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INFLUENCE OF THE BRAKING SYSTEM THAT IS CONTRARY TO LEGISLATION ON BREAKING CHARACTERISTICS OF PASSENGER CAR

Abstract. There are also the vehicles among the other vehicles in road traffic that have been modified without being authorised by their producer. These also include modifications such as structural modifications in the vehicle break system. Besides a brake system of road motor vehicles is one of the main factors influencing the active safety of vehicles. The design of the brake system, its technical condition and additional intervention in its construction may have a positive as well as negative impact on the braking distance length and the value of the mean braking deceleration achieved. The paper focuses on the influence of the brake disc diameter of the front axle on the achieved value of the mean braking deceleration and the braking distance length, while the braking system has been modified for several times without being approved by car manufacturer. The introductory part of the paper describes the braking distance sections and it also explains the term of mean braking deceleration. The following part of the paper deals with the measurement methodology, measuring equipment and the vehicle used during the measurements as well as procedures employed. The results obtained from the measurements are processed and presented in tables and also in graphs for greater clarity. The final part of the paper summarizes and evaluates the measured results. The importance of the paper lies in quantification of the influence of brake discs with different diameters on the vehicle active safety in the case of a particular vehicle.
Keywords: active safety, brake system, brake disc, braking distance

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Introduction

If a vehicle cannot move, this represents a problem. However, if it is already in motion and it cannot brake, the problem is much greater. The brake system fundamentally affects the level of vehicle active safety (Lazeet et al. 2016; Oyetubo, Afolabi, Ohida 2018). The design and technical condition of the brake system (Lagel et al. 2016) together with tyres (Selig et al. 2012) and other factors such as road surface (Metz 2016; Paraskevadakis et al. 2016) and slope influence (Mikušová 2017) the vehicle directional stability during braking and the braking distance length (Rievaj et al. 2013). The braking distance represents the distance which is travelled by a vehicle from the moment of pressing the brake pedal till the vehicle stops or till the moment when the driver stops applying the brake pedal (Zamzamzadeh et al. 2016) Fig. 1.

The total braking distance consists of the distance related to the driver perception and reaction time and the braking distance itself (Jammes et al. 2017). Further, the braking distance itself consists of the distance related to the brake system reaction time, initial braking and the distance travelled during full braking application effect (Gunney, Mutlu, Gavretli 2016).

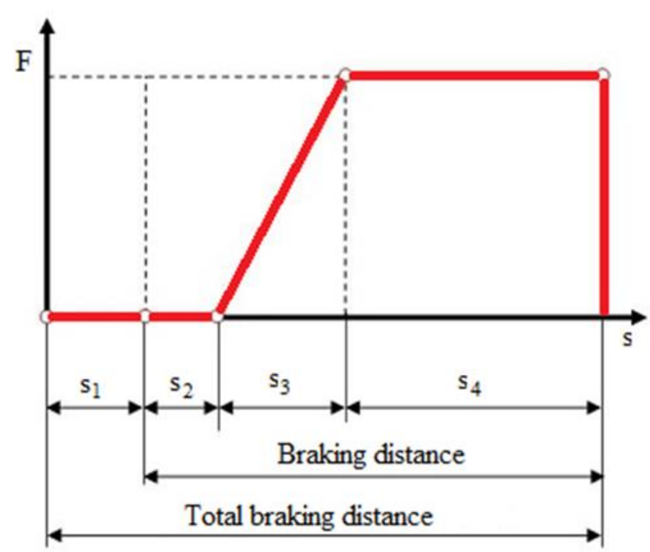

Fig. 1. The braking distance (Ondruš, Hockicko 2015)

The brake system reaction time represents the time interval elapsed from the moment of pressing the brake pedal until brake torque starts to act on wheels (Vrábel et al. 2017). It is the time during which all resistances are overcome and friction lining comes into the contact with friction surfaces which are friction surfaces of the brake disc in our case (Timur, Kuscu, Toylan 2017). The time interval from that moment till the moment of reaching full braking effect is called the initial braking (Gigan 2017). At the moment of full braking, the vehicle is continuously decelerated by the steady value of braking deceleration until it fully stops (Caban et al. 2016).

$$MFDD = \frac{v_b^2 - v_e^2}{25.92\ (s_e - s_b)}$$

v_b vehicle speed at $0.8 \cdot v_1$ (km·h^{-1})
v_e vehicle speed at $0.1 \cdot v_1$ (km·h^{-1})
s_b distance travelled between v_1 and v_b (m)
s_e distance travelled between v_1 and v_b (m) (Li et al. 2013)

Variable v_1 is considered to be initial vehicle speed i.e. the speed at the moment when the driver starts to act on the brake system controller (Li et al. 2013).

The aim of the paper is the measurement and quantification of the influence of the brake disc diameter on the value of mean braking deceleration as well as the braking distance length. The paper contains the methodology and the results of measurements with brake discs with different diameters of the front axle. The measurements were carried out by driving tests with the vehicle Volkswagen Golf II by using XL metre.

1. Methodology

The purpose of the measurement was to determine the influence of brake disc diameter on the braking distance length and on the achieved value of the mean braking deceleration MFDD. Three sets of front brake discs were used. The first set of brake discs was 239 mm in diameter, the second set contains the brake discs of 256 mm in diameter and the third set includes brake discs of 280 mm in diameter.

Vehicle used for measurements

The Volkswagen Golf II was used for the measurement, Fig. 2. The vehicle is not equipped with ABS system or any other similar electronic safety system. The technical parameters of the vehicle are given in Table 1.

Fig. 2. The vehicle used for measurements

Table 1. Technical parameters of the vehicle

manufacture year	1991
engine displacement	1.6 dm^3
fuel	diesel
body type	hatchback
vehicle dimensions	3 985 mm x 665 mm x 405 mm
vehicle curb weight	915 kg
total vehicle weight	1 465 kg
vehicle weight during the measurement	1 061 kg
construction of rear brakes	disc, 226 mm
tyres	summer, Bridgeston Turanza 195/50 R 15 82 H
front brakes	disc, 239 mm, 256 mm, 280 mm
rear brakes	disc, 226 mm

The vehicle is equipped with a Volkswagen Golf III main brake cylinder and a controller of brake effect of the rear axle.

Measuring equipment

The equipment used for the measurement was XL metre Pro Gamma with recording frequency from 25 Hz up to 200 Hz, Fig. 3. This electronic device is battery-powered and provides the ability to evaluate the data via a PC.

Fig. 3. Device XL metre used during measurements

The basic measuring range in the longitudinal and transverse axe is from -14 $m \cdot s^{-2}$ to +14 $m \cdot s^{-2}$. The device records the following parameters:

1) braking distance S_0 (m),
2) braking time t_{br} (s),
3) initial speed V_0 ($m \cdot s^{-1}$),
4) mean braking deceleration MFDD ($m \cdot s^{-2}$).

Measurement procedure

The proper tyre inflation was checked prior measurements. The measurement procedure was as follows:

1) Heating up the brakes and tyres to the operating temperature.
2) Fixing of XL metre on the windscreen.
3) Calibration of XL metre.
4) Reaching the specified vehicle speed.
5) Full braking of the vehicle after reaching the specified speed.
6) Complete stopping of the vehicle.
7) Saving the measured data.

Each measurement was repeated three times for the following speed ranges: 40 $km \cdot h^{-1}$, 60 $km \cdot h^{-1}$ and 80 $km \cdot h^{-1}$. Subsequently, brake discs of different diameter were mounted and the measurements were repeated.

2. Measured data

The data obtained by measurements are shown in the following tables (Tables 2 – 9). The tables contain the mean braking deceleration MFDD, braking distance length S_0, initial vehicle speed V_0 and braking time t_{BR}. During the measurements at speed of 80 $km \cdot h^{-1}$, significant vehicle directional instability was observed in the case of brake discs with diameter of 239 mm, and therefore the data from this measurement were not evaluated.

Table 2. Measurement with brake discs 256 mm at speed 40 $km \cdot h^{-1}$

	MFDD ($m \cdot s^{-2}$)	S_0 (m)	V_0 ($km \cdot h^{-1}$)	t_{BR} (s)
1	5.39	12.81	39.43	2.23
2	5.48	13.66	40.80	2.31
3	5.28	13.58	40.08	2.33
average	5.38	13.35	40.10	2,29

Table 3. Measurement with brake discs 256 mm at speed 40 $km \cdot h^{-1}$

	MFDD ($m \cdot s^{-2}$)	S_0 (m)	V_0 ($km \cdot h^{-1}$)	t_{BR} (s)
1	5.85	12.65	39.84	2.19
2	6.13	11.86	40.40	2.00
3	5.79	12.76	40.30	2.08
average	5.92	12.42	40.18	2.09

Table 4. Measurement with brake discs 280 mm at speed 40 $km \cdot h^{-1}$

	MFDD ($m \cdot s^{-2}$)	S_0 (m)	V_0 ($km \cdot h^{-1}$)	t_{BR} (s)
1	8.54	9.11	39.29	1.51
2	7.90	10.44	39.89	1.67
3	8.26	8.89	40.31	1.50
average	8.23	9.48	39.83	1.56

Table 5. Measurement with brake discs 239 mm at speed 60 $km \cdot h^{-1}$

	MFDD ($m \cdot s^{-2}$)	S_0 (m)	V_0 ($km \cdot h^{-1}$)	t_{BR} (s)
1	5.03	31.17	59.25	3.54
2	4.93	39.49	59.39	4.16
3	5.51	32.41	59.71	3.56
average	5.16	34.36	59.45	3.75

Table 6. Measurement with brake discs 256 mm at speed 60 $km \cdot h^{-1}$

	MFDD ($m \cdot s^{-2}$)	S_0 (m)	V_0 ($km \cdot h^{-1}$)	t_{BR} (s)
1	6.78	24.45	59.02	3.42
2	6.31	29.94	59.30	3.48
3	7.31	22.39	59.55	2.44
average	6.80	25.59	59.29	3.11

Table 7. Measurement with brake discs 280 mm at speed 60 $km \cdot h^{-1}$

	MFDD ($m \cdot s^{-2}$)	S_0 (m)	V_0 ($km \cdot h^{-1}$)	t_{BR} (s)
1	7.92	24.60	60.48	2.66
2	6.85	28.39	61.09	2.95
3	6.73	23.96	59.25	2.75
average	7.17	25.65	60.27	2.79

Table 8. Measurement with brake discs 256 mm at speed 80 $km \cdot h^{-1}$

	MFDD ($m \cdot s^{-2}$)	S_0 (m)	V_0 ($km \cdot h^{-1}$)	t_{BR} (s)
1	6.80	48.83	78.93	4.10
2	6.53	45.12	79.15	4.23
3	6.73	43.82	80.37	3.78
average	6.69	45.92	79.48	4.04

Table 9. Measurement with brake discs 280 mm at speed 80 $km \cdot h^{-1}$

	MFDD ($m \cdot s^{-2}$)	S_0 (m)	V_0 ($km \cdot h^{-1}$)	t_{BR} (s)
1	6.91	47.26	78.34	3.98
2	6.20	68.16	80.77	5.04
3	6.51	43.86	80.17	3.94
average	6.54	53.09	79.76	4.32

The results obtained from the measurements are processed also in graphs for greater clarity, Fig. 4 and Fig. 5. The graphs provide information about MFDD and braking distance length depending on the initial vehicle speed and brake disc diameter used.

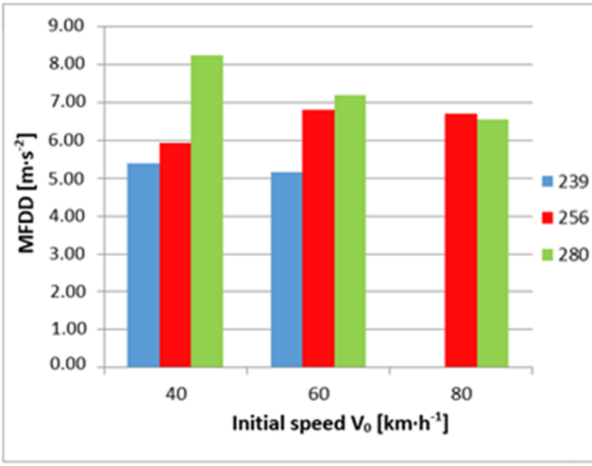

Fig. 4. MFDD depending on the initial vehicle speed and brake disc diameter used

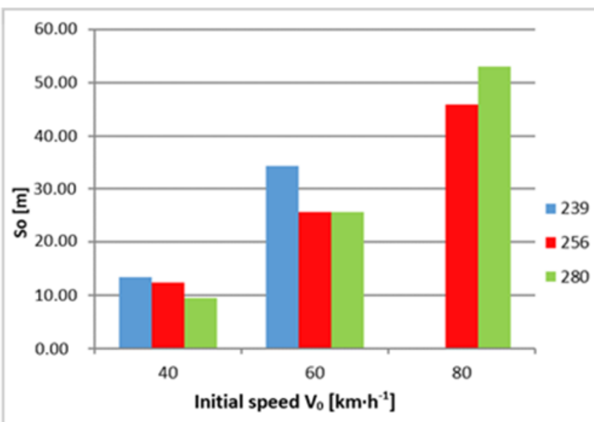

Fig. 5. S_0 depending on the initial vehicle speed and brake disc diameter used

3. Results

As it can be seen in previous tables and graphs, the brake disc diameter plays a significant role in achieved value of the mean braking deceleration as well as the braking distance length. In case of the replacement of the brake discs of 239 mm in diameter with the brake discs of 256 mm in diameter, no significant changes were observed. However, the largest changes in MFDD and S_0 were measured when changing the 256 mm brake disc diameter with 280 mm brake disc diameter. At speed 40 $km \cdot h^{-1}$, this brake disc change caused an increase in MFDD by 2.31 $m \cdot s^{-2}$ which resulted in braking distance reduction by 2.94 m. In the case of replacement of the brake discs of 256 mm in diameter with the brake discs of 280 mm in diameter, the braking distance was reduced by 23 % at the mentioned speed. During measurements of braking from higher initial speed 60 $km \cdot h^{-1}$ and 80 $km \cdot h^{-1}$ respectively, the measured differences were significantly smaller. For instance at speed of 80 $km \cdot h^{-1}$, the brake disc of smaller diameter (256 mm) caused the higher measured value of MFDD in comparison with the brake disc of 280 mm in diameter. This fact can be explained that there probably was not sufficient long time period between two measurements and thus the brake disc diameter of 280 mm was overheated and it was not cooled down to the operating temperature (Rievaj, Mokričková, Synák 2017). Brake discs with a diameter of 239 mm can be evaluated as inappropriate because locking of the rear axle wheels and vehicle directional instability were observed while braking from the initial speed of 80 $km \cdot h^{-1}$. The vehicle with these brake discs mounted did not achieve the MFDD value stipulated by legislation i.e. the value of 5.8 $m \cdot s^{-2}$.

Conclusion

Many factors have an impact on the course of braking, the braking distance length and the mean braking deceleration value. Based on the results presented in the paper, one of these factors is also a brake disc diameter. The diameter of brake discs may have an influence on the traffic accident occurrence or accident consequences. When interpreting the measurement results, it is necessary to take into account two facts which affected these results. The first one is the absence of electronic safety systems in the vehicle used for measurements. If the vehicle was equipped with an anti-lock wheel system, the locking of rear axle wheels would not occur and thus the resultant values would be different (Haugland 2013). Although, the vehicle was equipped with a rear axle load regulator compared to the serial vehicle, the locking of rear axle wheels occurred when using the brake disc of 239 mm in diameter. The second fact represents the additional mounting of the disc brakes on the rear axle instead of the origin manufacturer solution with drum brakes. In conjunction with the absence of the anti-lock system (Zhao 2014), this fact caused the locking of rear axle wheels while using brake disc diameter of 239 mm and this results in a negative impact on active vehicle safety. In terms of legislation, the results confirm the eligibility of the prohibition to carry out such interventions in the vehicle design which is not approved by the manufacturer.

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FIXATION OF TARPAULIN SHEET OF PLATFORM HDV AND ITS IMPACT TO AIR RESISTANCE

Abstract. This paper due to determine an aerodynamic drag for different ways of tarpaulin fixation, specifically tarpaulin tension and disposition on platform-type body of a HDV. More positions of the tarpaulin were investigated. Determination of the resistances was done by coast down test of the vehicle according to Slovakian technical standard (STN). The aerodynamic drag was calculated from actual vehicle deceleration during the coast down test from the actual velocity changes. The vehicle actual velocity was measured by GPS logging device. Results are values of resistance, which affect the vehicle and their sum represents the actual engine power needed for vehicles driving.
Keyword: aerodynamic drag, tarpaulin fixation, coast down test, platform goods vehicle

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Introduction

Tarpaulin platform-type bodies of road freight vehicles are currently the most used type of bodies (Rakovska 2016). It is mostly for their variability of usage, cost, technical simplicity and weight (Knez, Jereb, Obrecht 2014; Kalincak, Bartik, Grencik 2012). This type of body is very versatile, because it is easy to manipulate with it. We can change its position, tension and disposition therefore it is very adaptable for actual transport conditions. However, it could be the reason for increased fuel consumption of the vehicle, when we slovenly handle it (Skrucany, Sarkan, Gnap 2016; Van der Krieke, Van Raemdonck 2014; Mruzek, Gajdac, Kucera 2016; Vrábel, Jagelčák, Zamečník, Caban 2017; Sdoukopoulos, Boile, Anagnostopoulou 2015).

1. Aerodynamic drag and fuel consumption

A vehicle moves in exact time in exact space. A movement is dynamic action, which impacts to vehicle by resistances of surroundings are also dynamic (Kobryn, Figlus 2010; Matuszak 2012). In every instant, they have got different values. These values are influenced by ground (roadway), air (density, pressure, streaming), vehicle weight and movement (acceleration, deceleration, constant velocity). The sum of all resistances reflects a force, which acts against the movement of the vehicle (Kalina et al. 2017; Hausberger et al. 2011; Jazar 2009). Driving force of wheels must be equal to sum of resistances for ensuring vehicle movement. Driving force is created by vehicle engine. The smaller resistance acting to vehicle, the smaller driving force is needed. The engine expends smaller power therefore the immediate fuel consumption is smaller. Aerodynamic drag (air resistance) has the biggest impact just at high speed of vehicle. Nowadays, network of high-speed roads – highways – is extending so transport distance and transport speed are also extending. Consequently, air resistance is increasingly serious factor, which has got impact to fuel consumption (Rievaj, Mokrickova, Rievaj 2016; Polcar, Cupera, Kumbar 2016).

On the figure 1, we can see a process of single resistances which has got impact to tested vehicle in consideration of its actual speed.

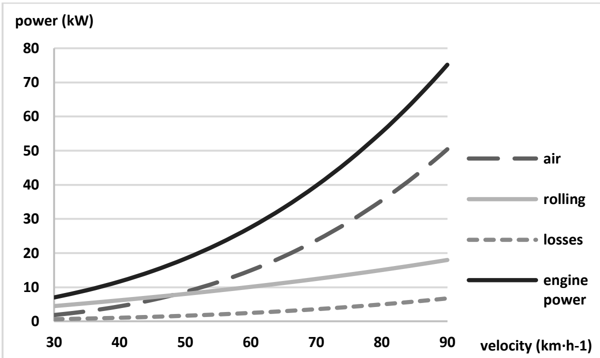

Fig. 1. Vehicle resistance powers

Curves indication air, rolling and transmissions express partial resistances which impact the vehicle. The sum of these resistances is overall resistance power (engine power) active during movement of vehicle, which the engine must expend in exact conditions for keeping vehicle in movement in required speed. These processes represent a two-axel vehicle with tarpaulin platform-type body, which weighs 12 tons (exact and for calculation considered weight is 11 tons) with usual tires, driver's cab with sleeping compartment. There are not any winds ahead or side winds and the vehicle is moving on flat road without slope. When the speed is 90 km·h^{-1}, the engine must expend approximately 75 kW. Vehicle engines of this category are in power classes from 130 to 190 kW so it can be around 40 – 60 % of their maximal power. Very interesting is process of air resistance, which becomes dominant around 50 km·h^{-1}. When the speed is higher, air resistance impact is increasing.

Table 1. Process of powers

Type	50 km·h^{-1}		70 km·h^{-1}		90 km·h^{-1}	
Air	8,7 kW	47 %	23,8 kW	60 %	50,6 kW	67 %
Rolling	8,1 kW	44 %	12,4 kW	31 %	18 kW	24 %
Losses	1,7 kW	9 %	3,6 kW	9 %	6,8 kW	9 %
Engine power	18,4 kW		39,8 kW		75,4 kW	

Size of air resistance is influenced by many physical factors, such as:

- Air density (depends on actual temperature and atmospheric pressure),
- Front surface of vehicle,
- Vehicle speed,
- Coefficient of air resistance C_d.

There are some factors, which cannot be influenced by operator or driver through transport. For instance air density is that factor, because it is surrounding state. Front surface of vehicle can be hardly influenced at tarpaulin platform-type body. Driver can directly influence the speed of vehicle but there are other factors, such as adhering schedule for loading or unloading goods. Coefficient of air resistance is a value, which changes considering to operating state of tarpaulin and its tension.

2. Coast down test

A coasting during which the vehicle is moving by inertia from the moment of neutral gear position shifting is decelerated due to the effect of driving resistances. This coast down test is done on the test track. Vehicle movement is direct and unevenly slowed during the test. Driving resistances are determined by calculation of the vehicle actual deceleration. It is also determined by known geometric characteristics of measured section and vehicle inertia parameters. Measured driving resistance of the vehicle and coasting characteristics are designated by calculation. This type of test reports to STN 30 0554 standard (Standard STN 30 0554) (Slovakian technical standard) and we proceeded in accordance with it. Some procedures were changed due to achievement of higher informative value of test results.

Vehicle

Vehicle MAN TGL 12.250 was used for measuring air resistance coefficient c_d. This freight vehicle is categorized as vehicle with overall weight 12 tons. Space for loading is covered by tarpaulin platform-type body. It is the most used variant with many benefits – simple manipulation during loading and unloading. The tarpaulin platform-type body could be rolled up therefore material with large sizes could be also loaded. This is not possible at box bodies, because they could be loaded only from the sides, which could be opened (usually doors from sides or back part of the vehicle. Transport companies have got lower inputs likewise lower operating costs, mainly costs for oil consumption and costs for maintenance.

Fig. 2. Freight vehicle MAN TGL 12.250

On the other side, there are some risks connected with these vehicles. Tarpaulin platform-type body could be easily disrupted or damaged. This fact motivates thieves, who could easily steal the goods from the vehicle. From transport company point of view, there must be more attention paid to binding the tarpaulin platform-type body while loading or unloading. Riding with insufficient fixation of tarpaulin platform-type body should cause these negative factors:

- Increased fuel consumption (increased air resistance caused by air flowing to loading space),
- Air flowing to loading space (danger for goods),
- Depreciation of loading space in case of bad weather,
- Depreciation of tarpaulin platform-type body (destruction of the body and costs for new body).

Test velocity

Test velocity of freight vehicle must be at such level, that results would be reliable with emphasis on accuracy. Higher velocity means that air resistance is increasing therefore measuring gives smaller inaccuracy in result values of air resistance coefficient. Test velocity must be set considering to communication profile and adhering speed limit. Movement was evaluated in speed interval 85 – 60 km·h^{-1} for measuring air resistance coefficient.

Atmospheric conditions

Due to STN 30 05 54 standard, these atmospheric conditions must be adhered:

- Air temperature from 5 to 25 °C,
- Air pressure from 97,33 to 101,25 kPa,
- Maximum wind force 1.5 m·s^{-1}.

Air temperature was measured by thermometer during each repetition. Air pressure was measured by meteostation and it was also verified by Institute of hydrometeorology of Slovak republic. Wind force was observed by anemometer during each repetition. This device observed average wind force in time of 60 seconds.

Recording device – GPS

GPS recording device was used for calculation of deceleration. This equipment gave information about velocity depending on time. It could record the velocity each second. The difference of these velocities means deceleration value. This quantity is immediate therefore it is necessary that the recording device GPS must work at high frequency and it must be exact.

Fig. 3. Recording device GPS

Measurement no. 1 – tarpaulin in normal operating condition

First measurement was done with tarpaulin platform-type body properly fixated on all sites. It was the measurement of air resistance coefficient on freight vehicle with tarpaulin platform-type body, which was done with operating parameters, without any load. The measurement would be the most accurate therefore there were 10 repetitions for this type of measuring.

Measurement no. 2 – unfolded tarpaulin on rear part of body

In the second measurement, there was done the coast down test of freight vehicle with tarpaulin platform-type body totally unfolded on the rear part. Unfolded tarpaulin is shown in the picture below.

Fig. 4. Freight vehicle with unfolded tarpaulin on the rear part

Driving with freight vehicle that have unfolded tarpaulin is usually used when the load overhang the loading space. Occasionally, this event could happen when driver forget to return the tarpaulin to primary condition after loading or unloading. Other cases are also when the driver forget to fix it or let it be for saving time to another manipulation.

The aim of this measurement was to refer the increasing of air resistance coefficient opposite to driving with tarpaulin in normal position. Increment of this value is caused by turbulent winds, which arise from air flowing on outlines of vehicle rear parts. These air flows are swirling what causes turbulences. In this case, air flow penetrates to loading space and it creates the zone of high vacuum, which pulls the vehicle behind. This air resistance increment is subsequently causing increment of fuel consumption.

Measurement no. 3 – partly unfolded tarpaulin on side part

In the third measurement, there was the coast down test done with partly unfolded tarpaulin on side part of the body, what is showed in the picture below.

Fig. 5. Partly unfolded tarpaulin

This instance where there is partly unfolded tarpaulin on side part of the body occurs more often in real operation. It means that binding rope is not passing through all holes therefore there are some gaps. It is done mostly for saving driver's time or saving time during loading and unloading. When the gaps are larger, there are more problems. Some dirt from external environment can permeate to the loading space therefore there may occur depreciation of loading space and tarpaulin on the freight vehicle. There is increased possibility of transported load depreciation. In these cases, there arise damage on transported load and the operator is responsible for this damage because of driver's negligence.

Measurement no. 4 – totally unfolded tarpaulin on side part

In the last measurement, there was done the coastdown test with freight vehicle with totally unfolded tarpaulin on side part of the body what is showed in the picture below.

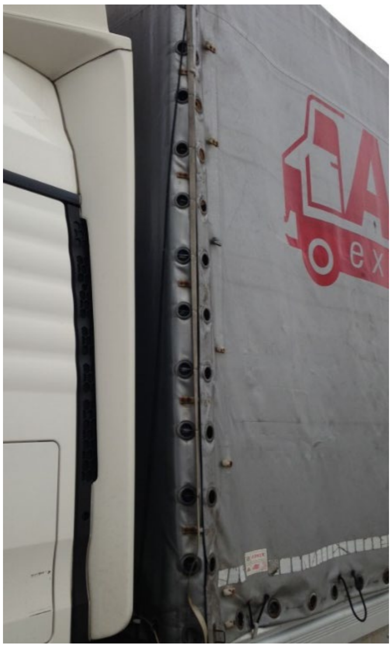

Fig. 6. Freight vehicle with totally unfolded tarpaulin on side part of the body

In this measurement, the tarpaulin was totally unfolded on side part on the body of freight vehicle. In case of freight vehicle increasing velocity, the tarpaulin was losing its original position because the air flows were very strong. Tarpaulin was lifted up because of this. Loading space was uncovered on side part of the freight vehicle body and the air resistance overpressure zone was there.

Table 2. Tarpaulin fixation influence to vehicle resistance

Tarpauilin position	C_d (-)	C_d growth (%)	Overall growth of resistance (%)		
			50 km·h^{-1}	70 km·h^{-1}	90 km·h^{-1}
Correct state	0,538	-	-	-	-
Unfolded rear part	0,564	4,8	2,2	3	3,3
Partly unfolded side part	0,545	1,3	0,7	0,9	1
Totally unfolded side part	0,633	17,6	9,15	11,5	13

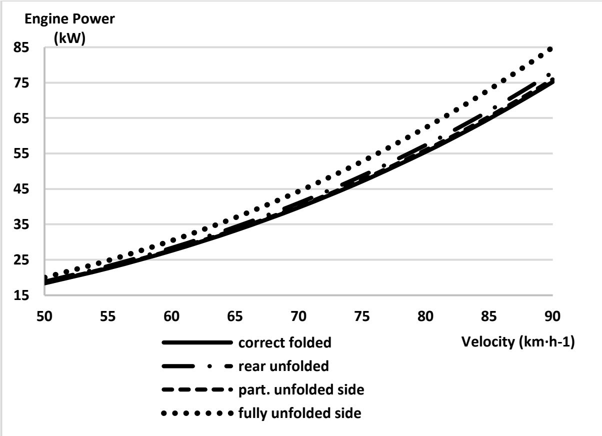

Fig. 7. Engine power according to tarpaulin fixation

3. Measurement conclusion

Measurement results prove the impact of fixation and position of tarpaulin and its parts to air resistance. When some parts of tarpaulin are looser fixated and there are possibilities to create 'bubbles, gaps' or freely 'waving" parts, the air resistance of vehicle is increasing. This effect influence fuel consumption. It is very hard to quantify this impact, because there are other factors instead of air resistance, such as losses in driveline, engine characteristics (efficiency process consider to turning load, specific fuel consumption). However, it could be stated, that immediate fuel consumption of this type of vehicle corresponds with percentage change of air resistance what is showed in table 2. It is not about average fuel consumption for entire vehicle operation, because it is only about immediate consumption at selected speed.

Air resistance coefficient value c_d was identified by measurement of coast down test for freight vehicle with tarpaulin platform-type body. The aims of this measurement was reviewing use of this method for measuring air resistance coefficient and refer to change of this value at different operational conditions of tarpaulin platform-type body on freight vehicle use in praxis.

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NEW TRAINING SCHEMES FOR THE FUTURE EDUCATION IN TRANSPORT SECTOR

Abstract. Transport is a social sector that is rapidly developing, changing and being influenced to the maximum extent by the technological development and innovation, among others, thus facing problems in staffing its several domains with appropriate and qualified personnel. This fact, makes the need for changes in training and education of future transport professionals. SKILLFUL project vision is to identify the skills and competences needed by the transport workforce of the future and define the training methods and tools to meet them. Paper focuses on mid-term results of the project.
Keywords: transport, professionals, training, technology

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Introduction

The transportation sector employs over 10 million persons in the EU today. At the same time, transport is a social sector that is rapidly developing, changing and being influenced to the maximum extent by the development of automation, electrification and greening of transport, among others, thus facing problems in staffing its several domains with appropriate and qualified personnel. This fact, makes the need for changes in training and education content, curricula, tools and methodologies absolutely imperative, incorporating lifelong learning aspects for the professionals in all transports areas. Additionally, the demographic trends (such as population age) are also going to play a key role over the next years, since large groups of professionals taking retirement should be replaced by younger generation of employees. So, an additional challenge is whether enough professionals having the right skills could be attracted to the transportation sector workforce. (SKILLFUL consortium, 2017)

SKILLFUL project vision is to identify the skills and competences needed by the transport workforce of the future and define the training methods and tools to meet them. Employability is strongly connected by the project to future transport job requirements for all transportation modes and multimodal chains for all levels/types of workers, while all training modes are included and integrated in a balanced way.

SKILLFUL is financed under Horizon 2020, reviewing the existing, emerging and future knowledge and skills requirements of workers at all levels in the transportation sector, to structure the key specifications and components of the curricula and training courses that will be needed to meet these competence requirements optimally in order to achieve European wide competence development. Project results are verified through wide range of pilot courses from all transportation modes Europe wide. (SKILLFUL consortium, 2017)

1. Future trends and scenarios in transport

A main challenge for the transportation sector is whether it can attract new employees, as well as equip the existing ones with the required skills required for meeting the needs of the already occurring or emerging changes.

During the first project phase SKILLFUL analysed and described the **technological changes** and trends that are expected to occur in transport sector in the short (2020), medium (2030) and long (2050) horizon future and how they are going to affect the employability of the transportation system professionals, together with other trends taking place in parallel, like demographic and socioeconomic changes, etc.

In this first phase more than 125 experts have been interviewed in total (for all sub-categories of future transportation trends), from more than 20 different European countries. Experts have been covering a wide area of positions and professional areas, ranging from the research and university area, to technical fields. As for future of the professionals of European transportation system, the experts have been asked to highlight the professions, jobs and occupations that foreseen to be most affected, by also defining the timeframe of these changes. In parallel, more than 80 relevant reports and documents, as well as scientific articles have been analysed, in order to collect all the information needed about the current and upcoming changes in the European transportation sector.

Among the key transport trends, electrification emerged as the most important factor that will bring changes into the future transportation system of Europe. Electrification is a very relevant theme for road transport in the medium (2020) and long (2050) terms, especially due to its potential contribution to the climate change targets. Digitalization and automated driving are considered to be a relevant theme for all transport modes. In the same context, the greening of all transportation modes is also at a very high ranking. Liquid second generation biofuels, gaseous fuels and synthetic fossil fuels are very relevant to road transport in the short term (2020), especially due to their potential contribution to the climate change targets, while for maritime transport LNG and also other new fuels provide greening possibilities in the medium term (2030), with emphasis also on new generation of inland-waterway vessels that will provide an integrated, energy-efficient, and flexible alternative to road transport. Ensuring the feeling of safety and security of European citizens is also considered to be a very important factor, referred to cause changes in the transport area and its future development. Other driving forces, in diminishing importance order are the following:

- Multimodality, Syncromodality;
- Interdisciplinarity in creation of new solutions;
- New transport vehicle types;
- Globalization of the economy;
- Condition-based megacity traffic management multistakeholder systems. Global traceability for Logistics Optimization;
- Smoother Travel through Electronic Visas (e-Visas) and Smart Airports;
- Novel infrastructure management and maintenance schemes;
- Tube freight transport concepts;
- Impact of 3D printing on production location and logistics.

Almost all experts highlighted the importance of digitalization trends in identifying related technologies (i.e. IT and telematics, Cooperative Systems and V2X interfaces, traffic big data handling algorithms and analytics) as the most influential for future Transport Workforce. Few more key enabling and supporting technologies were identified by the experts, such as robotics, security related technologies, etc.

Even more than technologies, **new business schemes** that accompany them are expected to change the working ecosystem of transport. MaaS will push users from ownership to usership; thus creating a number of connected jobs and business opportunities to it. As major relevant business schemes the following have been considered and analysed:

- Retail and (e)commerce development;
- Transport workplace flexibility;
- Do-It-Yourself (DIY) schemes;
- Crowdfunding schemes that allow new transport related applications to emerge;
- Transport on demand schemes that adapt flexibly to the kind and number of passengers or freight to be transported;
- Transport workforce flexicurity;
- Fuel availability schemes that offer energy for transport vehicles available at the specific time and the distinct localization.

The future transport workforce will not only be influenced by the changing and evolving needs of the sector and its associate business schemes and enabling technologies. It will also be shaped by the prevailing **social trends** in Europe, such as ageing of the workforce, resulting in the need to integrate immigrants into the workforce and the fight against the exclusion within certain groups, such as people with disabilities, computer illiterate people, etc. New technology will influence the existing modes of transport. Society will witness a shift in cultural attitudes spreading across the digital society and manifested by ownership and usage of the means of transportation. This will also fundamentally change the way transport will be designed and operated. The total mobility structure is changing (SKILLFUL consortium, 2017).

2. Estimated impact of changes in future transportation employability

All the above changes anticipated in the near or more distant future of the transport sector, as well as those who have already begun to occur to a lesser or greater extent, are expected to affect (in varying degrees) also the sector's employability, creating different conditions for the future transport professionals and new requirements and needs for their compilation and training.

An occupation that is expected to be affected the most is driver (of every kind). Taxi and bus drivers, metro drivers, urban rail drivers, truck drivers, public transport drivers, delivery drivers, etc. are expected to lose many of their duties or professions may even disappear to some extent, mainly due to development of autonomous vehicles and unmanned transportation systems in long term. Additionally, some of blue collar workers, such as stevedores, manual operators, factory workers, machine operators, warehouse operatives, conductors, shunters, loaders/unloaders, etc. are expected to be shortly eliminated or even vanished as professionals' positions, mainly again because of the evolution of automation, digitalization, robotics, full mechanisation of loading/ unloading and other relevant key developments.

On the other hand, several jobs are going to emerge, in order to cover the needs that will progressively occur by the several developments of new driving forces, as well as the elimination of already existing positions. Some representative examples that can be indicatively mentioned are the drones' operators and managers, who will remotely control vehicles deployed for logistics operations that is a profession expected to emerge in a medium-term horizon; the automated vehicle fleet operators and servicing-maintenance personnel, the shared mobility managers and MaaS operators, as well as the syncromodal specialists, expected to have extensive knowledge on syncromodal sustainable urban systems and on new business models for mobility providers.

Experts indicated that there is a growing need of IT specialists who could create, manage and operate specific transport related software and mobile computerized systems (Gavalas et.al, 2015). In the future, there will be a huge demand of specialists who will analyse and interpret collected transport big data, install sensors in several places (vehicles, infrastructures), maintain the equipment and tele-operate them. Many of the current jobs and tasks requiring physical labour workforce may be substituted by robotics in the future. However, intelligent systems and new technologies will require specialists to deal with them.

Additionally, another technological factor that is expected to affect the future transportation system of Europe is related to the proactive traffic management that covers methods for creating an accurate overall understanding of the current status of the transportation system and predicting changes in traffic conditions. It is a relevant theme, especially for road transport, already in the short term (2020).

Lightweight materials, graphene and nanocoatings are also expected to replace traditional materials in automotive, aviation and marine industries in the future. It is expected that paints, coatings and construction markets will be highly impacted in the next five years by self-healing materials. For example, fibres reinforced composites with liquid self-healing materials can be used in the aviation industry and self-healing coatings and paints can be used on car surfaces and marine assets, such as ships and docks, to protect metal beneath the sea from corrosion.

Moreover, Augmented Reality (AR) facilitates construction and maintenance works by minimizing accidents (e.g. accidentally damaging pipelines, electricity cables, etc.), while already existing AR software and applications allow controlling combinations of visible and invisible infrastructure elements.

Finally, during the analysis of data and the interviews of the experts some more technologies that need to be taken under consideration came up, such as the new embedded processors or the Building Information Modeling (BIM). (SKILLFUL consortium, 2017)

3. Future challenges for education

The aforementioned changes and developments in the transportation sector of Europe are expected to bring changes to the employability of the sector. They are expected to cause the alteration of many jobs (sometimes even their disappearance), as well as the emergence of various new occupations. In the light of this, the education and training sector will need to adapt rapidly and effectively in order to insure training/education provision efficiency and to fulfil new jobs skills and competences requirements effectively. Education will constitute a pivotal role in order to properly drive new potential workers on covering the future and each emerging demand. As a result, new education schemes will become increasingly focused, not just on knowledge, but also on strategic skills that students need to get a job.

In this respect, SKILLFUL project provides a general overview of new and emerging training tools, methodologies, and schemes, which will be the most promising for the transport education provision in the near and distant future. In doing so, new and emerging training facilities were identified and analysed using the broadest possible spectrum at several levels:

- Including a wide knowledge base and relying on multiple knowledge communication channels;
- Including all user groups and areas, such as blue collar workers, white collar workers, engineers, management teams or relevant competent authorities and political boards;
- Considering all forms and levels of education;
- Exploring potential initiatives and innovation proposed by or successfully applied, not necessarily from the transport sector but with emphasis on applicability in the transport sector;
- Exploring potential initiatives and innovation in the whole European region and beyond;
- Considering potential applications to transport workforce education provision for all areas including all transport modes (maritime, rail, road and air), as well as intermodality/cross modality.

To ensure the best coverage of the topic under investigation, the methodology relied on multiple sources of knowledge, respectively:

- A wide consultation of experts – either in the field of transport or education/training or both – form all over the European continent;
- An extensive review of the recent scientific literature;
- A complementary review of literature on local and regional initiative and innovation (grey literature).

Experts were first asked to rate skills and competences importance for the different transport job categories. From this question, it appears that hard and technical skills are of particular importance for low to middle-skilled worked (i.e. blue collar and professional drivers). Of less importance but nonetheless important are language (especially mother tongue mastery), ICT skills and several soft skills such as flexibility/adaptability, proactivity and engagement and interpersonal skills. For the white-collar job profiles, mother tongue mastery, team working/management and proactivity and engagement were rated as very to extremely important while all other skills were seen as fairly important. Noticeable is the fact that technical skills specific to the job were not seen as the most important. Considering the relative high importance dedicated to soft skills, this suggest however that expert attach higher importance to the skills necessary to an effective adaptation to a rapidly evolving workforce than to technical skills by themselves.

For researcher, engineer and manager all skills categories were rated as very important, with the exception of interpersonal skills which were rated as fairly important (but not very to extremely important) for researchers and engineers. For the decisions making job profiles (i.e. Authorities –politics), almost all skills were rated as very important with the exception of the skills that are specific to a particular job, ICT skills and innovation/creativity. This is quite consistent with the fact that while decision makers have to acquire a broad and general knowledge.

As for the improvements for specific education type/level, the improvements 'Adding special themes modules', 'Wider use of new training methods', 'Adequate and sufficient practice training', 'Faster adaptation to new legislations, technologies and labour market' and 'Better adequation between education, job requirements and industry' were quite consistently identified for all education type/level. The improvement 'higher versatility, multiskilling, flexibility and knowledge transfer' was proposed for the 'college-university' category but also – to a lesser extent - for VET education. Finally, the improvement 'Bigger and more specialized offer for in-house training in company' was proposed for in-house training. (SKILLFUL consortium, 2017)

4. Most promising existing, new and emerging training/education methodologies

The last aspect considered in research concerned the identification of the most promising training/education tools and methodologies. In total, 12 promising existing, new and emerging tools and methodologies identified by the expert panel in diminishing importance order are the following:

- E-learning (Distance/mobile/connected learning and online learning environment);
- Virtual/augmented reality;
- Gaming environment;
- Human led individualized training (e.g. executive coaching);
- Blended learning;
- Peer led/mentoring learning programme;
- Traditional lectures;
- Networked learning (e.g. social media networking);
- Smart learning technologies: personalized learning processes;
- Scenario/story based learning;
- Training on the job/experiential learning;
- Informal learning.

In the context of the review of the literature, 150 papers and reports were reviewed and analysed (112 from the scientific literature and 38 from the grey one) covering all the training tools, methodologies and schemes thought to be relevant for the SKILLFUL objectives.

Overall, the new and emerging tools and methodologies identified through the literature review were quite similar to those pointed out by the expert panel with some very few exceptions. Indeed, from the expert consultation, it appears that some standard educational tools/methods – that are not necessarily new (e.g. traditional lectures and/or human led individualized training) – are still of great importance and may still usefully be adopted in combination with more recent technologies.

The two major lessons learned from this review are on the one side the necessity to base learning on multiple resources, medias and techniques - as known as the blended learning approach - to insure learning performance and engagement into it and on the other side the necessity to place the learner as a central and active agent of his/her learning – process implicitly understood, for example, under the heutagogical, the authentic/active and/or the discovery-based learning approaches.

Blended learning may be conceived as a new way of education that depends on the use of multiple education resources (typically blended face-to-face learning with other information technology based features) which makes it a powerful approach for creating educational programs that can take into account the individual differences between students and bring different learning methods (Azhar, Mustapa, Ibrahim, & Yusoff, 2015).

Among the recognized and expected benefits of a successful blended learning approach are: increased active and authentic learning experience and performance, enhanced engagement and motivation, broader knowledge and skills (e.g. soft skills) acquisition, etc. (Canning, 2010). Finally, it is important to note that the benefits of a particular blended learning scheme will primarily depend on the components that are included into it (collaborative/peer-led components will, for example, enhances soft skills such as negotiation of communication skills).

Learner as a central and active agent of his/her learning: more and more, the pedagogical models suggest that the learnings should be conceived as active and proactive processes with a central place offered to the learner constructing his/her own learning experiences. In doing so, the learning experience is thought to be more authentic and leading to an increased learning engagement, motivation and autonomy from the learner as well as to increased performance and broader knowledge acquisition – as, for example, critical thinking, self-reflection, metacognition and soft skills (Blaschke & Hase, 2016).

Another major benefit is that it involves the learner in realistic requirements and scenario work practices that are aligned to authentic situation and hence better prepared them for personal life accomplishment and for the workplace and to become a lifelong autonomous learner. As compared to traditional educational models – with the learner considered as a passive recipient of learning content – this implies a major revolution and an essential mental shift in the way teachers and learners roles have to be considered.

All 12 tools, methods and supportive technologies presented above are thought to serve the purpose of these two components (i.e. blended learning and placing the learner at the center of his./her learning) and to facilitate their effective implementation. However, each of these categories present benefits and drawback and cannot be seen as a panacea for meeting all learning requirements. Instead, it is the well-designed and well-thought combination of several methods – adapted to the learning content as well as to the learner needs – that ensured effectiveness.

It is important to note that the rapid developing technology will increasingly impact future workforce skills and competences development in two ways: firstly, as it exerts pressure for change because the new technologies demand a new set of skills and, secondly, as it provides opportunities for transforming pedagogy because it provides access to information, networks for communication, and new means of presenting learning (Hannon et al., 2011).

5. Trainer and trainee competences requirements

The revision of the existing, emerging and future knowledge and skills requirements of workers at all levels in the transportation sector, with emphasis on competences required by expected future changes and paradigms, was performed during the first project phase. Based on this gained knowledge, further work was aimed to structure the key specifications and components of the curricula and training schemes that will be needed to meet these competence requirements optimally, with emphasis on multidisciplinary education and training programmes. With this respect project aimed at designing novel training/education schemes of which several will be tested as pilot training courses by SKILLFUL partners.

It was also necessary to develop quality criteria - for each training scheme, both in term of trainees' competence development and of trainers' capability building in accordance to new and expected emerging trends in the transport sector as well as in the educational section (using new training tools and methodologies).

In a traditional view, teachers and trainers of transport courses are experts who have a profound knowledge of their subject. However, internationalization, multimodality and interdisciplinary, as well as increasing emerging future trends in the transport sector make it necessary that such trainers and teachers develop a broader view on transport issues and acquire more interdisciplinary competences.

For example, transport engineers tutors will increasingly need to acquire basic knowledge on traffic psychology and behavioural science while driving instructors of professional drivers will in a near future need to acquire a better knowledge and understanding about emerging automotive technologies and about electrification aspects.

At the same time, recent progress in the education fields implies a major revolution and an essential mental shift in the way teachers and learners roles will have to be considered in the future. The role of the teacher is reinvented, no longer seen as a knowledge holder but rather as a learner partner and having at his/her disposal various powerful new educational tools and technologies for insuring the best adequacy between learning contents/settings and the learner's needs and previous experiences.

Teacher/trainer quality refers to all teacher-related characteristics that produce favourable educational outcomes. Besides these general consideration, a plethora of references and studies have considered discrete and specific components of teacher quality. These various aspects are usually categorized into three main dimensions, namely:

- **Knowledge**, including teachers' subject-specific content knowledge, subject-specific pedagogical content knowledge, and subject-unspecific psychological–pedagogical knowledge;
- **Skills**, relevant for the teaching profession as pedagogical skill, content-related practical skills, soft skills, and, of increasingly importance in the recent years, digital/ICT skills;
- **Personal dispositions** including the values, beliefs, commitments, and professional ethics that influence their behaviours toward students, families, colleagues, and communities.

Bearing in mind rapidly evolving context both in the field of transport and in the field of education, the full list of requirements for each training course/module have been be recommended, utilizing a wide consultation within the Consortium Partners and with external stakeholders and experts. The list also considers expected changes in trainer competences – in short, medium and long-term future – but also expected changes regarding teaching resources and modalities.

In accordance to requirements of trainers, also the minimum requirements of trainees have been defined for each training module/scheme. As compared to the current minimum requirements, emerging relevant requirements have been detailed here also considering the emerging trends in the fields of transport and of education and highlighting the expected changes and additional needs in the future (e.g. on ICT literacy, technological knowledge background, soft skills). (SKILLFUL consortium, 2017)

6. Pilot courses

The main objective of SKILLFUL project is to design appropriate training/education modules for key actors in the Transport sector to fulfil their emerging and foresighted required competences and skills in the most cost-efficient, modular and coordinated ways. In the context of previous steps, five types of training/educational schemes for various types of workers in all transport modes were designed to be tested as pilot training by partners as follows:

- **Transport infrastructure operators' training schemes.** Operators need new skills and competences to catch up with emerging technologies. For them life-long learning, with emphasis on new technologies, constitutes a necessity. But they typically have very little available time as they work under pressure and in tight shifts. Thus, for them webinars and other ICT-based training (and certification through web proctoring) schemes might be more appropriate;
- **Young scientists' seminars** as a joint initiative of ECTRI, FERSI and FEHRL from all Transportation sectors;
- **Lifelong training schemes** for low to middle-skilled segments of transport professionals;
- **Interdisciplinary thematic courses** on key technologies, services and trends with a cross modal dimension and/ or where important know-how can be transferred from one mode training to another one;
- **Pan-European Transport master curriculum**. A first core syllabus will be realised towards a Pan-European Transport Engineering master. This will include several modules, in accordance to the relevant future requirements. Trials of trans-national specialty courses will be tested to allow students from one country to attend courses from another university within their master degree.

In total 16 pilot courses will be tested in period 2018-2019.

Conclusions

1. All developments, relate to and affecting transportation, whether they relate to technological discoveries and developments, or to social and economic factors, directly affect also the employability, as well as the education and training needs of professionals in the transportation sector;
2. Some existing occupations are expected to change, fall dramatically or even disappear, some new professions are going to make their appearance to meet any emerging needs;
3. A number of gaps have been identified in relation to training. At the same time, a number of new training tools and technologies have also been identified;
4. The availability of technology in the education sector means that approaches using Virtual Learning Environments are now more possible: opening the potential to allow workers to retrain and up-skill. In addition, there have been a number of developments in relation to gamification and simulation which could be adopted in training for automation or in relation to cybersecurity;
5. It is expected that a number of these methodologies will be tested in the pilot training courses. The impact of these methods has not generally been quantified so pilots will offer an opportunity to test the methodologies;
6. More information on project can be found at http://skillfulproject.eu/

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