FALCON IV: VALIDATION OF SMART INFRASTRUCTURE ACCESS POLICY

K. Kural, MEng., MSc, Senior Researcher at HAN University of Applied Sciences, PhD student at TU/e.

F. Schmidt, MSc, PhD, has been working for Ifsttar (former LCPC) since 2009, as a research engineer in bridge engineering.

Sigurdur Erlingsson Ph.D. in Civil Engineering (1993) and professor at VTI and UoI.

Carl Van Geem Doctor in technical sciences (1996), Senior Researcher at the Belgian Road Research Centre.

I. Vierth, MSc. Senior Researcher VTI specializing in transport research.

D. Cebon, Professor of Mechanical Engineering at the University of Cambridge and Director of SRF.

A. Lobig, Research associate at the German Aerospace Center, specializing at innovations in rail and road freight transport.

G. Liedtke, Head of the Department of Commercial Transport at the German Aerospace Center.

Abstract

This paper describes part of the results of the ongoing CEDR-funded “FALCON” project, which aims to introduce a step improvement in road freight transport efficiency in Europe through the definition of a new performance-oriented legislative framework, and thus ensuring a proper match between vehicles and the infrastructure. A Smart Infrastructure Access Policy (SIAP) is being developed as the primary method of regulation, in which policy explicitly specifies the performance level required from the road freight vehicle with respect to safety, maneuverability, infrastructure loading, and environmental impact, while considering national topologies and operational conditions. The vehicle combinations, which are expected to operate within SIAP are in this paper validated against the number of criteria being, the infrastructure damage and deterioration, congestions, safety, and the effect on the modal split on national and cross border basis.

Keywords: **S**tandards and regulations, Smart Infrastructure Access Policy, Commercial Road Vehicle Technology

1. Introduction

The transport sector currently contributes to about a quarter of CO_2 emissions in the EU and is the only sector with an increasing trend according to European Environment Agency, 2017. One of the drivers behind this trend is the growing demand for freight transport resulting from the globalization. The road transport in the EU is the dominant mode that accounts for about 75% share of goods transport on land today, and is projected to increase in the forthcoming decades. It is expected that by 2030 the total freight transport volumes will grow further by approximately 38% with respect to 2011, while distributed over the transport modes, see Figure 1. This represents an increasing load on existing European road infrastructure, which cannot accommodate an additional transport demand without negative effects (damage on infrastructure, congestion, safety issues, …). Expanding the capacity of current European road infrastructure by nearly 40% is not viable within next decade due to the enormous financial investments required and knowing that even road maintenance is already a financial difficulty, carefully managed. Therefore, the risk of negative consequences as severe traffic congestions or increased costs for infrastructure maintenance appears to be in the future unavoidable, when using current legislative framework that allows very limited design of commercial vehicle combinations.

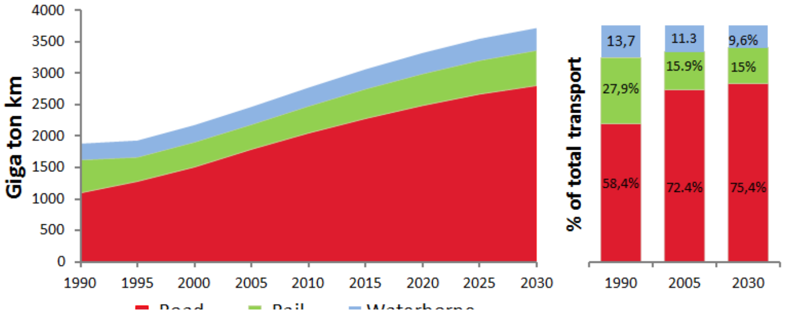


Figure 1. Transport demand prognosis, European Commission, 2011

Thus, the increasing demand for transport and mobility together with the congestion problem explicitly calls for intrinsically more efficient road transport system. As proved by practice in number of outside Europe, a Smart Infrastructure Access Policy (SIAP) and Performance Based Standards (PBS), have significant potential to optimize the use of limited infrastructure, while ensuring infrastructure protection, vehicle safety and numerous societal benefits.

This paper describes interim results of the ongoing CEDR-funded “FALCON” project, which aims to introduce a step improvement in transport efficiency through the definition of a new tailor-made performance-oriented legislative framework for European road freight transport. SIAP is being developed as the primary method of regulation, in which policy explicitly specifies the performance level required from the road freight vehicles with respect to safety, maneuverability, infrastructure loading, and environmental impact, while considering national topologies and operational conditions. This method is fundamentally different to the prescriptive approach, which mandates mass and dimension limits of vehicles and will be ensuring a proper match between vehicles and the infrastructure. This paper emphasizes on the validation of SIAP in number of key aspects, such as safety, congestion, infrastructure deterioration, but also investigates what the impact will be on the modal split if the SIAP is ratified.

2. Research approach

The validation of SIAP is based on previously achieved milestones within FALCON|CEDR project. The results presented also in Schmidt, 2018, and de Saxe, 2018, include:

- the definition of representative vehicle fleet that is based on vehicle combinations, which have good intermodal potential, and fit the logistic needs of selected EU-countries,
- the definition of the representative EU-road network components including various types of pavement structures, bridges, tunnels, and road geometry,
- through review of current EU policy related to the vehicle operation and infrastructure design principles,
- SIAP definition.

This input will be used to validate the SIAP in number of key areas including, safety, infrastructure damage considering both pavement and bridges, modal split, and the congestions.

3. Validation of Smart Infrastructure Access Policy

3.1 Safety

Method at a glance

To validate the safety, initially, categories of critical infrastructure segments are identified together with the Key Performance Indicators (KPI) for the vehicle combinations to quantify and ensure their nominal operation on the infrastructure segments. Furthermore, the framework to define the envelopes of the road classes for representative fleet is established. Subsequently, a set of varying operational conditions will be defined covering both the characteristics of the infrastructure and the current operational state of the vehicle combination. At next the, safe vehicle operation is verified in terms of defined KPI's through simulation of varying input conditions and states to the validated multibody dynamical models in a spirit of Monte Carlo approach. It is done on infrastructure segments that has been already paired with given vehicle combination. Resulting histograms quantify the safety performance of the vehicle combination.

Critical Infrastructure segments, KPI's and Road Classes

A critical infrastructure segments have been identified in which the vehicle has a higher chance of safety failures. Ensuring the vehicle operates nominally on these critical segments is considered sufficient to infer the safe operation in less critical situations.

The identified segments are:

1. Highway Exits ensuring the transition from a highway to a lower level road. This involves a curved exit from the highway which causes high levels of lateral acceleration and could possibly lead to rollover, or jack-knifing. Due to the off tracking, there exists a chance that the vehicle leaves its lane while negotiating low radius exits.

2.Single Lane Roundabouts (R<30m): Due to the off tracking, there exists a chance that the vehicle leaves dedicated space while negotiating low radius exits resulting in damage.

3.Multi Lane Roundabout (R>30m): These roundabouts are of larger radius than the single lane roundabouts. However, the existence of multiple lanes in the circular carriageway reduces the amount of space available a vehicle combination and due to increase nominal speed the risk of rollover is also present.

Considering rollover, jack-knifing, departure from the driving lane/space, and the inability to maintain the longitudinal speed as main failure modes, a set of KPI in terms of vehicle combination dynamical states in Table 1., has been defined.

Table 1 – KPIs | Vehicle Safety related states

Key Performance Indicator (KPI)	**Value**	**Units**
Lateral Acceleration	< Static Rollover Threshold of vehicle (3.5-4)	(m/s^2)
Articulation angle	< 30 (for high speeds above 40 km/h)	(deg)
Distance of outermost points to lane boundary	>0	(m)
Minimum Longitudinal Velocity	30	(km/h)

Safety assessment

Based on catalogue of representative infrastructure defined in Schmidt, (2018), two classes of input parameters for the safety assessment can be identified related the infrastructure design characteristics and the operational state of the vehicle combinations, both listed below.

Parameters Related to Infrastructure:	**Parameters Related to Operational State:**
Radius of curvature	Vehicle Load Density
Road Longitudinal Slope	Road Frictional Condition
Road Cross Slope	

As for the numerical values and the probability distribution per variable we refer to FALCON final report to be published by end of 2018. Given the varying input conditions and the pairing between the vehicle groups, defined in de Saxe, 2018, and the infrastructure levels, the Monte Carlo analysis was done to analyze all input permutations in terms of defined KPI's. The output is represented by the histogram that is elaborated per vehicle, per KPI, and identified critical infrastructure segment. An example is given in Figure 2. for vehicle combination Tractor - Link Trailer - Link Trailer - Semitrailer at highway exit. The histogram gives the confidence that lateral acceleration, being one of KPI, can be met even during the varying operational conditions.

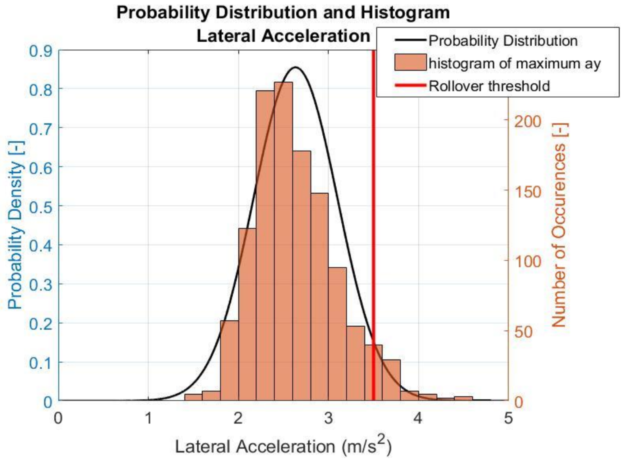


Figure 2. Histogram of lateral acceleration belonging to vehicle combination Tractor-Link Trailer-Link Trailer-Semitrailer at highway exit scenario.

Complete set of dynamical simulations done in spirit of Monte Carlo approach governed the definition of the road classes given in Table 2. Through approximately 1500 simulations done per vehicle combination it is ensured a good fit between the vehicle combinations and the critical infrastructure segments by satisfying all KPI's.

Table 2 – Initial Draft of Road Classes

Road Level	Road Description	Lane Width (straight Road)	Lane Width (in Exit)	Radius of Exit	Long. slope	Minimum Radius of Single Lane Roundabout		Minimum Radius of Multi Lane Roundabout		Vehicles Permitted
						Outer	Inner	Outer	Inner	
3	Motorways	3.5m	(3.5+50/R) m	70m – 150m	±4%	25m	17m	Multi Lane roundabouts not permitted		1.1, 1.2, 1.3, 1.4, 2.1, 2.2, 2.3, 3.1, 3.2, 3.3, 3.4, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 5.1, 5.2, 5.3, 5.4, 6.1, 6.2, 6.3, 6.4, 6.5
2	Inter Urban Arterial Main Express Roads	3.25m	(3.25+50/R) m	40m – 150m	±6%	14m	2m	30m	24.7m	1.1, 1.2, 1.3, 1.4, 2.1, 2.2, 2.3, 3.1, 3.2, 3.4, 4.3, 4.4, 4.7
1	General Access	2.75m	(2.75+50/R) m	50m – 150m	±10%	12.5m	5.3m	30m	24.7m	1.1, 1.2, 1.3, 1.4

Besides the specification in Table 2., also the characteristics such as annual daily traffic, and accident history should, or road roughness and healthiness should be considered as criteria to make a paring between a vehicle combination and the infrastructure segments.

3.2 Modal Split

Previous work within the FALCON|CEDR project defined a representative vehicle fleet with vehicle combinations, which have promising intermodal potential and fit the logistic needs of selected EU-countries. High capacity vehicles may affect energy savings and lead to reduced emissions of transport. However, as they also contribute to a reduction of transport costs, a modal shift towards road freight can be expected. This may outweigh the positive effect on the environment. The objective of this section is to give an estimate of this impact.

Method at a glance

The FALCON project developed 27 different vehicle concepts, which contain reference vehicles and different kinds of high capacity vehicles. The estimation of modal shift effects requires information about the amount of transports, which are suitable to be replaced by the new vehicle concepts. Hence, in a first step, the theoretical substitution potential of selected vehicle concepts must be determined. As a result, the market share of the respective vehicle concept is derived. This work is done based on a DLR-internal data set about the usage of vehicles registered in Germany in the year 2002. The substitution potential serves as an input for the estimation of changes in modal split share for rail freight. This is done in the second step. These changes are estimated using direct cost elasticities. Some assumptions are necessary regarding e.g. transport prices for rail and road, average distances or transport cost reduction due to new vehicle concepts.

Substitution potential

The developed vehicle concepts differ in several aspects, e.g. type of loading unit, number of axles, volumetric capacity or operational gross vehicle weight. For the substitution potential of new vehicle concepts, the most important variables from a logistics perspective are transport volume (m^3) and payload (tons). For the present analysis, the vehicle concepts described in table 1 were defined.

In the analysis, all transported goods in the data set were considered (e.g. palletized or packaged goods), except for bulk cargo. Typically, bulk cargo is not transported on the road and therefore the vehicle concepts are mainly developed with general cargo in mind. Furthermore, the transport costs (€/tkm) differ depending on transport distance. Concerning this aspect, the following two distance classes were considered: national distance over 200 km up to 500 km and international distance over 500 km. A vehicle is identified as substitutable, if all of the following conditions apply:

- Vehicle has a payload of 23 tons or higher
- Vehicle has a high volume-utilization of at least 90%
- Increased transport volume (loading meters, pallet space) will not lead to a violation of the weight limit

The results are depicted in Table 3. It becomes apparent, that both vehicle types have comparable shares in both national and international distances. For national distances approximately 24 % of the vehicles registered in Germany in 2002 fulfil the requested conditions and can theoretically be replaced by the vehicle type 1 and 2. For international distances about 35 % of the vehicles can be replaced by vehicle type 1 and 2. This theoretical substitution potential doesn’t include vehicles, where the weight limit is reached but the volume utilization is less than 90%. Therefore, the potential could be even higher.

Table 3 – Substitution potential of selected vehicle concepts

	Reference Vehicle	**Vehicle Type 1**	**Vehicle Type 2**
Volume [m³]	80	117.5	143.7
Max. Payload [tons]	27	39.6	48.5
% vehicle on national distance 201 – 500 km	-	24.4%	24.3%
% vehicle on international distance > 500 km	-	34.5 %	34.5%

Modal Shift effects

The changes of the modal split can be estimated for the four different rail freight segments: Maritime combined transport, continental combined transport, wagon load transport and block train transport. The estimations are based on the use of elasticities, i.e. the change in demand of rail freight due to changes in transport costs of road freight. For example, an elasticity of -2 means, that a reduction of costs of road freight of 1% results in a reduction of demand for rail services of 2 %. Further aspects like rail and road freight transport pricing, average distance and transport performance (tkm) in the different segments are also considered for the estimation of the modal shift effect. Thus, the following assumptions were made:

- The cost reduction due to new vehicle concepts compared to a conventional semitrailer may differ between the vehicle concepts. Kraaijenhagen et al. (2014) calculated the total cost of ownership for different existing longer and heavier vehicles. The cost reduction potential varied between 16 and 27 %. Simplifying for this analysis, the cost reduction is fixed at 20 %.
- Prices for rail and road freight transport depend on transport distance (national/international) and the respective segments (maritime combined transport, continental combined transport, wagon load transport and block train transport) (Sonntag, Liedtke 2015)
- Market share of the vehicle concept for national and international distances (substitution potential)
- Average national and international distances in each transport segment (Sonntag, Liedtke 2015)
- Discontinuation of rail freight services due to the introduction of new vehicle concepts and further loss of market share (erosion effects)

The results of the modal shift analysis of vehicle type 1 are summarized in Table 4. The results show, that the wagon load service is strongly affected by the introduction of the vehicle type 1. The transport cost reduction for road freight transport strongly affects wagon load services, leading to a cessation of said services. This induces a further loss of market share of the wagon load services and leads to a reduction of wagon load services by about 22 %. In contrast to that, block trains seem to be resistant to the described effect. This is since the block trains still focus on bulk transport, which is not considered here. The maritime and continental combined transports have a moderate reduction by 11 % and 12 %. The downstream erosion effects are less intense compared to the wagon load service, as the service frequency is higher, in general. The analysis of vehicle type 2 yielded similar results, which are therefore not described below.

Table 4 – Modal Shift effects according to the new vehicle concepts

Rail Freight Segments	**Vehicle Type 1**
Maritime Combined Transport	-11.2 %
Continental Combined Transport	-12.0 %
Wagon load	-22.4 %
Block train	-2.4 %

The presented analyses identified a theoretical substitution potential of high capacity vehicles with a volume up to 143.7 m³ and a maximum payload of 48.5 tons. Thus, on national distances about 24 % of the registered vehicles in Germany in 2002 can be replaced by both vehicle types. On international distances, about 35 % of the vehicles can theoretically be replaced. Whether the full potential will be tapped depends on further aspects, e.g. the real reduction of initial and variable costs, costs of retrofitting from rail to road service or the usability of the vehicle concepts for the individual requirements. Nonetheless, the introduction of high capacity vehicles causes a reduction of the demand for rail freight services between 2 % and 22 % for the individual rail freight segments. The wagon load service may go out of business due to the considered vehicle concepts. In this case the downstream cessation of rail freight services is of high relevance and leads to further reduction of modal split share.

To diminish these effects, a closer multimodal cooperation between rail and road services should be achieved, as opposed to a competition between both transport modes. A multimodal transport system requires: Highly automated technologies for the transshipment of general cargo between road and rail, flexible container units suitable for road and rail, competitive rail freight services and suitable rail freight infrastructure. The transport policy should permit new vehicle concepts on the road and simultaneously strengthen the rail freight to prevent further loss of rail freight market share.

Cross-border Scenario

The impacts of the use of high capacity vehicle for national transports in Sweden have been simulated with help of the Swedish national freight model Samgods, see Vierth et al. (2008). Between 1996 and 2015 the maximum truck dimensions were 60 tonnes and 25.25 meters in Sweden compared to 40 tonnes and 18.75 meters in most other European countries. Sweden extended the maximum weight to 64 tonnes in 2016 (in place) and 74 tonnes in 2018 (not yet implemented). The annual volume of CO2 emissions is calculated to increase by about 240,000 tonnes in the whole of Sweden (correspondingly six percent) if no modal shifts are assumed and to decrease by about 100,000 tonnes (correspondingly 2.5 percent) if modal shifts are assumed. The shift is mainly from road to rail.

Vierth (2014) applied an updated version of the Samgods model to study the impacts of the permission of longer trucks (maximum 25.25 meters instead of 18.75 meters) and longer freight trains one by one and in combination in a cross-border long-distance corridor between central Sweden and the Ruhr area in Germany. The modal shifts addressing longer trucks in the cross-border corridor are calculated to be larger and relate to both rail and sea as, in analysis of the impact of smaller truck dimensions for national transports in Sweden Vierth et al. (2008). In the longer truck scenario, the CO2-emissions caused from trucks that drive on or towards the cross-border corridor (inside and outside Sweden) are calculated increase by 16,000 tonnes per year. The outcome of these two studies indicate that the conditions for the permission of High Capacity Vehicles and the operation of SIAP as well as the potential impacts on the modal split and CO2-emissions differ between national and cross-border freight transports. Other external effects as well as public and private investment costs need to be considered as well and shall be investigated in the future.

3.3 Infrastructure Damage and deterioration

Method at a glance

For the road infrastructure damage assessment, a four representative pavement structures were selected described in Schmidt, (2018), being as follows:

- thick bituminous
- flexible
- semi-rigid
- concrete pavement.

The structures were tested for the deterioration while considering the axle loads impact from six of the vehicles of the representative fleet given in de Saxe, 2018, two of which are currently in use on European roads. The loading condition of the axles comply with representative loading defined also in, de Saxe, (2018). Figure 3. shows a few examples of the load distribution at axles of the combination. Combination 2.1 consisting of rigid truck and central axle trailer, currently in use in Europe, has 1 single axle, 1 tandem axle and 1 tridem axle group. Combination 6.1, consisting of rigid truck, dolly, link trailer and semitrailer has 1 single axle, 3 tandem axle groups and 1 tridem axle group.

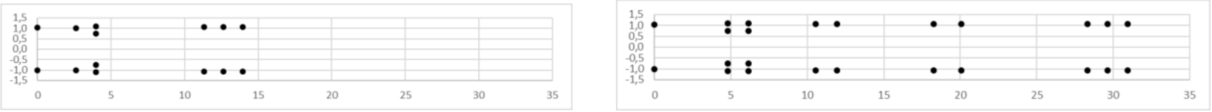
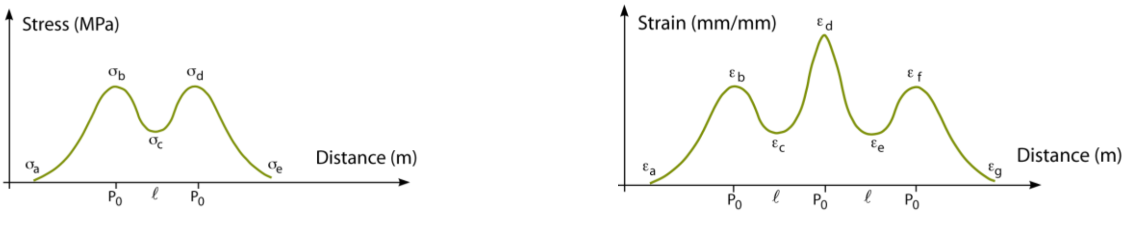


Figure 3: Axle distribution for Combination 2.1 (left) and Combination 6.1 (right)



Tensile stresses at the bottom of the pavement (tandem axle)

Strains at the bottom of the pavement (tridem axle)

Figure 4: Relaxation of stresses and strains under tandem and tridem axle groups

Strain-stress response of the vehicle axle loads were computed using the software Alizé-LCPC, where a multi-layer linear elastic model is used for the representation of the pavements. Variations in temperature between different seasons and extreme climate conditions were not considered at this phase, however will be addressed as well later. The trucks are modeled as a succession of axle groups (single, tandem or tridem axles). The impact of the vehicle configurations was then compared. The impact is expressed as “aggressiveness”, defined as follows.

From the strains ε_i or stresses σ_i computed with Alizé-LCPC for each of the individual axles within each of the axle groups of a truck, we determine the number of repetitions $N_{gr,i}$ of the loads applied by each of the axle groups before breaking of the pavement. For this, two different fatigue laws were used: one for the thick-bituminous and flexible pavements, and one for the semi-rigid and concrete pavements.

For the load applied by a reference axle (a 5kN single wheel of a 10kN reference axle) the strains or stresses computed with Alizé-LCPC give rise to the number of repetitions N_{ref} of the load applied by the reference axle before breaking of the pavement. This number is obtained from the application of the appropriate fatigue law. For an axle group ***gr*** that consists of 1 single axle, the number of repetitions $N_{gr,i}$ is also directly obtained by the application of the appropriate fatigue law. For tandem and tridem axle groups the number of repetitions $N_{gr,i}$ is obtained by the use of Miner's rule, combining the effects of all the axles within the axle group. For this, we compute the maximum number of repetitions of the loads applied by each of the axles within the axle group before breaking of the pavement, whereby we take the partial relaxation of strain or stress between the passages of the consecutive axles in the axle group into account. Figure 4. illustrates the relaxation principle.

We define the aggressiveness $A_{gr,i}$ of the i-th axle group as the ratio between N_{ref} and $N_{gr,i}$:

$$A_{gr,i} = \frac{N_{ref}}{N_{gr,i}} \qquad (1)$$

We then define the aggressiveness A of a vehicle combination *T* as the sum of the aggressiveness's $A_{gr,i}$ of all ***m*** axle groups of the combination:

$$A(T) = \sum_{i=1}^{m} A_{gr,i} \qquad (2)$$

Subsequently, other indicators of aggressiveness are defined. To take the internal volume V for cargo for each of the vehicles into account, we divide the aggressiveness A by V for each combination *T*:

$$AperV(T) = \frac{A(T)}{V(T)} \qquad (3)$$

Analogously, the differences in GCM between the vehicle combinations are acknowledged by following formula:

$$AperGCM(T) = \frac{A(T)}{GCM(T)} \qquad (4)$$

Considering the combination 1.3 (Tractor Semitrailer) the most frequently used in Europe, the aggressiveness's defined above for vehicles from groups 2-6, can be normalized with the values obtained for this vehicle combination as e.g. for AperGCM:

$$AperGCMrel1.3(T) = \frac{AperGCM(T)}{AperGCM(1.3)} \qquad (5)$$

Next, we denote Mc(T) for the cargo mass transported by truck T, that be employed to obtain the ratio R(T) between Mc(T) and GCM(T) of truck T indicating the net share of the cargo on complete vehicle combination weight:

$$R(T) = \frac{Mc(T)}{GCM(T)} \qquad (6)$$

Finally, we define last indicator of aggressiveness as follows:

$$ArelCargo(T) = \frac{AperGCMrel1.3(T)}{R(T)} \qquad (7)$$

Since the absolute values of “aggressiveness” depend on the pavement type, these indicators cannot be compared cross-pavement type. For each of the pavement types, we computed the values of A for each of the 6 trucks and then ordered them from smallest to largest value. In this way, each truck gets a ranking (1 to 6) per pavement type and per aggressiveness indicator. Then we computed for each truck the average of its rankings. For “aggressiveness A” this is represented by the blue blocks in the diagram in Figure 5. The same is done for respectively AperGCM, AperV and ArelCargo, in red, green, and purple, respectively. The last block in the block diagram is the average of the values for each of the other blocks for that truck.

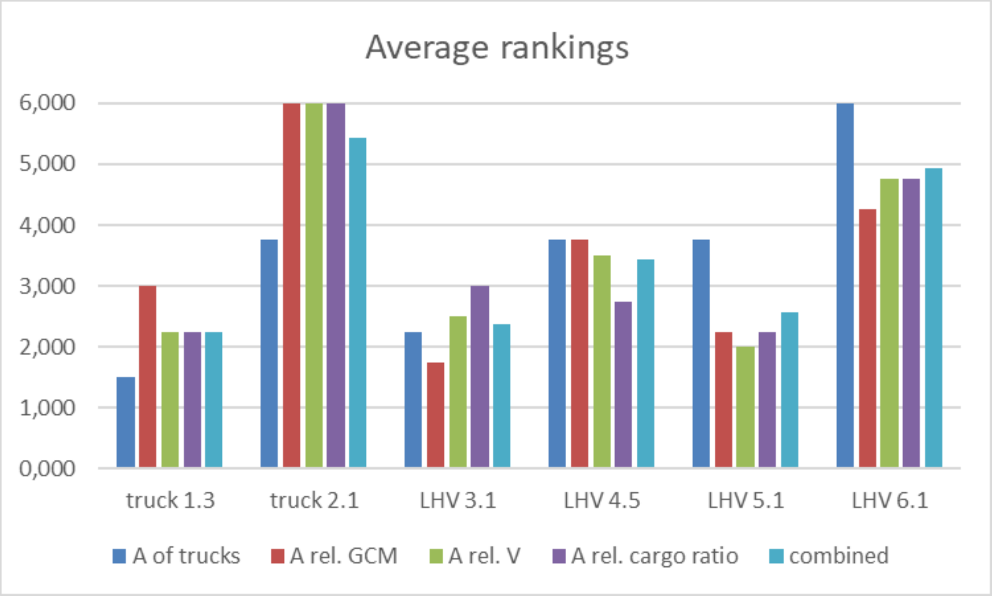


Figure 5: relative rankings of trucks in function of different aggressiveness indicators

With the assumptions we made for the computations, it can be observed from the Figure 3., that raking of vehicle combination 2.1 reaches the highest values, indicating the most significant impact on selected pavement structures in terms of introduced aggressiveness measures. Given the fact the vehicle combination 2.1 fully comply with current EU directive 96/53, it is apparent that vehicles from groups 3-6 does not represent a potential threat for the current infrastructure.

Besides the pavement related calculations, the impact on the bridges is also addressed. The assessment of the impact of vehicles on the European bridge stock is done for all the vehicles whose parameters have been gathered from the representative fleet, for the bridges listed in the infrastructure catalogue, and by using the European design criteria, both listed in Schmidt, 2018. For each of these vehicles, the weights and dimensions are known; therefore, computing the effect induced by each category is possible by calculating the convolution of the axles loads with the influence line of the considered effect. These influence lines are theoretical ones, as it has been done during the background works of Eurocode, EN 1991.

At first, the aggressiveness of all vehicles from the representative fleet have been compared to the aggressiveness of vehicle 2.1, which is considered as the reference vehicle. Hence in Figure 66., for each vehicle (designated by column and consistent with numbering of used in, de Saxe 2018), the ratio of the damaging effect of this vehicle to the same damaging effect of vehicle 2.1 is given, for all 25 chosen effects (and therefore the 25 colored dots).

It can be observed that for some effects, entire representative fleet displays similar aggressiveness (for example effect 4 -E4, orange dot-) whereas other effects enable to distinguish the differences per vehicle in terms of aggressiveness more considerably. This highlights the need choose properly various influences lines, and therefore the critical elements in specific bridges structures. Moreover, from a vehicle perspective, it can be seen that combination 2.1 is not the least aggressive vehicle in the fleet: each other vehicle exhibits ratios of effects higher and lower than 1, which means that there exist structural elements which are less damaged and more damaged by other vehicles than vehicle 2.1. This is the case even for the very long high-capacity vehicles (columns 19 to 27).

At this stage, it should be emphasized that HCVs allow to carry more weight and volume of the cargo than the conventional vehicles in group 1 and 2 of the fleet. Therefore, the calculated effects have been normalized by the volume and the weight of transported cargo using the representative loading conditions, see Table 5. for an excerpt of the results. Herewith, we can classify the vehicles depending on their effects: if all their effects are higher than those of vehicle 2.1, they will be considered as more aggressive (coloured by red, in Table 5). In the opposite case, they will be classified as less-damaging vehicles (marked as green). When all the effects are of similar value, the vehicle will be marked in yellow.

Resulting ranking proved that, assessed HCVs are -generally- less aggressive than the reference vehicle (or vehicles globally in use, like 1.3). Moreover, it should be noted that the classification coming the normalization by volume/length is not the same as the one being made with the mass-normalized values. Therefore, a more precise classification between the damaging effect of the various vehicles could be done, but decisions should be made (type of normalization, threshold of the meaning of higher/similar/lower, type of structures and effects to be analyzed, …) mainly on national level.

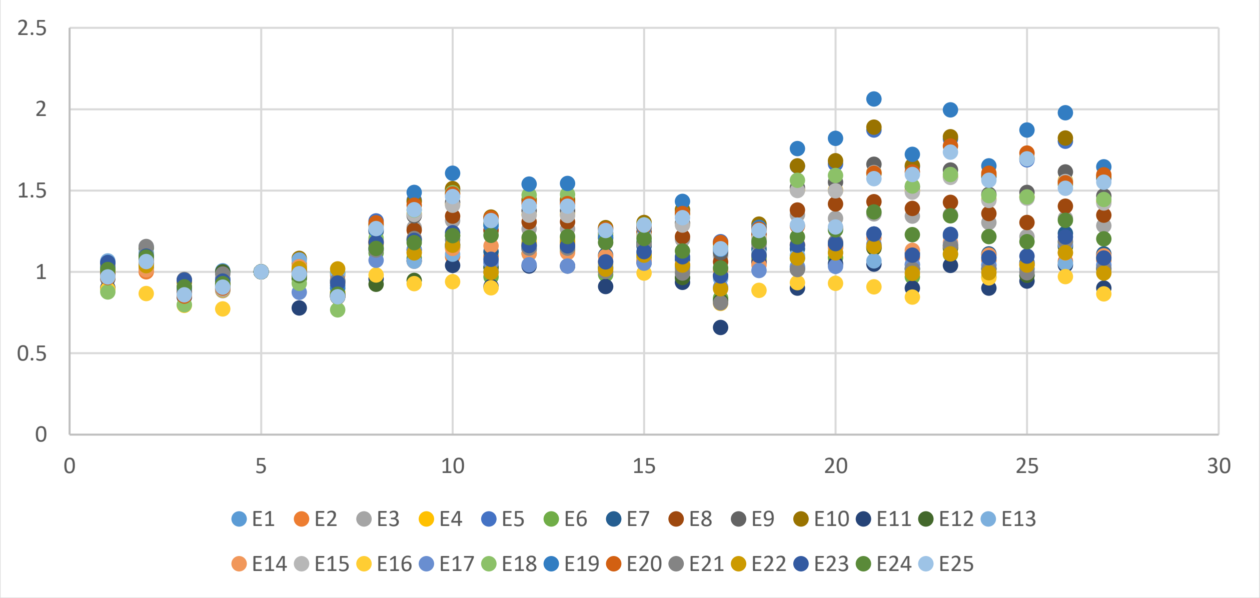


Figure 6: Ratio of effect of vehicles with effect of reference vehicle (2.1) on vertical axis, vehicle type, according to de Saxe, 2018, on horizontal axis.

Table 5: Comparison of damaging effect of vehicles, compared to the reference vehicle 2.1.

Structure	Normalization with length[†]	Normalization with mass[†]
1	🟥 4.5, 5.1, 6.1 🟨 2.1, 3.1 🟩 1.3	🟥 4.5, 5.1, 6.1 🟨 2.1, 3.1 🟩 1.3
2	🟥 4.5, 5.1, 6.1 🟨 1.3, 2.1, 3.1	🟥 4.5, 5.1, 6.1 🟥 3.1 🟨 1.3, 2.1
3	🟥 4.5, 5.1, 6.1 🟨 1.3, 2.1, 3.1	🟥 4.5, 5.1, 6.1 🟨 1.3, 2.1, 3.1
4	🟥 4.5, 5.1, 6.1 🟨 1.3, 2.1 🟩 3.1	🟥 4.5, 5.1, 6.1 🟨 1.3, 2.1, 3.1
5	🟥 4.5 🟨 1.3, 2.1, 5.1, 6.1 🟩 3.1	🟥 4.5, 5.1, 6.1 🟨 1.3, 2.1, 3.1
6	🟥 4.5, 5.1, 6.1 🟥 3.1 🟨 1.3, 2.1	🟥 5.1, 6.1 🟥 3.1, 4.5 🟨 1.3, 2.1
7	🟥 4.5, 5.1, 6.1 🟥 3.1 🟨 1.3, 2.1	🟥 3.1, 4.5, 5.1, 6.1 🟨 1.3, 2.1
8	🟥 4.5, 5.1, 6.1 🟨 1.3, 2.1, 3.1	🟥 6.1 🟥 5.1 🟨 1.3, 2.1, 3.1, 4.5
9	🟥 4.5 🟨 1.3, 2.1, 3.1, 5.1, 6.1	🟥 4.5, 5.1, 6.1 🟨 1.3, 2.1, 3.1
10	🟥 5.1 🟨 1.3, 2.1, 4.5, 6.1 🟩 3.1	🟥 5.1 🟥 6.1 🟨 1.3, 2.1, 3.1, 4.5

[†] Vehicles more damaging than vehicle 2.1 are in red, vehicles damaging approximately in the same amount than vehicle 2.1 are in yellow, and vehicles less damaging are in green)

3.4 Congestions

Using the model introduced in Morrison (2013), the simulations will be performed to investigate the effects on motorway congestion and fuel consumption. Baseline scenarios will be simulated with the traffic flow composed of passenger cars, light goods vehicles and standard HCVs. A proportion of conventional articulated HCVs is then replaced by a smaller number of HCVs recruited from the representative fleet, carrying the same total payload mass and volume, the availability of the results is anticipated in August 2018.

4. Conclusion and Discussion

Results presented in this paper provided an insight related to the implementation of vehicles from FALCON representative fleet, and operating within SIAP, into a practice. Number of aspects is considered being the safety, infrastructure damage and modal split. It can be concluded that none of newly proposed vehicles does represent load to the infrastructure (represented by both pavement and bridges), which would exceed the impact caused by reference vehicles from group 1-2, currently operating within European council directive 96/53/EC. In fact, some vehicles from group 3-6 are more infrastructure friendly then reference vehicles when the impact is normalized by the vehicle combination capacity. As for the safety, an approach has been outlined how the operation of arbitrary vehicle combination may be assessed in terms established safety related KPI's that guarantees the nominal operation on critical infrastructure segments. Considering the results of the modal split, the introduction of multimodal HCV's operating in SIAP, will be most denotable for the wagon load, and substantially less significant for or maritime combined transport or block trains. In the future, it is expected that introduction of SIAP-like frameworks on EU level will positively influence the logistic sector through more CO_2 efficient multimodal transport, and it will also allow to deal with gradually increasing transport demand on currently existing roads through good matchmaking between the vehicles and the infrastructure.

5. References

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