impact would be to reward those operators whose vehicles are environmentally friendly and to penalize those that are environmentally harmful. This cited in pending EU legislation as the bonus/malus system which would require European agreement as much heavy goods vehicle operates across country borders.

The final workshop was held at EMPA laboratory, Dubendorf, Switzerland in November 2008 and concluded that

- the Footprint project had significantly increased our knowledge of the environmental impact of road and rail vehicles
- the environmental impact of transport was a European problem which required a European solution
- available evidence suggested that environmentally harmful vehicles may also be unsafe
- with increasing number of vehicles it becomes essential to inform operators that their vehicles may be unsafe
- data collected by Footprint project can be used to set environmental limits
- environmental limits should be based on measurements of vehicles in service as well as laboratory and track testing
- vehicle impacts should be limited through a mixture of regulation and user charging
- the EU green transport package of 8 July 2008 commits Member States to developing more sustainable transport use including the internalisation of external costs
- the Commission proposal of a bonus/malus system which was revenue neutral to reduce the noise from the existing rail vehicle fleet was desirable

- theoretical predictions of the impact of any charging policy should be checked by in service measurements
- and that the next phase should concentrate on developing criteria for environmentally friendly vehicles

Within the Ecovehicle project the global aims are

- to increase the safety of vehicles operating on road or track by making measurements in service and informing the operator
- to develop equivalent criteria for environmentally friendly road and rail vehicles
- to check the effectiveness of any user charging regime to accelerate the introduction of environmentally friendly vehicles

I.3 Technical developments

The technical developments envisaged are

- Installation of additional footprint measuring systems on primary roads, railway lines and bridges which carry a high proportion of freight traffic. Possible installation of footprint measurement systems on secondary structures.
- Analytical methods of evaluating Footprint data to decide whether a vehicle is being operated in an unsafe manner or is outside statutory or regulatory limits.
- Addition of emission sensors to Footprint sites to determine trends in environmental emissions.
- Development of techniques for calibrating sensors and sites.
- Methods of informing operators/drivers of vehicles that are operating outside statutory limits.
- Defining limits for environmentally friendly vehicles.

I.4 Work plan

There are five major tasks; the key aspects of each are described below together with deliverables and milestones.

Task 1: data collection and exchange

- to collect more data from different sites in various countries to broaden the existing data sets
- to check the infrastructure and environmental impacts on secondary roads and tracks
- to develop techniques for determining the dynamic loading as well as the quasi-static loading on structures including bridges
- to facilitate data exchange between infrastructure maintainers
- to refine methods of determining reliability and uncertainty in the data sets
- to develop methods of determining the performance of a vehicle’s suspension

Methodology

Identify suitable measurement sites and decide whether to increase the sensor array to determine more environmental impacts. Calibrate sites using a common method and collect environmental data of passing vehicles.

Deliverables

- common methods of data collection
- data sets which characterise the environmental impact of different types of vehicles

Milestones

- common methods of calibrating measurement sites
- methods of data exchange

Task 2: data analysis and environmental impact

Analyse data to determine trends in

- number and class of vehicles in service

- variation in day/night and summer/winter
- relative importance of type and quality of the infrastructure
- identification of vehicles that may be unsafe and how to alert the drivers/owners
- proportion of vehicles that can be considered environmentally friendly and environmentally harmful
- impacts of any user charging regime
-

Methodology
Develop and agree methods of characterising the environmental impact of vehicles. Analyse data in a similar manner so data can be compared between sites and countries. Assess the contribution of the measurement site to the environmental impact of vehicles. Decide how to identify vehicles that might not be safe and how to alert drivers and operators.

Deliverables
- common methods of analysis
- contribution of measurement site to measured impacts

Milestones
- which vehicles might be operated in an unsafe condition
- methods of alerting drivers and operators

Task 3: developing equivalent criteria for environmentally friendly road and rail vehicles
- to assess the analysed data to determine the mean values of the various environmental and infrastructure impacts
- to use statistical analysis to determine possible limits for environmentally friendly and environmentally harmful vehicles

Methodology
Analyse data sets to determine the distribution in environmental impacts. Determine the mean and standard deviations of the various impacts. Compare between sites and countries and analyse any differences. Compare between rail and road modes for similar axle loading. Formulate criteria for environmentally friendly and harmful vehicles and engage in discussion with vehicle manufacturers, operators, infrastructure maintainers and local authorities.

Deliverables
- determine average and extreme impacts
- discuss possible environmentally friendly criteria with stakeholders

Milestones
- comparison of data between sites
- criteria for environmentally friendly vehicles

Task 4: relating impact to user charging
- to consider the appropriate environmental impacts for user charging which should include noise emissions, gross vehicle weight, axle load, vibration and local pollutants
- to identify limit values for each impact
- to propose appropriate values for bonus/malus payments

Methodology
From an analysis of the data sets, consider which impacts should be costed taking into account their local and global influence. Then to identify what would be a suitable charging regime, and how this could be applied to different types of vehicles.

Through discussion with stakeholders, identify the appropriate limit values and what might be an appropriate bonus/malus payment.

Deliverables
- deciding which impacts should be costed

- identifying suitable charging regimes

Milestones
- agreeing limit values for each impact
- proposing appropriate bonus/malus payments

Task 5: dissemination
- to discuss with manufacturers, operators and local, national and European authorities
- to organise workshops alongside each project meeting to consider progress
- to present results at conferences and in publications

Methodology
The interaction between the vehicle, the infrastructure and the environment involves many stakeholders of which the vehicle operator and the infrastructure maintainer are the most important.

Individual discussions, workshops and articles in the press will be used to initiate and conduct a dialogue.

Additional partners will be welcome to join the project.

Deliverables
- discussions with stakeholders
- holding workshops alongside project meetings

Milestones
- publicising articles in the press
- presenting project outcomes at conferences

I.5 Method of working

Project meetings will be held at regular intervals (say 6 monthly) at which the work will be reviewed. Additional meetings will be held as and when necessary to discuss specific tasks. Leaders will be appointed for specific phases or tasks.

Technical reports will be issued on completion of tasks with a report verification procedure to be agreed. Financial claims to be submitted to the appropriate national authority. The coordinator will verify such claims if necessary on submission of supporting evidence.

I.6 Consortium agreement

The intellectual property (IPR) arising from this co-operation will be placed in the public domain wherever possible. The Consortium Agreement will form the basis of agreement between the partners; a copy is attached. This agreement sets out the general principles covering organisation, working method, rights of use, mutual assistance, information exchange, confidentiality, liability, and terms of agreement, arbitration and substantive law.

I.7 Criteria, risks and rewards

Environmental – reduction in pollution, noise and ground borne vibration.

Social – less freight traffic on roads, encouragement of environmentally friendly vehicles.

Benefits - the results of this project will contribute towards the five crucial objectives for European Transport systems to realise their full potential, to promote the competitiveness of European businesses and to ensure that maximum growth, employment and environmental sustainability are achieved. These objectives are: liberalising market access; ensuring integrated transport systems across Europe; ensuring fair and efficient pricing within and between transport modes; enhancing the social dimension; and ensuring rules are properly implemented. This proposal addresses the fundamental problem of how to measure and allocate the socio-economic environmental cost associated with the use of road and rail transport for the conveyance of goods. This has been most recently identified in the EU white paper on infrastructure charging. The results of this project will depend upon the adoption of policies and the implementation of measures that will encourage vehicles with low environmental impact.

Risks – much of the preparatory work has already been done either in other projects, e.g. DIVINE, and Footprint, or by individual companies and institutions; the partnership has the breadth of knowledge to overcome any unforeseen difficulties either experimentally or theoretically.

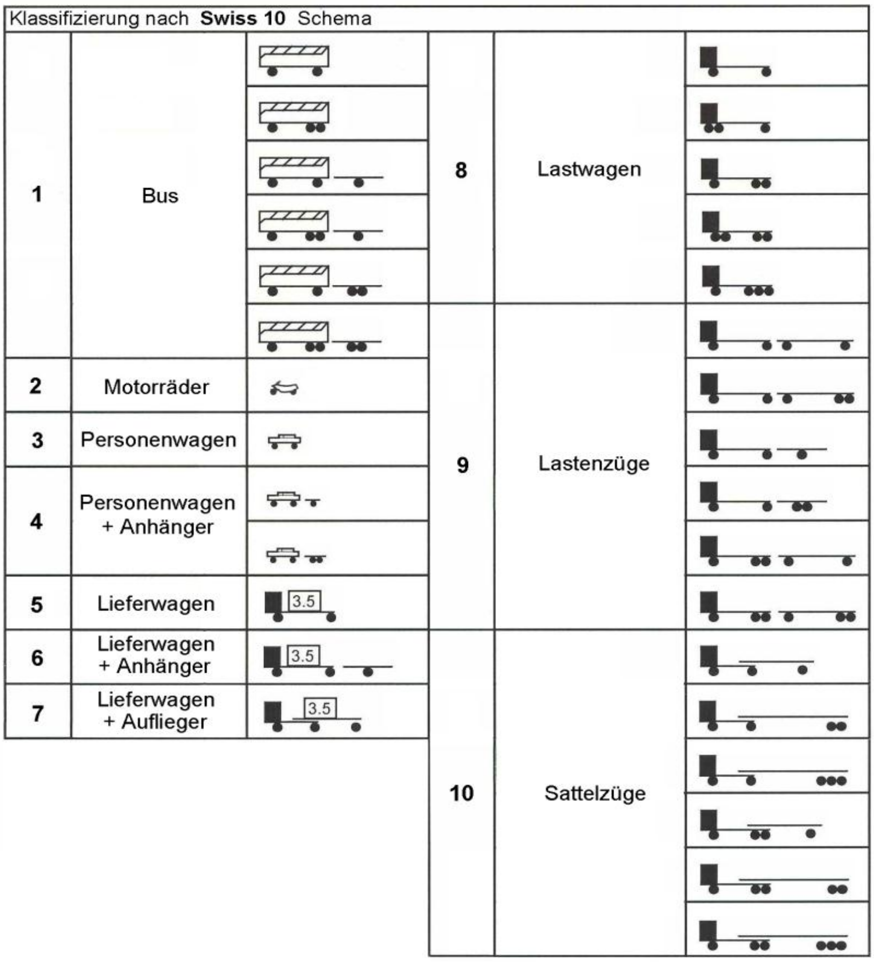
Rewards – to assist the shift in moving freight efficiently, a pricing regime has to be developed and agreed at European level for which the dynamic interaction is the biggest uncertainty; the ultimate goal is to reduce the environmental impact of freight traffic in Europe.

I.8 Timetable

The project period will be 36 months with a starting date to be announced

Task/months		0	12	24	36
I	data	--			
II	analysis	--			
III	criteria	------------------------------			
IV	user charging	-----------------			
V	dissemination	---			

II Swiss10 Vehicle Categories



Abbreviations

Abbreviation	Meaning
ARE	Swiss Federal Office for Spatial Development
ASTRA	Swiss Federal Roads Office
BAFU	Swiss Federal Office for the Environment
DSRC	Dedicated Short Range Communication
EC	European Community
EMPA	Eidgenössische Materialprüfung und Forschungsanstalt, Swiss Federal Laboratories for Materials Science and Technology
EN	European Standards
ETH	Swiss Federal Institute of Technology
EZV	Eidgenössische Zollverwaltung, Federal Customs Administration
FMS	Footprint Monitoring Site
GVM	Gross Vehicle Mass
GVMallowed	Allowed GVM according to the LSVA databank
HDV	Heavy Duty Vehicles
HFV	Heavy Vehicle Fee
ICWIM	International Conference of Weigh in Motion
ISO	International Organization for Standardization
LKW	Lastkraftwagen, heavy vehicles
LSVA	Swiss Heavy Vehicle Fee: Leistungsabhängige Schwerverkehrsabgabe
NOx	Combination of NO and NO_2
OBU	On Board Unit
PM	Particulate Matter
RPLP	redevance sur le trafic des poids lourds
SCR	Selective Catalytic Reduction
UVEK/DATEC/DETEC	Federal Department for the Environment, Transportation, Energy and Communication
VSS	Verein Schweizerische Strassenfachleute
WHO	World Health Organization

Abbreviation	Meaning
WIM	Weigh-in-Motion

References

[EC DIR 1999]	Directive 1999/62/EC of the European parliament and of the council of 17 June 1999 on the charging of heavy goods vehicles for the use of certain infrastructures
[EC Reg. 595/2009]	REGULATION (EC) No 595/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL (18 June 2009) on type-approval of motor vehicles and engines with respect to emissions from heavy duty vehicles (Euro VI) and on access to vehicle repair and maintenance information and amending Regulation (EC) No 715/2007 and Directive 2007/46/EC and repealing Directives 80/1269/EEC, 2005/55/EC and 2005/78/EC
[EN ISO 11819-1]	Acoustics - Measurement of the influence of road surfaces on traffic noise - Part 1: Statistical Pass-By method, (1997)
[EN ISO 11819-1]	EN ISO 11819-1: Acoustics - Measurement of the influence of road surfaces on traffic noise - Part 1: Statistical Pass-By method, 1997
[FEDRO 2012]	Federal Roads Office , 2012. Classification for allowable axle loads and gross vehicle weights. www.admin.ch/ch/d/sr/741_11/a67.html
[Heutschi 2008]	Heutschi, K., (2008). On single event measurements of heavy road vehicles in freely flowing traffic. Acta Acustica united with Acustica 94 (5), pp. 709-714.
[Heutschi 2012]	Heutschi, K, Poulikakos, L.D., Noise Monitoring of Trucks. Euronoise, Prague 2012
[Kienast 2011]	Kienast, H., Partl, M.N. Astra Bericht Nr. 457869/04, WIM Vergleichmessungen, WIM Anlage Oberbuchsiten. 22 Sept 2011.
[Krebs 2012]	Peter Krebs, Ueli Balmer "Fair and Efficient", The distance related Heavy Vehicle Fee (HVF), www.bbt.admin/bundespublikations, Form 812.004.1.e. Also available in German and French. 2012
[Mayer 2009]	Mayer, R., Poulikakos, L., Lees, A. editors: Impacts of vehicle with infrastructure and the environment as measured by Footprint measuring systems, Eureka-Empa Report, October (2009)
[Molinari 2001]	Molinari, M. (2001). Spezifikation für Abnahme und periodische Kontrolle von dynamischen achslastwaagen (WIM). Bundesamt für Strassen. Specification for acceptance periodic calibration of WIM sensors
[Poulikakos 2007]	Poulikakos, L.D. et all. Swiss contribution to Eureka Project Logchain Footprint E!2486. ASTRA/BAFU/KTI report Nr. 1193. Research contract FEDRO 2004/008 (2007).
[Poulikakos 2010]	Poulikakos, L.D. et al. Footprint II- Long Term Pavement Performance and Environmental Monitoring on A1. Research contract FEDRO 2006/020, FOEN 05.0302.PJ/G062-1792 commissioned by Swiss Federal Roads Office (FEDRO) and Swiss Federal Office for the Environment(FOEN) Report Nr 1288 (2010)
[Poulikakos 2010]	Poulikakos, L. D., Heutschi, K., Arraigada, M., Anderegg, P., Soltic, P. (2010). Environmental Footprint of Road Freight: Case Studies from Switzerland. Transport Policy, 17, pp342-348.
[Poulikakos 2012]	Poulikakos, L.D., Heutschi, K., Soltic, P., Environmental Impact of Heavy Vehicles Based on Noise, Axle Load and Gaseous Emissions. International conference on Weigh in Motion, ICWIM6, Dallas, June 2012
[WHO 2012]	(http://www.euro.who.int/en/what-we-do/health-topics/environment-and-health/noise, accessed 22.6.12
[www.Eureka.be]	European cooperative project Eureka, homepage, www.Eureka.be, Project Number E!2486.

Projektabschluss

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
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Eidgenössisches Departement für
Umwelt, Verkehr, Energie und Kommunikation UVEK
Bundesamt für Strassen ASTRA

FORSCHUNG IM STRASSENWESEN DES UVEK

Formular Nr. 3: Projektabschluss

erstellt / geändert am: 01.10.2012 / 20.11.2012

Grunddaten

Projekt-Nr.:	ASTRA 2010/019
Projekttitel:	Environmental Footprint of Heavy Vehicles Phase III: Comparison of Footprint and LSVA Criteria
Enddatum:	Dec 2012

Texte

Zusammenfassung der Projektresultate:

Each month ca. 100'000 valid heavy vehicle data on gross vehicle mass, axle load, noise, Euro emissions category, Swiss 10 vehicle category, declared mass as well as other parameters was collected for March, September and November 2011 at the Footprint monitoring site on the A1 motorway in central Switzerland. From the analysis of this data the following was concluded:
1. The data for the three months are consistent and repeatable, both in the number of vehicles, maxima, minima and median values of the parameters investigated.
2. The vehicle fleet is mostly Swiss category 10, 9 and 8 with engine categories that are mostly Euro-V (ca. 66%), Euro-IV (ca. 10%) and Euro-III (ca. 19%).
3. The majority of vehicles analyzed carry below the allowable in Switzerland of 40 t, however there is small but significant number of vehicles carrying more than 40 t.
4. A comparison of the actual weight carried obtained from weigh in motion (WIM) sensors and the allowable weight according to the LSVA databank showed that less than 0.6% of vehicles have been overloaded. The most number of overloads happened in November with 0.6 % of 105'037 vehicles or 617 vehicles.
5. The mean axle load values for axles 2 was the highest with axle one following closely. Swiss categories 5 and 6 have the lowest axle loads. Buses (Swiss cat 1) have axle loads as high as Swiss 7, 8, 9 and 10.
6. Although the mean at about 5 t axle load in every category is within the allowable limit of 11.5 t for drive axle and 10 t for other axles. There are vehicles within most categories that bypass this limit.
7. Noise measurement results show no additional effect due to winter tires which would be seen between September and November.
8. There was no systematic dependence of the noise emissions on the Euro emis-sions classes for each Swiss 10 category. This shows that the Euro-V emissions classes are not necessarily less noisy. However, the larger vehicles Swiss 9 and 10 are noisier than the other categories. This data indicate that although the ve-hicle fleet is becoming more environmentally friendly with respect to pollutant emissions, it is not more environmentally friendly with respect to noise emissions.
9. Possible correlation between the tire profile depth, tire pressure, engine power and the measured maximum pass-by level, normalized for 80 km/h was investigated. The results using 42 random vehicles from the traffic stream indicate no signifi-cant influence of these parameters on noise generation.
10. With the help of the noise emission model developed, the individual footprint of a vehicle can be estimated from parameters that are known or observable. Such data can be obtained from the vehicle ID and used to calculate a vehicles' noise emissions.
11. Two models are proposed for the calculation of the total footprint of heavy vehi-cles, enabling using a holistic approach taking into account a combination of all their individual footprints. The results show that although the median value of the total footprint in all categories is low, in almost every category there are vehicles with a very high combined footprint.
The results of the project can aid in developing a bonus/malus mechanism based on the "polluter pays principle" in order to reduce the environmental impact of vehicles at source. Due to the important adverse effects of noise on residents and as the measurements this project have shown, newer heavy vehicle models are not necessarily quieter, it is recommended that the LSVA should be revised in order to account for external costs due to traffic based noise as provided by the EC. It is further recommended to use differentiated noise charges to reward the use of quieter vehicles.

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Zielerreichung:

A statistically significant amount of heavy vehicles were evaluated for their combined environmental footprint taking into account dynamic load, noise and pollutant emissions as planned by the project.

Folgerungen und Empfehlungen:

The results of the project can aid in developing a bonus/malus mechanism based on the "polluter pays principle" in order to reduce the environmental impact of vehicles at source. Due to the important adverse effects of noise on residents and as the measurements this project have shown, newer heavy vehicle models are not necessarily quieter, it is recommended that the LSVA should be revised in order to account for external costs due to traffic based noise as provided by the EC. It is further recommended to use differentiated noise charges to reward the use of quieter vehicles.

Publikationen:

1. Heutschi, K, Poulikakos, L.D., Noise Monitoring of Trucks. Euronoise, Prague 2012

2. Poulikakos, L.D., Heutschi, K., Soltic, P., Environmental Impact of Heavy Vehicles Based on Noise, Axle Load and Gaseous Emissions. International conference on Weigh in Motion, ICWIM6, Dallas, June 2012

3. Poulikakos, L.D., Heutschi, K., Soltic, P., A comprehensive definition for green heavy duty vehicles, in production 2012

4. Schlussbericht

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Bundesamt für Strassen ASTRA

FORSCHUNG IM STRASSENWESEN DES UVEK

Formular Nr. 3: Projektabschluss

Beurteilung der Begleitkommission:

Beurteilung:

Die Projektziele sind im Forschungsgesuch wie folgt umschrieben:

„"1.2 Project Goals: ,'The overall goal of this follow up project is to monitor the following parameters of interest: axle load, gross weight, noise and engine type, in order to develop an overall footprint of individual heavy vehicles for a statistically significant sample. The results of the project can aid in developing a bonus/malus mechanism based on the "polluter pays principle" in order to reduce the environmental impact of vehicles at source. Furthermore, the heavy vehicle fee in Switzerland is based on admissible weight (vehicle and load), not actual weight, and it is suspected that some vehicles are overloaded and therefore heavier than allowed and paid for. Therefore one of the goals of this project is to quantify these vehicles."'
Beurteilung: Diese Ziele wurden erreicht.

Zur Umsetzung wurden neun Aufgaben definiert: Task 1: Initial data evaluation WIM+LSVA / Task 2: Installation, operation and evaluation of noise monitoring / Task 3: In-situ measurements of all parameters including tire pressure in cooperation with ASTRA WIM calibration / Task 4: Analysis of calibration vehicles
Task 5: Analysis of sample LSVA+ WIM+ Noise data / Task 6: Policy options / Task 7: Participation in Eureka meetings / Task 8: Identification of sample of environmentally unfriendly vehicles / Task 9: Final Report.
Alle diese Aufgabenbereiche wurden bearbeitet, bei der Task 6 wäre eine Vertiefung in einem Nachfolgeprojekt vorstellbar.
Die Begleitkommission hatte die Möglichkeit die Forschung Footprint III in allen Bearbeitungsschritten zu verfolgen, sie wurde jeweils umfassend und rechtzeitig dokumentiert. Anregungen wurden von der Forschungsstelle entgegengenommen. Die Beurteilung der BK ist positiv.

Umsetzung:

Die Ergebnisse in Footprint III können für die Weiterentwicklung der LSVA benützt werden. Die Details sollen in einem Nachfolgeprojekt definiert werden.

weitergehender Forschungsbedarf:

Auf der europäischen Ebene wurde das Eureka Projekt Ecovehicle (E!7219) eingereicht, es scheint gut zu den schweizerischen Absichten zu passen und es könnte mit einem Footprint Nachfolgeprojekt kombiniert werden.

Mit Gewichtsmessung an fahrenden Strassenfahrzeugen lässt sich das Gesamtgewicht recht verlässlich und genau ermitteln, hingegen fehlen verfügbare Datensätze für die entsprechenden Fahrzeugleergewichte, so dass sich die für den Umweltfussabdruck relevanten Nutzlasten nicht leicht ableiten lassen. Hier besteht eine Datenlücke, die geschlossen werden sollte.

Einfluss auf Normenwerk:

Kein direkter Einfluss.

Der Präsident/die Präsidentin der Begleitkommission:

Name: Gantenbein Vorname: Andreas

Amt, Firma, Institut:

Unterschrift des Präsidenten/der Präsidentin der Begleitkommission:

20.11.2012

Forschung im Strassenwesen des UVEK: Formular 3 Seite 3 / 3

List of Road Research Reports

Forschungsberichte seit 2009

Bericht-Nr.	Projekt Nr.	Titel	Datum
1334	ASTRA 2009/009	Was treibt uns an ? Antriebe und Treibstoffe für die Mobilität von Morgen *Transports de l'avenir ?* *Moteurs et carburants pour la mobilité de demain* *What drives us on ?* *Drives and fuels for the mobility of tomorrow*	2011
1335	VSS 2007/502	Stripping bei lärmmindernden Deckschichten unter Überrollbeanspruchung im labormasstab *Désenrobage des enrobés peu bruyants des couches de roulement sous sollicitation de roulement en laboratoire* *Stripping of Low Noise Surface Courses during Laboratory Scaled Wheel Tracking*	2011
1336	ASTRA 2007/006	SPIN-ALP: Scanning the Potential of Intermodal Transport on Alpine Corridors *SPIN-ALP: Abschätzung des Potentials des Intermodalen Verkehrs auf Alpenkorridoren* *SPIN-ALP: Estimation du potentiel du transport intermodal sur les axes transalpins*	2010
1339	SVI 2005/001	Widerstandsfunktionen für Innerorts-Strassenabschnitte ausserhalb des Einflussbereiches von Knoten *Fonctions de résistance pour des tronçons routiers urbains en dehors de la zone d'influence de carrefours* *Capacity restraint functions for urban road sections not affected by intersection delays*	2010
1325	SVI 2000/557	Indices caractéristiques d'une cité-Vélo. Méthode d'évaluation des politiques cyclables en 8 indices pour les petites et moyennes communes. *Die charakteristischen Indikatoren einer Velostadt. Evaluationsmethode der Velopolitiken anhand von 8 Indikatorgruppen für kleine und mittlere Gemeinden* *Characteristic indices of a Bike City. Method of evaluation of cycling policies in 8 indices for small and medium-sized communes*	2010
1337	ASTRA 2006/015	Development of urban network travel time estimation methodology *Temps de parcours en réseau urbain* *Methodologie für Fahrzeitbewertung in städtischen Strassennetz*	2011

1338	VSS 2006/902	Wirkungsmodelle für fahrzeugseitige Einrichtungen zur Steigerung der Verkehrssicherheit *Modèles d'impact d'équipements de véhicules pour améliorer la sécurité routière* *Modelling of the impact of in-vehicle equipment for the enhancement of traffic safety*	2009
1341	FGU 2007/005	Design aids for the planning of TBM drives in squeezing ground *Entscheidungsgrundlagen und Hilfsmittel für die Planung von TBM-Vortrieben in druckhaftem Gebirge* *Critères de décision et outils pour la planification de l'avancement au tunnelier dans des conditions de roches poussantes*	2011
1343	VSS 2009/903	Basistechnologien für die intermodale Nutzungserfassung im Personenverkehr *Basic technologies for detecting intermodal traveling passengers* *Les technologies de base pour l'enregistrement automatique des usagers de moyens de transports*	2011
1340	SVI 2004/051	Aggressionen im Verkehr *L'aggressivité au volant* *Aggressive Driving*	2011
1344	VSS 2009/709	Initialprojekt für das Forschungspaket "Nutzensteigerung für die Anwender des SIS" *Projet initial pour le paquet de recherche "Augmentation de l'utilité pour les usagers du système d'information de la route"* *Initial project for the research package "Increasing benefits for the users of the road and transport information system"*	2011
1345	SVI 2004/039	Einsatzbereiche verschiedener Verkehrsmittel in Agglomerationen *Application areas of various means of transportation in agglomerations* *Domaine d'application de different moyen de transport dans les agglomérations*	2011
1342	FGU 2005/003	Untersuchungen zur Frostkörperbildung und Frosthebung beim Gefrierverfahren *Investigations of the ice-wall grow and frost heave in artificial ground freezing* *Recherches sur la formation corps gelés et du soulèvement au gel pendant la procédure de congélation*	2010
647	AGB 2004/010	Quality Control and Monitoring of electrically isolated post- tensioning tendons in bridges *Qualitätsprüfung und Überwachung elektrisch isolierter Spannglieder in Brücken* *Contrôle de la qualité et surveillance des câbles de précontrainte isolés électriquement dans les ponts*	2011

1348	VSS 2008/801	Sicherheit bei Parallelführung und Zusammentreffen von Strassen mit der Schiene *Sécurité en cas de tracés rail-route parallèles ou rapprochés* *Safety measures to manage risk of roads meeting or running close to railways*	2011
1349	VSS 2003/205	In-Situ-Abflussversuche zur Untersuchung der Entwässerung von Autobahnen *On-site runoff experiments on roads* *Essai d'écoulements pour l'évacuation des eaux des autoroutes*	2011
1350	VSS 2007/904	IT-Security im Bereich Verkehrstelematik *IT-Security pour la télématique des transports* *IT-Security for Transport and Telematics*	2011
1352	VSS 2008/302	Fussgängerstreifen (Grundlagen) *Passage pour piétons (les bases)* *Pedestrian crossing (basics)*	2011
1346	ASTRA 2007/004	Quantifizierung von Leckagen in Abluftkanälen bei Strassentunneln mit konzentrierter Rauchabsaugung *Quantification of the leakages into exhaust ducts in road tunnels with concentrated exhaust systems* *Quantification des fuites des canaux d'extraction dans des tunnels routiers à extraction concentrée de fumée*	2010
1351	ASTRA 2009/001	Development of a best practice methodology for risk assessment in road tunnels *Entwicklung einer besten Praxis-Methode zur Risikomodellierung für Strassentunnelanlagen* *Développement d'une méthode de meilleures pratiques pour l'analyse des risques dans les tunnels routiers*	2011
1355	FGU 2007/002	Prüfung des Sulfatwiderstandes von Beton nach SIA 262/1, Anhand D: Anwendbarkeit und Relevanz für die Praxis *Essai de résistance aux sulfates selon la norme SIA 262/1, Annexe D: Applicabilité et importance pour la pratique* *Testing sulfate resistance of concrete according to SIA 262/1, appendix D: applicability and relevance for use in practice*	2011
1356	SVI 2007/014	Kooperation an Bahnhöfen und Haltestellen *Coopération dans les gares et arrêts* *Coopération at railway stations and stops*	2011
1362	SVI 2004/012	Aktivitätenorientierte Analyse des Neuverkehrs Activity oriented analysis of induced travel demand Analyse orientée aux acitivtés du trafic induit	2012
1361	SVI 2004/043	Innovative Ansätze der Parkraukmbewirtschaftung Approches innovantes de la gestion du stationnement Innovative approaches to parking management	2012
1357	SVI 2007/007	Unaufmerksamkeit und Ablenkung: Was macht der Mensch am Steuer? Driver Inattention and Distraction as Cause of Accident: How do Drivers Behave in Cars? L'inattention et la distraction: comment se comportent les gens au volant?	2012