Transport technic and technology
Volume XV Issue 1 Year 2019
DOI: 10.2478/ttt-2019-0001

OPPORTUNITIES FOR SOLVING URBAN AND ENVIRONMENTAL PROBLEMS BY PROGRESSIVE CITY LOGISTICS TOOLS

Abstract. At present, high traffic intensity level on the roads currently saturates a great demand for individual transportation. Mobility is an important part of everyday activities in cities. The increasing number of passenger and freight vehicles on the widening transport infrastructure raises several problems. The range of use of public passenger transport does satisfy enough the citizens needs and its use is constantly decreasing, especially in the new EU countries. One of the reasons is also the growing sale and production of new passenger cars in the EU, resulting in congestion in the road infrastructure of cities and environmental problems. These issues are dealt with the modern City Logistics concept. The contribution focused on the basic principles of city logistics, the reasons for its development and, in particular, the possibilities of practical use. An example is the city of Trenčín in Slovakia, where a regional rail passenger transport is proposed for city traffic service including Park and Ride system.

Keywords: urban, transport, logistics, environment, city

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Introduction

High traffic intensity level on the roads is caused by a great demand for individual transportation. The congestion level is also reflected in the accident rate, which is still very high despite the various measures to reduce them compared to other European countries. Many traffic accidents in cities, as well as high traffic intensity, inadequate capacity of urban communications, result in the emergence of crisis situations. It leads to air pollution and the greenhouse effect and there is an essential problem with excessive energy consumption.

One possible tool for preventing crisis situations in cities is the concept of City logistics. This part of logistics is very important because the movement, transport and handling of material are an influential part of the logistical chain.

Margins are up and down 2.5 cm, left and right 2 cm. Before the title of paper are left 4 free lines.

Between two columns a space of 6 mm is to be left.

The first line of the paragraph is to be shifted 7 mm from the left margin.

The headings of introduction, chapters, sub-chapters, acknowledgement and references are printed in small letters in 10 pt Bold-Regular type and aligned left Style Normal.

Headings of chapters and sub-chapters are numbered by one Arabic numeral and sub-chapters by two numerals between and after every numeral are dots.

The titles of chapters, sub-chapters, conclusions, acknowledgement and references should be separated from the text by the one-line interval.

1. Modern tools for energy consumption monitoring

Considering the high intensity of passenger and freight vehicles, high fuel and energy consumption is expected. There are currently several modern methods and analyzes that monitor and evaluate this consumption. Subsequently, they try to find the optimal solution and optimal variant of transport modes that will be the least energy intensive. There are explained modern tools for energy consumption monitoring, specifically Well-to-Wheels Analyses and Standard EN 16258:2012 in this section.

1.1. Well – to – Wheels Analyses

Well-to-wheel analysis (WTW) refers to specific lifecycle analysis applied to transportation fuels and their use in vehicles. The WTW stage includes resource extraction, fuel production, delivery of the fuel to a vehicle, and end use of fuel in vehicle operations. Although feedstock for alternative fuels do not necessarily come from a well, the WTW terminology is adopted for transportation fuel analysis.

The WTW by JEC pursue the objectives of estimating greenhouse gas emissions, energy efficiency and industrial costs of a wide range of automotive fuels and power-trains options significant for Europe in 2020 and beyond.

Each WTW analysis consists of two parts. The first is called Well to Tank Analysis (WTT) from source to tank. Assessment of energy intensity and production of emissions in the gas industry in individual stages of production. Storage of fuel cells, mainly used for the production of raw materials, for transport of natural gas, for transport, production of fuel and distribution to gas stations.

The second part is called Tank to Wheels (TTW) analysis. It assesses the energy intensity and production of greenhouse gas emissions from vehicle fuel combustion. It takes into account the quality of individually produced fuels and also the possibility of burning different types of fuels in internal combustion engines. Together, these two parts take into account the entire life of the individual types of fuels from the well to wheel.

The conclusions can be summarized as follows:

- the key role in the production of GHG emissions and in energy consumption is played not only by the character of the motor fuel and the way it is produced but also by the efficiency of the drive unit in the vehicle
- An alternative to renewable fuels can bring significant reductions in GHG emissions, but generally at a higher cost of energy
- the results of the environmental impact assessment must always be further evaluated in terms of real resources, practical feasibility, cost levels and positive public acceptance
- moving from fossil to alternative fuels from renewable sources is currently very expensive. Reducing GHG emissions always results in increased costs. However, higher costs may not automatically mean a greater reduction in GHG emissions.

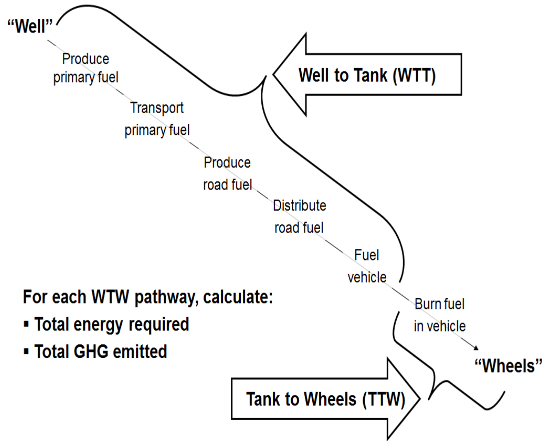

Fig.1. Graphic representation of Well-to-Wheels Analysis

The outcome serves as a sound and broadly accepted scientific reference.

- WTW differs from a Life Cycle Analysis (LCA), as it does not consider energy and emissions involved in building facilities and the vehicles, or end of life aspects.
- WTW analysis focuses on and – TTW), that is the major contributors to lifetime energy use and GHG emissions.
- No estimates of overall “costs to society” such as health, social or other speculative cost areas are made.
- Assumes all plants and vehicles to meet current and incoming future regulations. When considering regulated pollutants, all plants and vehicles are assumed to meet current and incoming future regulations.

1.2. Standard EN 16258:2012

This European Standard EN 16258:2012 Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers) specifies a general methodology for calculation and declaration of energy consumption and greenhouse gas emissions (GHG) in connection with the provided services (cargo, passengers or both). It specifies general principles, definitions, system boundaries, methods of calculation, allocation rules (allocation, assignment) and recommendations on information to support the standardized, accurate, reliable and verifiable declarations regarding energy consumption and greenhouse gas emissions associated with the freight service. It also contains examples of the use of these principles.

The calculation for one given transport service must be performed using the following three main steps:

- step 1: identification of the various sections of the service,
- step 2: calculation of energy consumption and greenhouse gas emissions for each section,

- step 3: sum the results for each section.

The standard does not consider only the secondary emissions produced and energy consumed during the fuel combustion (energy conversion from fuel to mechanical energy), as well as “Naše more” 65(4)/2018., pp. 192-196 primary, incurred in the extraction, production and distribution.

- ew - well-to-wheels energetic factor for the defined fuel,
- gw - well-to-wheels emissions factor for the defined fuel,
- et - tank-to-wheels energetic factor for the defined fuel,
- gt - tank-to-wheels emissions factor for the defined fuel.

Well-to-wheels is “well on wheels”, that also covers primary and secondary emissions and consumption. Somewhere this factor is also called as LCA (life-cycle-analysis). The tank-to-wheels factor is thinking only of secondary emission and consumption. This Standard specifies the general methodology for calculation and the declared value for the energetic factor. The factor in greenhouse gas emissions must be selected in accordance with Annex A Emission gases are composed of several individual components (gas). Each one has different chemical and physical properties and participates in environmental degradation. In order to compare emissions from different activities, fuels, vehicles, where emissions have a different track, and one representative unit must be designed for the purpose of comparison. This is the CO2 equivalent, which is a measure of the specific emissions impact similar to the impact of CO2. The label is CO2e (equivalent)

2. City logistics

The definition of City Logistics follows from the logistics definition: "Logistics is an interdisciplinary science that deals with the coordination, alignment, interconnection and optimization of the materials, information and finance flow in terms of customer satisfaction with optimal spending. "City logistics is the process of optimizing logistics and transport activities, involving various companies with the support of advanced information systems in the city with regard to the transport environment and its impact on the emergence of congestion, safety and energy savings. Therefore one of the tasks of city logistics is to provide comprehensive transport serviceability.

There are cities in many European countries that are beginning to have problems with the traffic situation, although we can not fully compare the problems of our cities with the problems of major European and world cities. Cities try to handle these situations with different measures and drive as much traffic out of town as possible. Of course, most of these measures, especially construction, have a particular impact on transit traffic, when it is possible to route this kind of out-of-town traffic through the construction of by-pass roads. However, the problem remains with the organization of source and destination traffic that is heading directly to the city. It is precisely the solution to these problems in the cities that gave rise to the emergence of city logistics.

City logistics is part of logistics that deals with issues related to the movement of goods flows and means of transport within the city. Therefore, the primary task is the organization of passenger and freight transport in cities and the organization of goods flows and flows of consignments entering or leaving the city. The main reason for this new direction in logistics was the increase in the number of vehicles in cities.

In the understanding of city logistics, related only to the freight sector, three stakeholders - the carrier, the self-government and the private sector - are involved. It is the triangle of city logistics. If we extend the scope of city logistics to the area of passenger transport, we also need to increase the number of participants who will be involved in the development of solutions. These are, in particular, passenger transport undertakings, police forces and, last but not least, citizens.

The basic principles of city logistics have been elaborated in a number of expert and scientific papers and theses. A comprehensive approach gives Cisarova :“Given that city, logistics is perceived in a number of countries to be essentially negative and not conceptually addressed, it is appropriate to define the preparation and phases that should be preceded by the introduction of a quality global concept. First of all, it is necessary to resolve the issue of transit traffic. The city logistics itself solves or should solve only the problems arising from traffic-logistic service, not heavy freight transport. However, there are cities that have major problems with transit, but they are smaller towns with less than 50,000 inhabitants located on busy 1st and 2nd class roads. Transit traffic, as well as transit traffic, can be guided by traffic restrictions”.

This issue is also addressed to a large number of transport experts and scientists. For example, Julian Allen, Christian Ambrosini, Michale Browne, Daniele Patier, Jean-Louis Routhier and Alan Woodburn propose a wide review of survey methods that have been carried in Europe, based on the conclusions of the BESTUFS II project. From survey work carried out with experts in 11 European countries, a comparison of urban freight transport data collection efforts is made to better understand what currently takes place and to identify examples of good practice. Authors observe that the extent of urban freight data collection varies significantly between the European countries, as existing urban freight data comes mainly from the disaggregation of national survey results. Finally, authors identify a set of gaps in data collection, as well as the need for greater standardization in data collection methods and in analysis and reporting of this data.

Jesus Gonzalez-Feliu, Routhier, J. L et al propose a statistical-based modelling approach to propose a data estimation tool that can be transposed to different cities, avoiding the needs of making very costly surveys. The proposed framework needs standard inputs able to be obtained by public authorities and/or private stakeholders to make a diagnosis of urban logistics in current situations. The joint process of collecting data and modelling is described, and the different modules of the framework are presented. The authors conclude by presenting the main applications and further developments.

However, at present, it is important to address, in particular, the solution of city logistics in passenger transport. The authors of the contribution perceive city logistics as an important tool that can optimize energy intensity and environmental problems too. Therefore, the contribution is a kind of link the modern energy consumption methods analysis, city logistics and using railway transport in cities as an ecological transport mode.

2.1. Reasons for creating the city logistics

There are a number of reasons why city logistics is becoming more and more important. These include:

- Environmental: the negative impacts of transport on its surroundings are generally known (noise, exhales, soil cover, etc.). By proposing effective solutions to urban and freight transport in cities, these negative impacts can be reduced;
- Transport: the road network in the cities has been diminished during its construction to a lower capacity. Today, however, the traffic flow is far higher than previously thought. Therefore, measures in city logistics can at least partially solve this situation;
- Living standards in the city: a city is a place for its inhabitants to provide not only their living needs but also their social needs. Improving the living standards of city residents can greatly help to improve the traffic situation, mitigate negative environmental impacts, or reduce traffic in the chosen area or time.

2.2. Opportunities for solving urban and environmental problems in practice

Solving problems related to increasing the number of vehicles in cities can be solved in a number of ways, but finding an optimal solution is not easy. City Logistics offers a lot of suitable logistics concepts for passenger and freight transport optimization, which usually consist of one or more combinations of the following city logistics approaches:

- Vehicle entry restrictions or permissions; depending on the type of vehicle (size, weight, amount of produced emissions), vehicle entry is permitted or prohibited in a particular area. Mostly, the weight limit applies to the total weight and width of the vehicle or to certain emission limits.
- Paid communications and toll-road fee system; in this case, to introduce tolls for selected types of vehicles that are interested in entering the marked part of the city that is subject to the city toll system. This solution can reduce the number of unacceptable vehicles on toll roads on the one hand, and it can be beneficial for the city budget on the other hand,
- Night supply; when the supply is done at night, the vehicles are avoided by the daily traffic peaks while not feeding them. This results in benefits such as shorter driving times, the possibility of using larger vehicles to replace several small ones, reducing emissions and fuel consumption, fewer roads, modes of transport should be achieved, and consequently the less number of journeys,
- Distribution of goods by other means of transport. By introducing this measure, a modal shift of the goods to ecologically acceptable
- Making urban transport more attractive; only the high-quality, fast-moving urban public transport at regular intervals should motivate citizens to prefer public passenger transport to individual motoring.
- The use of the urban rail transport kinds as a main means of transport; in large cities with built-up tramways, overground and underground railways (metro), this mode of transport should form a transport system and should provide passengers with an attractive concept of transport.
- Utilization of the rail network (or private sidings) for city traffic service. Several railway lines in many cities pass relatively close to the centre and there is a low number of trains. There are also unused private sidings. In this case, there is a possibility of the new trains introduction as public transport, whereby these trains will use the existing regional or main lines private sidings.
- Using the systems such as „Park and Ride“, „Kiss and Ride“, „Bike and ride“, the system of sharing transport“ and so on.
- Support for the walking and cycling by the building the paths and cycle tracks.

3. Practical use in the city of Trenčín by using railway transport

There is a problem with an excessive increase in individual car transportation thus also congestion in the many Slovak cities. The problem has been appearing for last year not only in big cities but in small towns too. Instead of creating alternatives for the city to create a parking space on the fringe of the city before entering its centre, the large number of cars park directly in its narrow centre and core, resulting in an increase in the number of cars in the city centre.

For example, these problems are actually in the city of Trenčín which had a total of 54,916 inhabitants according to the population survey in January 2018. Although the city charged almost all the parking places in the centre and close the city centre, the problem has not been solved yet. If there is no option to park the motor vehicle in the parking garages on the periphery, the drivers will have to park their vehicle in the city centre.

3.1. The proposal of the solution by using rail transport

In accordance with the city logistic concept is proposed to extensive usage of rail transport. A suitable way to solve the present situation is to use the existing railway lines or private sidings passing through the city of Trenčín and ensure their operation at dense intervals, thus creating the "Urban railway transport". This should create an alternative way to go through the city by a private car in order to connect the city centre with its other parts more efficiently.

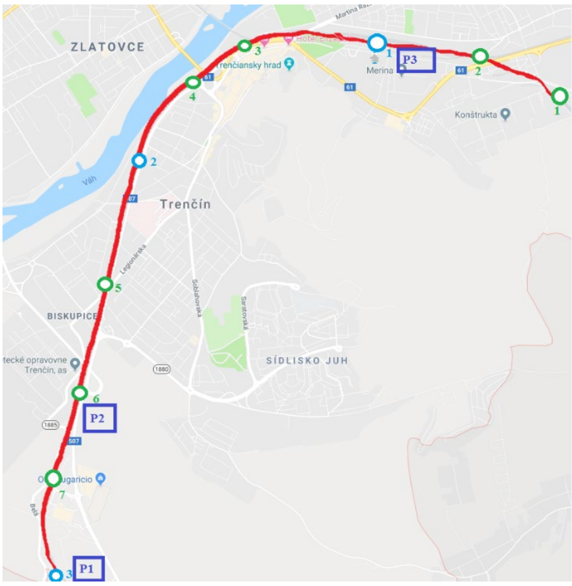

Fig. 2. Suggested stops in Trenčín

Start of the route is proposed on the rail leading to the area of military siding on the estate housing „Pred Poľom“ (no. 1, green colour) and continues through the railway station Trenčín (no. 1, blue colour), further down the railway line no.143 through the stop „Trenčín – predmestie“ (no. 2, blue color) to„Trenčianska Turná“ (no. 3, blue color) as the final stop where the train units will change direction. The private siding belongs to the Slovak Army, there is an average of 1 train per year, and its use is very problematic but possible.

The proposed route should cooperate together with the proposed parking and applying appropriate measures, such as the cost of using these car parks, which should include the ticket to the proposed train. In addition to the priority objective, an alternative to public transport buses will also be created along the entire route. Thus, not only the city's inhabitants but also the entrants can go from one side of Trenčín to another or to the city centre and back faster.

The calculation of the interval run from the new „Pred Poľom“ stop to „Trenčianska Turná“ station at the intended average speed of 35 km per hour and the total distance 6,720 meters, which is considered with 30 seconds additional time for the motor starting run and stopping, and 30 seconds for the dwell time in 10 of 12 stops during the whole ride, the result of running time is 20.5 minutes. It means the train units should ensure the entire territory traffic service theoretically over 20 minutes. Also, they would do three back runs during one hour if they did not give priority to any other passengers or freight train.

There are proposed total 10 stops in the given order, with 3 already existing stops (marked by blue colour in figure 2) and 7 new proposed stops (marked by green colour in figure 2).

3.2. Usage of the Park and Ride transport system

One of the most widespread problem-solving systems in the city is Park and Ride (P & R), "park and go by public transport". The P & R system is a typical application of intelligent transport systems. It includes parking places and other facilities that enable the interconnection of individual and public transport and combine their advantages. The basic task is to enable an advantageous transfer to urban public transport, thus reducing the number of passengers to the city centre by individual transport.

On the proposed transport route is important to build three catch car parking in front of the centre of Trenčín. The first car parking (A) would serve for cars coming from Banovce nad Bebravou. The parking is designed in the area between the railway and the existing local road, located at the railway station at the beginning of Trenčianska Turná. The second car parking (B) should be built at a downhill run from the D1 highway, which should primarily serve to shut-down cars from the D1 motorway and to offer them the possibility of parking in the contact with rail transport.

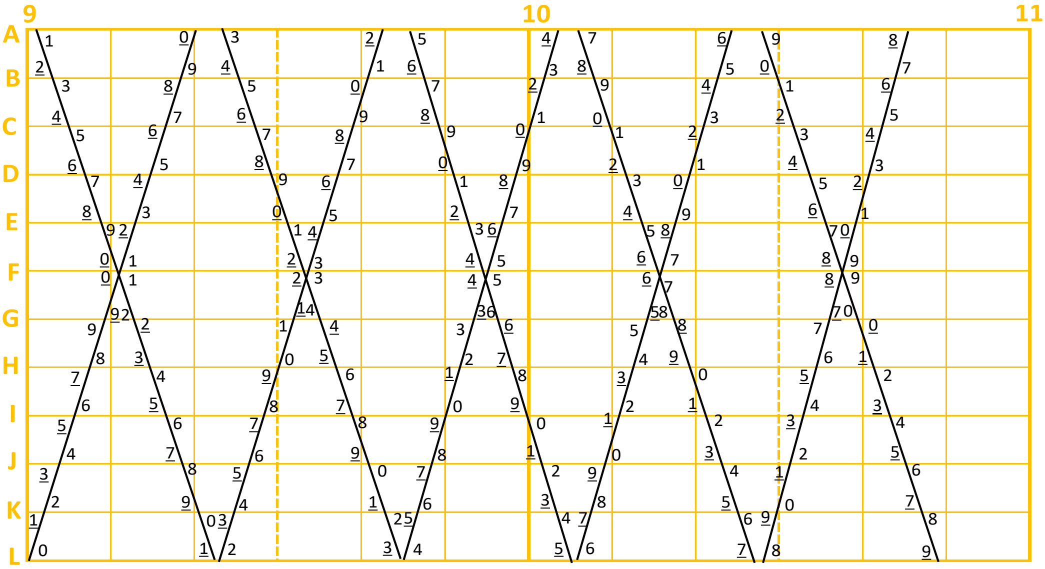

Fig. 3. A preview of two hours period train traffic diagram

Conclusion

At present, mobility is a part of everyday activities in cities. The increasing number of passenger and freight vehicles on the widening transport infrastructure causes a number of problems that can not be solved alone, but also in terms of impacts on the whole area. The similar problems are in the city of Trenčín. The measures, that have been taken so far, have not been able to disburden the city from frequent congestion and traffic collapse. These problems preclude to improve the transport service in the city.

Due to this persistent unfavourable situation in the city of Trenčín, the purpose of the contribution was to propose measures for the use of regional passenger railway transport for the city transport service. To meet this goal, specific measures have been proposed for the deployment of the transport system and technology together with regional rail transport. For Trenčín, the proposal brings new alternatives to solve the transport problems and to reduce the intensity of individual car traffic, thus relieving the city centre from a large amount of road traffic. At the same time, it supports public transport systems and also the use of regional rail transport, thereby improving the ecological and environmental aspects of the city.

The proposed concept that is being considered in Trenčín, should become a key global technology in urban logistics. It should help optimize passenger transport in cities and tackle global transport problems, as well as to reduce emissions and greenhouse gases in the city, thereby improving the urban environment.

The optimal solution to this issue would be to electrify this particular line and achieve the highest possible occupancy of railway vehicles.

Acknowledgements

The paper is supported by the VEGA Agency under Project 1/0095/16, “Assessment of the quality of connections on the transport network as a tool to enhance the competitiveness of public passenger transport system”, that is solved at Faculty of Operations and Economics of Transport and Communication, University of Žilina.

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Transport technic and technology
Volume XV Issue 1 Year 2019
DOI: 10.2478/ttt-2019-0002

PROPOSAL OF TECHNOLOGY OF TRAIN COMPOSITION IN KOŠICE STATION

Abstract. The rolling stock, its operation and maintenance are one of the problems that concern every rail carrier. Appropriate scheduling of wagons composition, its circulation and maintenance is not simple, especially if the carrier has a low number of locomotives and wagons used every day. In this paper is proposed a technology of wagons composition in the station Košice.
Keywords: railway transport, operation, the composition of the train

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Introduction

The gradual development and growth of the rail transport market have allowed new, private carriers to enter the market.

The liberalization of rail transport and its legislation have brought the benefits of these carriers to the market. The entry of private carriers into railway infrastructure can lead to an increase in the quality of transport and the services provided, as well as an increase in competitiveness. The arrival of new transport operators on the rail transport market has mainly contributed to reliable, more comprehensive and cost-effective services.

The improvement of these services brought by new competitors is leading to greater customer interest. This contribution of new services, as well as increasing the comfort and safety of transport, will cause competition among carriers.

The carrier's interest is to maintain and expand their performance and maximize profit. However, in the transport market, it has to face competition between different carriers of all modes of transport as well as between carriers of the same mode of transport.

1. Impact of liberalization on the transport market

One of the possibilities of the global transport market and promotion of the improvement of railway transport services is liberalization, i.e. opening of the transport market, entry of carriers on the market on non-discriminatory terms.

The EU rail transport market was long inaccessible to the private sector. The promotion of liberalization was solved by acceptance through the adoption of legislative measures designed to lead to fair, non-discriminatory competition and the rail services market. The White Paper and the first Directives have gradually established a solid basis for liberalizing rail transport.

The liberalization of transport market brings various effects, which in the context of the assessment of synergies can affect in different ways the company, a customer as such, and transport undertakings operating on the railway transport market as well.

Private railway passenger operators want to increase their market share together with national railway passenger transport companies, therefore, the quality of passenger transportation is getting higher, which positively influences the attractiveness of railway passenger transport.

2. Analysis of the current composition of carrier's trains

The simultaneous composition of trains of Regiojet company divides into two branches. The southern branch, which includes all the trains that are operated on the lines Brno, Bratislava, and Vienna and the northern branch, which includes lines connecting Prague with Havířov, Opava, Návsí and Košice

The composition of trains subject to specific carrier criteria. One of the main criteria is to create a kind of basic trunk, or a basic set of ranked wagons that will form the basis of every carrier trainset and will offer all kinds of tariff classes. Care must be taken to accommodate wagons with kitchen, children's compartments and appropriate arrangements of business, standard, astra and low-cost tariff classes offered by the carrier.

The offered service on the trains can be divided into several tariff classes of the carrier, as the service in these classes differs.

The carrier offers a selection of the following classes:

- Business;
- Relax;
- Standard;
- Astra;
- low cost;
- sleeping car;
- baby compartment;
- silent compartment;

- immobile passengers.

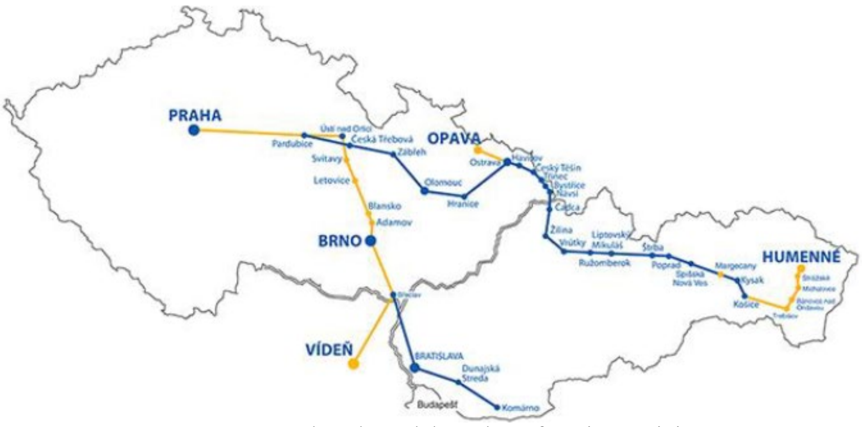

Fig. 1. North and South branches of carrier Regiojet

Business class

In this class, priority is given to serving the clients which is one of the other benefits of pleasant transport. Throughout the journey on board is staff available at any time to satisfy your wishes – whether it's about providing information or ordering from a menu.

Relax

There is a steward in every two carriages for customer satisfaction, providing on-board services. At the Relax service from the cart is not provided, quality refreshments are provided during the journey at an affordable price

Standard class

On-board services are also provided by the steward. Operation from the cart at the Standard tariff is provided after the departure from Prague; from Kysak, Ostrava-Svinov and from Brno (in the direction of Prague); free illy coffee and a refreshment order from our menu follows 40 – 60 minutes after servicing from the cart, may be adapted to the occupancy of the wagon.

Offers:

- adjustable leather or plush seats;
- compartment for babies, silent compartment;
- WIFI.

Astra wagon

The benefits of the ASTRA wagon will be appreciated by those who want to work or have fun by watching the fun portal. When booking a ticket, you choose a place with a monitor or a practical table. Board service is similar to the aircraft from the cart, which guarantees fast service without unnecessary disturbance. After service from the cart, you can order from the on-board menu packed and fast-servicing snacks.

Offers:

- adjustable seats with built-in LCD multimedia screens;
- large-carriages for 80 people ensuring relax for work and entertainment;
- socket and USB for each seat;
- WIFI.

Low cost

It offers a simple, calm and undisturbed journey at the lowest price that does not offer any service.

Offers:

- plush unstretchable seats;
- large-carriages for 80 people;
- undisturbed travel at the lowest price;
- free bicycle transport;
- WIFI.

Wagons-lits

Passengers traveling with sleeping wagons can enjoy full sleep on a bed or a couchette. Compartment with a bed or with couchette is different from the number of beds and the quality of the beds. Compartment with beds provide better privacy (3 persons), each has a dressed bed and an independent seat. Seats in couchette compartment (6 persons) are layout before the silent hours with the help of the crew. The bed-clothes are secured by passengers alone, from the prepared packages.

Offers:

- sleeping cars are available in the RJ 1021 Prague-Košice and RJ 1020 Košice-Prague;
- for purchase: hygienic package 3,20 € security luggage lock 1,20 €;
- WIFI.

Standard/compartment for babies

Compartment for babies is designed for children and parents to ensure a comfortable trip.

Offers:

- large-capacity compartment, 6 adult seats and children's stools (2-6 years);
- merry pictures, toys, Žlutík magazine, games, television with children's films;
- reservation of seats no. 61-66 at Standard rate;
- WIFI.

Silent compartment

The place in this compartment can be booked in Standard and Business class, which provides customers a comfortable and undisturbed journey.

Offers:

- limited use of mobile phones, loud listening to music, and more;
- not recommended for children under 15 years of age;
- WIFI.

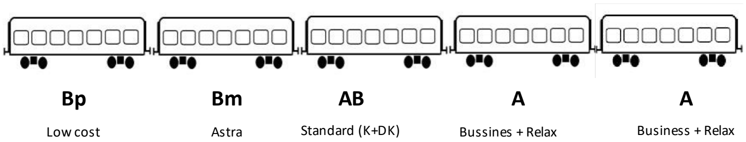

Fig.2. The tribal composition of five wagons

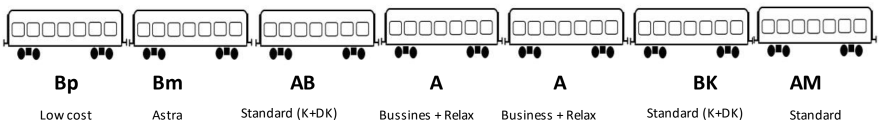

Fig. 3. The tribal composition of seven wagons

In the following table, the current state of the carrier's fleet is processed according to individual types of wagons, their total number and backup wagons for possible repair and maintenance.

Table 1. Overview of the current state of the vehicle fleet of Regiojet

Type of wagon	Quantity	Backup wagons
A	38	2
AB	16	0
Am	13	1
Bm	10	0
Bp	14	1
Bk	14	0
B	6	2
AS	2	0
Bc	14	1
Total	127	7

2. Proposal for the technology of train composition in Košice station

This section describes the technology of train composition in the Košice railway station and the circulations of individual trains. Due to the deficient number of wagons of the carrier's fleet, it was necessary to process the wagon circulation on individual trains so that they were fully utilized, therefore it is necessary to divide the train sets and compose the wagons to the specified directions of the northern branch taking into account the necessary transport capacity on the train.

A similar theme was also addressed by Ing. Dlugoš, where in his thesis on the basis of the current operating station, resolved with the circulations of trainsets on the line Komárno - Dunajská Streda - Bratislava but for the engine units, therefore the proposal in this paper solves the circulations of wagons.

a) RJ 409/400 (to Vrútky, to Prague goes as train 1008/1011

- 1011 – arrival to Košice station 22:43, after that displacement to refill water and cleaning;
- trainset is consist of 162 locomotive and seven wagons;
- subsequent departure at 03:45 as **1008** to Prague station.

b) RJ train 1021/1012 (1121)

- arrival to Košice at 06:14 as 1021 / subsequent departure at 07:45 from Košice station as 1012;
- train 1021 consist of (5) 6 couchette wagons and 5 – 8 seat wagons (max. 13 wagons in trainset);
- trainset 1021 is divided on 3 parts after arrival;
- group of wagons on 1021 behind locomotive (3 wagons) goes on track n.4a to shut down;
- group of wagons in the middle 1021 (1 seat wagon and 3-4 couchette wagons) goes as train 1121 to Humenné station with locomotive 750;
- group of wagons in the end of train (4-7 wagons) goes on train set 1012;
- at the time of ordered shunt, backup of ZSSK make a shunt of shutted down wagons from train 1003 (1-3 wagons) to train 1012 – this wagons are shutted down according to capacity demand;
- train 1012 is consist of 7 seat wagons with 162 locomotive to Praha station.

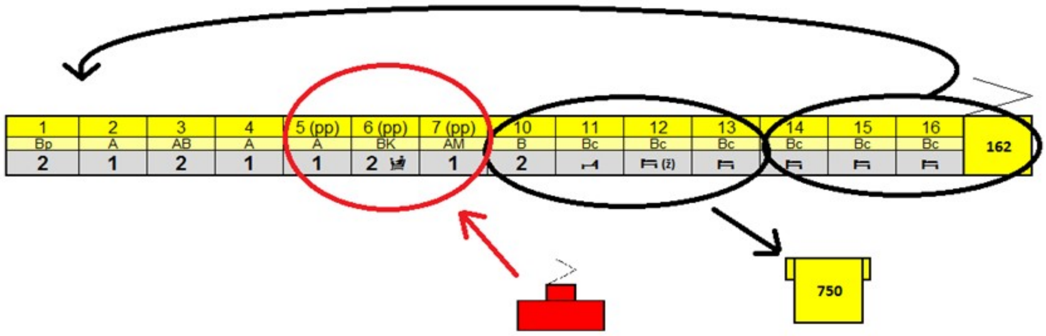

Fig. 4. Dividing the train set 1021 into 3 parts

c) RJ 1003 or 1120/1020

- the arrival of train 1003 at 15:43 which consist of 7 wagons / then the whole train set is shut down and goes to refill water and cleaning;
- the front part of train set 1003 will shut down with a locomotive of Regiojet on track n.15 (1-3 wagons);
- train set 1020 is consist of 3 parts:

  - **group 1** – at the end of train 1020 are wagons from train 1003 (part of the train set 1003 was shut down on track n.15);
  - **group 2** – is situated in the middle of train set 1020 is consist of wagons from the train set 1021 from 4a track;
  - **group 1 and 2** – shunt from track n.4a with wagons from the train set 1021 and shut down of wagons from 1003 to track n.15 will be done before train 1120 from Humenné station arrive;
  - **group 3** – wagons behind locomotive 162 of train 1020 are made up of the train set 1120. After the arrival of train 1120, groups 1 and 2 will be pushed to train 1020.

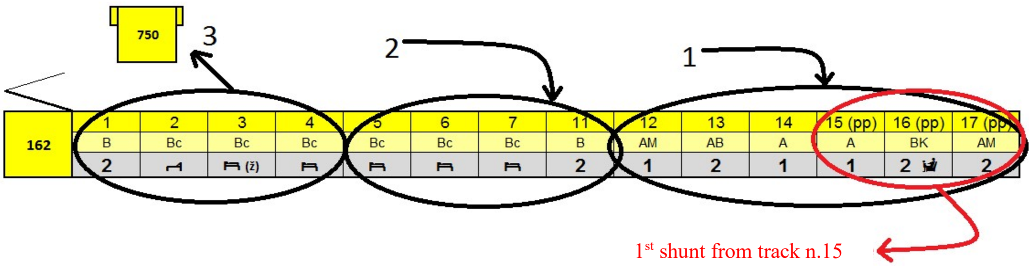

Fig. 5. The composition of the train set 1020

Conclusion

This proposal in this paper presents the method of compositing wagons to individual trains of the carrier and the technology of composition on the sections of the northern branch. The suggestion for the solution arose at the initiative of the railway carrier Regiojet operating trains in this part of the ŽSR railway network.

The composition of the carrier's fleet also contributes to the quality of transport that we can consider to be one of the main components of rail passenger transport. Operation and ownership of such a quantity of railway vehicles require its tax, where care must be taken not only for its use in service but also for its maintenance. When analysing the fleet and its current state, we conclude that the carrier has an insufficient number of wagons and therefore it is difficult to operate as many sections at once. This proposal was prepared for ŽST Košice, with the current number of wagons, where for the trains of the carrier this station is departure station and arrival station.

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Transport technic and technology
Volume XV Issue 1 Year 2019
DOI: 10.2478/ttt-2019-0003

RAILWAYS AS A KEY PART OF INTEGRATED TRANSPORT SYSTEMS

Abstract. Integrated passenger transport system consists of many factors with various impacts on the entire system quality. In passenger transport, there are mostly individual passengers therefore it is difficult to determine all transport requirements. In the passenger transport system, there are several modes of transport, but passengers mostly use road and rail transport. Passenger transport system is influenced by many qualitative factors with various impacts. The paper is focused on analysis of the role of railways in integrated passenger transport systems. The analysis is from passenger point of view because the key element in railway passenger transport is the passenger (customer), who requires the transport from one place to another. A basic precondition for accomplishing the main requirement (transport), is making the complete offer which provides not only transport, but also other complementary services. There are several types of passenger trains, which jointly create a part of integrated transport system. Quality of this transport system depends on train route topology, timetable of trains, number and location of all stations and stops. Primary function of the transport system is providing transport for passengers on regional, national-interregional and international level; therefore, the analysis involves these levels.
Keywords: railway transport, passenger transportation, integrated transport, transport system

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Introduction

Passenger transport is generally considered as an activity, which arises as the consequence of spatial division of places, where people are in exact time and their need to move. Motivators for moving could be commuting – job or education, dealing with personal or working matters, travelling for vacation – hiking, sport, health, cultural and social facilities, visiting relatives and friends. Requirements for transport of passengers originate in the need to move, while the passenger transport is dependent on the willingness of travelling. Basic and general factor, which has got a significant impact to the transport of passengers, is demography. Specifically, the most relevant aspects are the progress of population quantity, economic and social indicators, standards of living, age structure, employment rate and disposable income. Regularity of transport is also key factor, which depends on structure of passengers and their reasons for travelling. Other specific factors are spatial accessibility of transport hub and price for transport. Influences on transport offer are geographical conditions, transport infrastructure, transport vehicles and environmental effects. Transport infrastructure factor consists of its structure, length, density, throughput, accessibility to residences and overall quality.

Passenger transport is divided into individual and public. Individual passenger transport includes walking, cycling and car transport. Public passenger transport includes railway, road, water, air, city and unconventional transport. From spatial point of view, passenger transport is divided into local, regional and long-haul, which is then divided into interregional transport – in one country or international transport – among two or more countries. From operational point of view, passenger transport is the sum of acts for providing mass transport of passengers which includes boarding, selling and checking the travel tickets, transfer of passengers' luggage, ensure all individual needs of passengers and organizing of other complementary services. From economical point of view, passenger transport is classified into tertiary sphere – services. It means that there are not any material production values, but it is reflected in costs. In general, passenger transport has got a great social and political importance. Legislative fundamentals of organising and managing the passenger transport are constituted in higher legal standards and internal regulations of transport companies. (Kováč et al., 2011)

1. Quality criteria of passenger transportation

There are many associated criteria of passenger transportation such as safety, duration, price, reliability, comfort and complementary services. Safety is the dominant criterion and it is guaranteed normative by licences, permissions, certificates and verifications. Safety is measured by indicator of accidents per one billion passenger-kilometres. (Singhania et al., 2017)

Transport duration means the exact time of passenger moves from one place to another and it is closely related with speed. It does not mean the speed of the transport vehicle, there are other periods, such as time to go from home to the station, time to buy the travel ticket, boarding time, transport time, time to get off the train and time to reach the destination point. In case, where the traveller combines the trains, time for waiting to another train is also counted. Partial indicators are:

- Getting off the vehicle time,
- Going on stairs time,
- Transport on escalators time,
- Transport in elevators time,
- Transport on walkways time,
- Buying travel ticket time. (Kendra, 2014)

Transport price is the criterion, which is dependent mostly on economic indicators. In market economy, there are three factors, which create the magical triangle – costs, demand and competition. These factors are dependent on each other and they are also influenced by national economy, political situation and demography. Internal costs of the transport company are influenced by strategic objectives, economic situation and legislation. Transport demand reflects the range, how the transport company can affect the price for transport. Higher demand means opportunity to increase the price for transport, because travellers want to use the trains. Lower demand forces the transport company to decrease the transport price, because they must enhance the number of passengers in trains. Transport demand is highly influenced by macroeconomic indicators, such as GDP, employment rate and population economic activity rate. Another factor with significant impact is competition, which means other railway companies but also other means of transport, such as road, air or water transport. The transport company must deeply analyse and compare the price for transport with other transport companies, which offer the same or similar transport services.

Other factors with significant impact are reliability, offer of travel possibilities, vehicle occupation and coherence of transport system. Reliability is relative, because it depends on transport time and distance, while it proportionally decreases with mode of transport combination, for example train-bus. The most reliable are direct connections. Offer of travel possibilities has got a significant impact to quality of the whole transport system and structural modifications in passenger transport. It can be evaluated from spatial and temporal density. Spatial density means number of tariff point per some area, while temporal density means number of links per some time unit. Level of vehicle occupation compares real usage of the vehicle with maximum usage of vehicle.

Connectivity of passenger trains and other means of transport can be distinguished also from temporal and spatial point of view. Temporal connectivity is such sequence of arrivals and departures of different passenger trains and other means of transport, which allows changing the different passenger vehicles easily regarding necessary time. Spatial connectivity means the distance between two passenger vehicles, among which the passenger is moving. (Gasparik et al., 2016)

Travel comfort is also very important for passengers, especially nowadays. It consists of vehicle construction, interior hygiene, physiological and psychical influences. Subjective feelings and experiences have also significant impact along with current mood of each passenger. Overall subjective feeling is the result of different conditions with different seriousness. Practically, there is a significant difference when the passenger travels to celebration or funeral. Qualification of these subjective feelings with some methods has not been successful yet.

Other complementary services with some impact to quality of traveling are services provided on board or in stationary facilities. For example, travel ticket office, info office, waiting room, toilets, wireless internet connection, post office, shop, restaurant, café and luggage storage are standard services provided in stationary facilities. On the other hand, there are services provided on board of the vehicle, for example luggage transport, bicycle transport, seat reservation, wireless internet connection, catering, electric socket, toilets, compartment for children, couchette, restaurant car, visual and acoustic information. Staff behaviour is also very important, because their function is not only checking the travel ticket, but also provide information about traveling and they must induce a good feeling among passengers. (Dedik et al., 2017)

Entire quality is defined as an ability to satisfy all requirements of customers. Specific signs for services in transport are insubstantiality, impossibility to store, inseparability, variability, complexity and uniqueness. Level of service quality can be perceived as a disharmony among expectation and perception. (Nedeliaková et al., 2013)

Customers – passengers have got different priorities which relate to quality of service. They usually remember low quality and high quality is a standard for them. The main challenge is to identify the passengers' needs and satisfy them in all cases, because every transport is realized in different conditions.

In central Europe, there is a modern trend of establishing integrated passenger transport systems in selected regions. Cores of these systems are terminals, where passengers can change vehicle and the mode of transport such as get off the bus and get on the train.

Fig. 1. Integrated passenger transport terminal in Moldava nad Bodvou mesto, Slovakia

These terminals are hubs, whence all routes and lines from some region or district are connected. Building these new terminals will improve transport accessibility in the selected region. Operators, who participate in the integrated passenger transport system, are more effective and notice increased demand for transport services. (Stoilova, 2018)

Basic element of the railway passenger transport system is railway passenger station, what is transport hub – a starting and finishing point for flows of passengers. Passengers can change the train type from long-haul train to regional train or contrariwise or simply enter or leave the system of railway transport. This is the reason, why it is multi-directional system, not one-way system, as the classic cross-docking system used in freight transport. Main functions of railway passenger stations are:

- ensuring safe, regular and fluent transport,
- ensuring technological services for operators,
- ensuring operation of facilities for traveling public (waiting room, ticket store etc.).

To sum up, it is necessary to accomplish preconditions to make railways efficient in integrated transport system:

- dominance of customer (passenger),
- timetable dependent on passengers' needs,
- synchronized arrivals and departures in all point in the transport system,
- harmonised conditions for all operators in the transport system,
- high reliability and punctuality.

There are some disadvantages of integrated transport system for railways:

- overcrowding of transport vehicle may occur,
- increased number of trains could reduce the throughput of railway,
- preference of busses (more flexible).

2. Economic aspects of railway passenger transport

Railway passenger transport must be evaluated from economical point of view. Basic evaluation method is operating costs calculation. Costs are financial representation of company sources consumption for realizing services per time. Internal costs of the transport company arise from operation of trains on railways. Thanks to calculation, the exact amount of these costs is known. In railway passenger transport, the calculation unit is the service – transporting of passengers. It can be defined by quantity (number of trains, vehicles), time (staff working time, time of traveling) or other way (passenger-kilometres, train-kilometres). (Dolinayová et al., 2016)

In general, there are these costs: vehicle costs (vehicle price – amortization, repairs and maintenance, insurance, operational cleaning), railway infrastructure access, staff costs (wages of vehicle-drivers and stewards), traction energy consumption and other indirect costs (management, marketing, travel ticket selling system, information system etc.). Sum of all costs, which are converted to one typified train on the route, is the base for making the tariff charges.

Railway vehicle costs are calculated this way:

$$r_{trkm}^{RV} \frac{D_Y + \Sigma RM_Y + OC_Y + INS_Y}{\text{Ø } annual\ vehicle\ kilometrage} \quad (1)$$

where: r^{RV}_{trkm} – railway vehicle costs rate for train-kilometre [€/trkm]; D_Y – depreciation of vehicle per year [€]; ΣRM_Y – entire costs for repairs and maintenance of vehicle per year [€]; OC_Y – entire costs for operational cleaning of vehicle per year [€]; INS_Y – entire costs for vehicle insurance per year [€]; Ø annual vehicle kilometrage – average kilometrage of railway vehicle per year [km].

$$C_{RV} = \Sigma trkm\ .\ r_{trkm}^{RV}\ .\ NRV_{tr} \quad (2)$$

where: C_{RV} – entire railway vehicle costs per route [€]; Σtrkm – sum of train-kilometres per route; r^{RV}_{trkm} – railway vehicle costs rate for train-kilometre [€/trkm]; NRV_{tr} – number of railway vehicles in the train on the route [vehicles].

Staff costs are calculated this way:

$$r_{emph}^{S} = \frac{price\ for\ working + equipment}{\Sigma\ work\ time} \quad (3)$$

where: r^{S}_{emph} – staff costs rate for employee-hour [€/emph]
price for working – all month company's costs for the employee [€]; equipment – month costs for equipment of employee [€]; Σ work time – entire month work time of employee [hours].

$$C_S = t_r\ .\ CR_S\ .\ r_{emph}^{S} \quad (4)$$

where: C_S – staff costs per route [€]; t_r – train ride time [hours]; CR_S – conversion ratio: train ride time →employee-hour; r^{S}_{emph} – staff costs rate for employee-hour [€/emph]

Traction energy consumption costs are calculated this way:

$$C_{TEC} = \frac{\Sigma gtkm\ .\ mc_{TE}\ .\ s_{TE}}{1000} \quad (5)$$

where: C_{TEC} – entire traction energy consumption costs per route [€]; Σgtkm – gross-tons-kilometres per route; mc_{TE} – measurable consumption of traction energy per thousand gross-tons-kilometres; s_{TE} – traction energy rate [€]

From operating costs calculation, tariff rates can be appointed. The tariff reflects valuable relations among the operator and passengers. These rates must include internal goals of the operator (increasing profit, decreasing costs, market share etc.), social sphere (quality and offer of public transport, reducing regional gaps etc.) and environmental aspects. Current transport demand and complementary transport offer are also important part of setting tariff rates. Application of economic aspects is described in the case study of fictional Express train from Bratislava to Bardejov in Slovakia.

Table 1. Operating costs per one drive of fictional train.

COSTS (€)		
vehicle	1051.76	26.61%
infrastructure	649.18	16.42%
vehicle-driver	190.88	4.83%
stewards	184.38	4.66%
traction energy	888.74	22.48%
indirect	988.31	25.00%
sum	**3953.24**	100.00%
converted to one seat	12.35	
converted to one placekm	0.023265	

Comparison of costs and revenues are shown in table 4. When the result > 0 → operation of passenger trains is economically effective. On the other hand, when the result ≤ 0 → operation of passenger trains is not economically effective therefore the transport company would find some way how to reduce costs or increase revenues. Some government subsidies are also one of possible ways how to make operation of passenger trains economically effective.

Table 2. Economic effectiveness of fictional train on the route.

Route: BRATISLAVA - BARDEJOV		
Sum of costs	3953.24	€
Converted to one seat	12.35	€
Sum of revenues	5210.00	€ with VAT
minus VAT	4168.00	€
Result (revenues – costs)	**214.76**	**€**

The case study indicates that it is economically effective to operate trains on this route according to proposed conditions, which are not specified above. It shows the way how to consider operation of trains on new routes. Transport companies must consider enormous number of factors and conditions, which are necessary for objective and accurate assessment of providing railway passenger transport services.

Conclusions

1. Railway passenger transport companies (operators), who participate in the integrated passenger transport system, are more effective and notice increased demand for transport services.
2. All quality criteria of passenger trains have got different impact to the integrated transport system. It is necessary to determine their accurate impact, because they are closely dependent on passengers' needs and requirements and every passenger has got individual opinion.
3. Compare individual passenger needs with defined quality standards. The difference would indicate the level of passengers' satisfaction with the service.
4. A great emphasis is put on connectivity with other types of trains to eliminate waiting time in stations or terminals, where passengers must change the vehicle. Elimination of needless waiting can be reached by higher number of trains, buses and other passenger vehicles, which are used in passenger transport system.
5. Economic aspects of train operation are important for transport companies. Basic step is to compare operating costs with revenues to determine the economic effectiveness of train operation.

Acknowledgment

The paper is supported by the VEGA Agency by the Project 1/0791/18 "The Assessment of Economic and Technological Aspects in the Provision of Competitive Public Transport Services in Integrated Transport Systems" that is solved at Faculty of Operation and Economics of Transport and Communication, University of Zilina.

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Transport technic and technology
Volume XV Issue 1 Year 2019
DOI: 10.2478/ttt-2019-0004

ASSESSING THE IMPACT OF USING FUELS MADE FROM VEGETABLE OIL ON SELECTED OPERATIONAL VEHICLE CHARACTERISTICS

Abstract. Vegetable oil based fuels significantly enable reducing the costs of fuel purchased. CI engine vehicles with rotary and inline injection pump can be fuelled by vegetable oil based fuels instead of being fuelled by diesel. This is very common, since their price is lower in comparison with diesel. The article focuses on the impact of using fuels made from vegetable oil on selected vehicle characteristics in particular conditions. It includes the measurements of the impact of using fuels such as FAME, fresh oil and used oil on the engine smoke opacity, content of selected emissions in the exhaust gases as well as on the engine power and torque's course. The measurement results are mutually compared with the results measured when using diesel. In order to secure the measurements to be repeatable, they were performed in laboratory at the cylinder test station MAHA MSR 1050. The vehicle tested during its last 100,000 kilometres driven by vegetable oil based fuel has been selected for these measurements. Therefore, by these measurements, it was also possible to assume partially the impact of long-term using aforesaid fuels on selected vehicle characteristics.
Keywords: emissions, FAME, fuel, engine power, vegetable oil,

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Introduction

Most of the costs for an operation of vehicle are those of purchases of fuel (Synák, 2019). Part of the owners of agricultural machineries and tractors as well as vehicles with CI engines reduces the costs of fuel purchased by using fuels produced on the basis of vegetable oil. These include oils such as FAME, fresh vegetable oil and used vegetable oil (Mohadesi et al., 2019).

FAME, i.e. fatty acid methyl ester, is a fuel of natural origin. It can be made from used vegetable oil by removing glycerol molecule. This is further followed by transesterification of fats with methanol. The production of FAME is also possible at home. The price per litre of FAME depends specially on the vegetable oil's purchase price. Production costs of FAME made from 1 litre of oil used are approximately of 0.13 € (Karimi et al., 2016).

Fresh oil represents an oil of natural origin made from sunflower or oilseed rape. The vegetable oil can be bought from about 0.70 €/l (komodityonline). It is not processed in any way before being used in a vehicle.

Used oil represents a type of oil used when cooking meals, most often when frying. It is necessary to be filtered through a sieve or gauze before being used in a vehicle.

When comparing the costs of diesel fuel and fuels made from vegetable oil, it leads the drivers to use fuels made from vegetable oil (globalpetrolprices).

The purpose of this article is to compare the impact of using selected fuels made from vegetable oil and diesel on several aspects of vehicle operation under specific conditions. The article contains the results of measuring the impact of fuels made from vegetable oil on the engine smoke opacity, exhaust gases volume composition from the harmful emissions point of view and, on the course of the engine power and torque's curves depending on the engine speed. Each of the measurements was performed with using diesel fuel, FAME, fresh vegetable oil and used oil.

Since the engine smoke opacity is regularly measured during a vehicle inspection, it is also measured in this article. Therefore, the purpose is to determine whether a vehicle fuelled by selected fuel meets the requirements for smoke opacity value that is verified during vehicle emission inspection.

Exhaust gases volume from the emission point of view focuses on the presence of CO, CO_2, HC and NO_x.

CO, i.e. carbon monoxide, is produced from the partial oxidation of carbon. CO has an adverse effect on human health. It binds with haemoglobin 300 times stronger than oxygen, and so it prevents oxygen from its transfer from lungs into organism. CO has a share in increasing premature mortality of population (Šarkan et al., 2016).

CO_2, carbon dioxide, is a greenhouse gas. Its share in the greenhouse effect is more than 50 % (Škorupa et al., 2018).

UHCs, unburned hydrocarbons, are products of incomplete combustion of fuel in an engine. Hydrocarbons irritate the human mucous membranes and some of them are carcinogenic (Shim et al., 2018).

NO_x, nitrogen oxides, are produced in the engine combustion area at higher pressures and temperatures. These conditions are fulfilled mainly by CI engines (Synák et al., 2018). Nitric oxide (NO), nitrogen dioxide (NO_2), nitrous oxide (N_2O) together with dinitrogen trioxide (N_2O_3) and dinitrogen pentoxide (N_2O_5) are produced during the period at which an engine works in the above mentioned conditions. NO_x have adverse effects on human health as well as on the greenhouse effect. They also cause acid rain (Skrúcaný et al., 2018).

In order to start measuring, a vehicle with CI engine fuelled its last 100,000 kilometres by vegetable oil based fuel has been chosen. By measuring the engine power and torque, it was possible to find out whether the engine can have a power and torque prescribed by the manufacturer.

1. Measurement methodology

The measurements included measuring the smoke opacity, exhaust gases volume and the course of the engine power and torque. Each of the measurements was made with using diesel, FAME, fresh vegetable oil and waste vegetable oil.

The measurements were performed with Mercedes 300 D 124 W, a vehicle with inline fuel pump and indirect fuel injection. The construction scheme of fuel system is shown in Fig. 1.

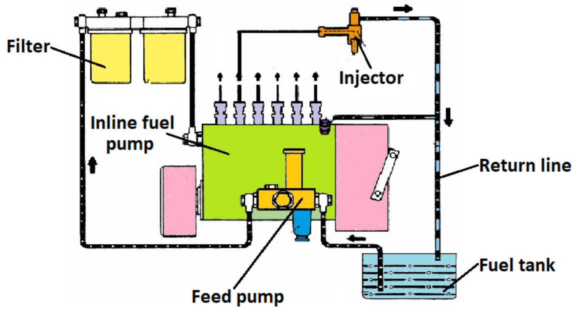

Fig. 1 Inline fuel pump (Janoško et al., 2010)

A fuel is transported via feed pump from the fuel tank trough fuel filters into the high pressure inline fuel pump. Here, the fuel is pressed down to the pressure of about 12 MPa and it is further transported through the high pressure pipes into injectors. These secure a fuel distribution in the distributor pumps. Superfluous fuel is returned back to the fuel tank. In order to prevent particular fuels from being mixed during the measurements, the fuel was transported by fuel can instead of fuel tank, see Fig. 2.

Fig. 2 Fuel can

This way of fuel drawing from a can prevents the measured fuel from being mixed with the others.

The process of fuel replacing was as follows:

- Fuel pump hose was put into to the can with fuel prepared for measuring,
- Hose with superfluous fuel was put into another can,
- Bleeding of fuel system, starting of engine,
- Can was filled up by piping with superfluous fuel of minimum 2 litre volume,
- Return line piping was shifted into the can with fuel prepared for measuring.

Pumping of superfluous fuel from the previous measurement was secured by putting the return line hose into another can. At the same time, only new fuel prepared for particular measuring was transported into the whole fuel system.

Each fuel replacing has the same process.

1.1. Smoke opacity measurement

Smoke opacity was measured by MAHA MDO2 – LON V 6.11. by free acceleration method. It was measured by the opacimeter that works on the optical principle – the exhaust gases are illuminated by a light, when the value of smoke opacity measured relates to the value of light absorbed.

The method of free acceleration lies in measuring the smoke opacity during the time when a pedal is fully applied up to 1 second, i.e. a full fuel amount is reached. Acceleration pedal is released after the maximum engine speed has been achieved and recorded. The process is repeated 3 times. After that, the arithmetic mean is calculated from the values measured (Kralik, 2019).

1.2. Exhaust gases composition measurement

Exhaust gases composition was measured by MAHA MGT 5. The components measured were CO, HC, CO_2 and NO_x. The measurements were performed during simulating a vehicle driving on the cylinder power test station MAHA MSR 1050 at the driving speed of 50 $km.h^{-1}$ and 90 $km.h^{-1}$. The accuracy of test station's measuring is ±2 % (Šarkan et al., 2017). There was used the first gear at both speeds.

Firstly, for a drive simulation, it was necessary to calculate the value of vehicle driving resistances by which the cylinders were braked. Since there was a plane drive at the constant speed chosen, the engine must have overcome the rolling and the air resistances. The value of rolling resistance has been calculated according to following equation:

$$F_r = m \, . g \, . f \qquad (1)$$

F_r – value of rolling resistance [N]
m – vehicle mass [kg]
g – gravitational acceleration [m.s^{-2}]
f – rolling resistance coefficient [-] (Radosavljevic et al., 2019)

Having the mass of the vehicle in running order of 1,440 kg, the rolling resistance coefficient of vehicle tyres 0.008 has the value of 113 N.

The value of air resistance has been calculated according to the relation:

$$F_a = 0{,}5 \, . \, v^2 \, . \, c_x \, . \, S \, . \, \rho \qquad (2)$$

F_a – value of air resistance [N]
v – driving speed [m.s^{-1}]
c_x – air resistance coefficient [-]
S – size of front face [m^2]
ρ – air density [kg.m^{-3}] (Skrúcaný et al., 2016)

Having the speed of 50 km.h^{-1} and the air density of 1.29 kg.m^{-3}, the value of air resistance is 77 N. It is 250 N when having the speed of 90 km.h^{-1}.

The calculated values of driving resistances were entered into the cylinder test station computer. The cylinders were subsequently braked by the same value.

The measurement of the exhaust gases composition was performed after the vehicle had been stabilized at the required speed. The driving speed was observed with deviation of ± 0.5 km.h^{-1}.

1.3. Measurement of the course of the engine power and torque’s curves

The measurements were performed at the cylinder test station MAHA MSR 1050 respecting the fourth transmission gear. The vehicle was fixed on the test station and after the engine had been conditioned at the fourth gear with having the acceleration pedal fully applied, the maximum engine speed was reached and, thus, the engine power was measured. After that, a driver applied the clutch pedal when still using the fourth gear, and let the wheels slow down freely in order to measure the mechanical losses between the engine and cylinders. Then the computer calculated the course of the engine power and torque’s curves (MAHA MSR).

2. Results

2.1. Engine smoke opacity

The Table 1 shows the measured value of engine smoke opacity depending on the fuel used. The first column shows the fuels used during measurements. The second column displays the value of smoke opacity and the third column displays the difference of smoke opacity measured in % compared with diesel. The last column shows the value of variance which is calculated as the arithmetic mean of deviations between the measurements.

Table 1 Engine smoke opacity depending on the fuel used

Fuel	Smoke opacity m^{-1}	Change in the value compared with diesel %	Variance m^{-1}
Diesel	0.64	0	0.10
FAME	0.49	- 23.4 %	0.08
Fresh oil	0.40	- 37. 5 %	0.13
Used oil	0.38	- 40.6 %	0.12

The graph in the Figure 3 also shows the results for its better transparency.

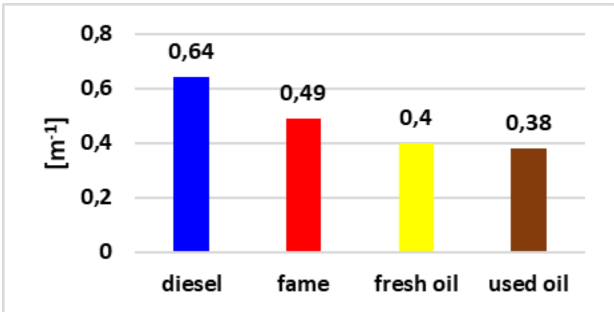

Fig. 3 Engine smoke opacity depending on the fuel used

As seen from the Table 1 and Figure 3, the highest value of smoke opacity was reached during diesel measurement. By using waste oil, the engine smoke opacity reduced up to 40.6 % in comparison with diesel.

2.2. Exhaust gases composition

The following part of the article shows the impact of the operation of vehicles fuelled by diesel, FAME, fresh and waste oil on the exhaust gases volume in the engine. The table 2 displays the impact of using particular fuels on the values of CO and CO_2. The results are matched to the driving speeds when being measured.

Table 2 HC and NOx concentrations in the exhaust gases

Fuel	**CO %**	**Difference compared with diesel %**	**CO_2 %**	**Difference compared with diesel %**
Diesel				
50 km.h^{-1}	0.02	0	3.8	0
90 km.h^{-1}	0.02	0	4.7	0
FAME				
50 km.h^{-1}	0.02	0	4.0	+5,3
90 km.h^{-1}	0.03	+ 50	5.2	+10.6
Fresh oil				
50 km.h^{-1}	0.05	+150	4.4	+15.8
90 km.h^{-1}	0.06	+200	5.2	+10.6
Used oil				
50 km.h^{-1}	0.06	+200	4.5	+18.4
90 km.h^{-1}	0.06	+200	5.2	+10.6

For better transparency, the values of HC concentration are shown in the form of graph, see Fig. 6

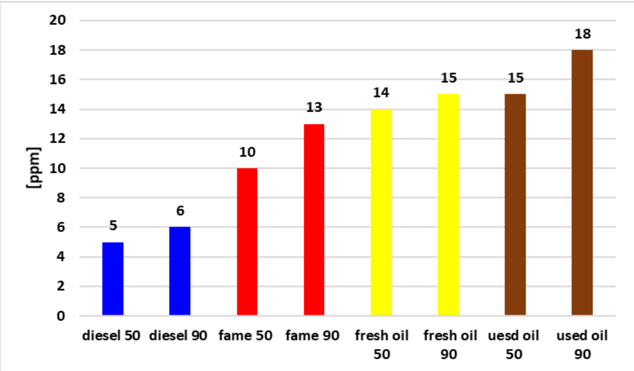

Fig. 4 Values of HC concentration in the exhaust gases

When using fuels made from oils, HC concentration multiplied.

The Fig. 7 shows the values of NO_x concentration in the exhaust gases depending on the fuel used.

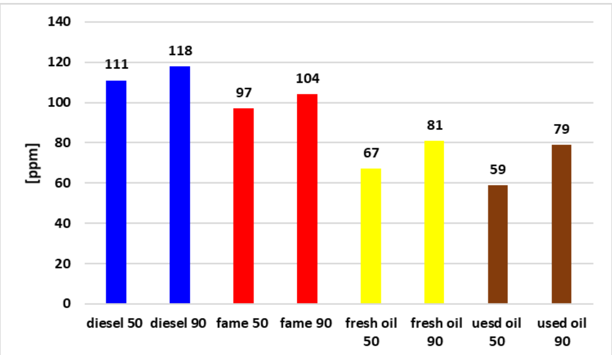

Fig. 5 Values of NOx concentration in the exhaust gases

When using oil based fuels, NO_x concentration in the exhaust gases decreased.

2.3. Engine power and torque courses

The impact of the fuel used on the engine power and torque is shown in the Fig. 8. The graph's horizontal axis displays the engine speed in min^{-1}, its left vertical axis shows the engine power in kW, and its right vertical axis shows the engine torque in Nm. Orange flatter curves represent the course of torque, and red steeper ones represent the course of the engine power. The course of power´s curves on the cylinder test station are in blue, and, between the engine and cylinders are in green.

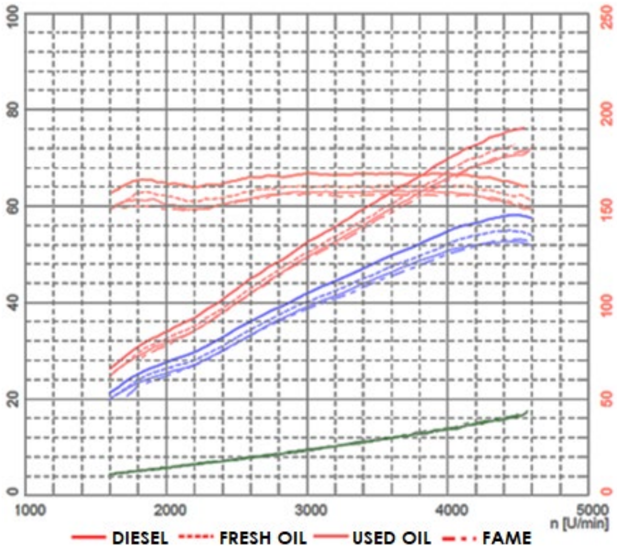

Fig. 6 Impact of fuel on the engine power and torque's courses

As seen from the Figure 8, it can be said that all of the courses are mostly the same. Over the whole measurement, the highest power is seen when using diesel. When using fresh oil, the course of the engine power and torque was lower. When using FAME and waste oil, the curve course was almost identical taking into consideration the deviations of MAHA MSR 1050. The biggest difference in the engine torque was measured when using diesel and FAME at the speed of 1,800 min^{-1} - 12 Nm, power of 5 kW, and the engine speed of 4,200 min^{-1}.

To understand the impact of fuels used on the vehicle acceleration better, it is possible to make a theoretical calculation of maximum acceleration with using the first gear. The engine torque is important for a maximum possible value of vehicle acceleration. The calculation is therefore made by taking into consideration the engine speed at which the biggest difference of engine torque had been measured.

The first step is to determine the wheel force according to relation:

$$F_w = (M_t \, . \, i_c \, . \, \eta_m) \, / \, r_d \qquad (3)$$

F_k - the wheel force [N]
M_t - the engine torque [Nm]
η_m - the mechanical transmission efficiency
r_d - the wheel radius [m] (Radosavljevic, 2019)

The engine torque measured at given speed with using diesel is 162 Nm, see Fig 6. The overall transmission ratio when using the first gear is given by relation:

$$i_c = i_I \,.\, i_r \tag{4}$$

i_c - the overall transmission ratio [-]
i_I - the transmission ratio at the first gear [-]
i_r - the constant transmission ratio in the transfer case [-] (Rievaj et al., 2014)

The value of transmission ratio at the first gear is according to (cars-data) 3.86 and, in the transfer case it is 3.46. The overall transmission ratio at the first gear has the value:

$$ic = 3.86 \,.\, 3.36 = 13.36 \tag{5}$$

The vehicle has got tyres with size of 195/65 R 15. The wheel radius is:

$$r = [2 \,.(195.0.65) + (15 \,.\, 25.4)] : 2 = 371.3\ mm \tag{6}$$

The wheel force is:

$$F_w = 162 \,.\, 13.86 \,.\, 0.90 \,/\, 0.37 = 5246.13\ N \tag{7}$$

The maximum possible value of resistance against the acceleration can be calculated using relation:

$$F_a = F_w - F_v \tag{8}$$

$$F_a = 5246.13 - 113 = 5133.13\ N \tag{9}$$

Then the maximum vehicle acceleration can be calculated:

$$a_{max} = O_a/m \,.\, \delta \tag{10}$$

a is the vehicle acceleration [m.s^{-2}]
O_a is the maximum possible value of resistance against the acceleration
m is the vehicle mass
δ is the rotational mass coefficient (Synák, 2019)

The calculation of the rotational mass coefficient is time demanding and requires identification of mass and radius of every single rotational component in the engine, between the engine and wheels and between the wheels themselves. In this case, there is no need for so high measurement accuracy. The coefficient value for calculation with using both, diesel and FAME is δ = 1.45, according to [9].

The possible vehicle acceleration with diesel used:

$$a_{max} = 5133.13/1440 \,.\, 1.45 = 2.46\ m.s^{-2} \tag{11}$$

The maximum theoretical vehicle acceleration when using diesel at the engine speed of 1800 ot.min^{-1} with the first gear used is 2.46 m.s^{-2}. By analogical calculation, it is possible to determine that when replacing diesel with fame, under these conditions, the vehicle can have the acceleration of 2.27 m.s^{-2}. The theoretical difference of vehicle acceleration when using diesel and FAME is 0.19 m.s^{-2}.

Conclusions

Using of vegetable oil based fuels does affect the engine smoke opacity, the exhaust gases composition as wells the course of the engine power and torque for little.

The value of smoke opacity measured when using diesel fuel has reached the value of 0.64 m^{-1}, while the maximum permissible value of smoke opacity is 2.50 m^{-1}. Therefore, the engine is able to meet the prescribed emission limits of smoke opacity also after having tested its last 100,000 of kilometres driven. The value of engine smoke opacity also shows the condition of engine and its parts, for example the degree of wear of piston rings, movable components in the injections, and the elements in high pressure pump (Yesilyurt, 2019). In case of these parts being worn out extremely, it could lead to wrong fuel dispersion, or to combustion of engine oil with a fuel, and thus the values of smoke opacity would be substantially higher (Figlus et al., 2016). The measurements have shown a significant reduction of smoke opacity by using fuels made from vegetable oil. Thus, the vehicle is capable to meet the requirements imposed on the smoke opacity during the regular vehicle inspection even when using vegetable based fuels.

Using of fuels made from vegetable oil has also had a significant impact on the exhaust gases composition. CO, CO_2 and HC concentrations when using these fuels have increased in comparison with the values measured when using diesel oil. NO_x concentration has decreased when using vegetable based fuels. A possible explanation of such changes in particular exhaust gases components concentrations is that there is a different length of hydrocarbon chain of particular fuels and, probably, the lower heating value of fuels, too (Chand, 2002). Out of these, it can also be concluded the different composition of fuels. While diesel composition is regularly inspected, the other fuels are not. Thus, the composition of vegetable oil based fuels may always vary greatly or little.

When determining the impact of using selected fuels on the course of the engine power and torque curves, the impact of wear was small, even negligible. The highest values of engine power and torque were measured when using diesel, and then with fresh oil and waste oil. The lowest values were measured with FAME used. However, the differences were minimal. The low impact of fuels on vehicle dynamics was also proven by calculation of maximum theoretical vehicle acceleration. Its difference is hardly to recognize, especially from the driver's point of view, bearing in mind that the difference can be only seen in the narrow range of engine. The cylinder test station MAHA MSR 1050 also provides a function of measuring the dynamic vehicle acceleration. However, there is no possibility to measure the difference in maximum theoretical acceleration, since the different course of the engine power and torque curves was only in that narrow range of engine speed. When having the acceleration pedal fully applied, the engine speed would have been quickly overcome, and, thus, the acceleration would not have been able to measure. Representing the calculation of possible vehicle acceleration proves that using selected fuels will not cause the deterioration in dynamic vehicle characteristics when having an acceleration pedal fully applied.

Acknowledgment

This article was created to support project named as: VEGA no. 1/0436/18 - Externalities in road transport, an origin, causes and economic impacts of transport measures.

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